Using Smart Transport Technologies to Mitigate Greenhouse Gas Emissions from the Transport Sector in Asia and the Pacific
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CHAPTER 1

Introduction
1.1 Background

The transport sector plays a fundamental role in the social and economic development of society. A life without access to modern transport services is next to impossible today. Almost every human activity is linked to the transport sector: connecting students to schools and universities, workers to their workplaces, consumers to sellers or enabling participation in social and leisure activities, to name a few. As the sector is primarily powered by fossil fuels, it is responsible for environmental externalities such as greenhouse gas emissions. In 2016, the transport sector was responsible for 25 per cent of global carbon dioxide emissions, an increase of 71 per cent over 1990 levels, with transport by road responsible for 75 per cent of transport emissions. Apart from greenhouse gas emissions, it also contributes to traffic congestion, noise pollution and road crashes. Rapid economic growth in the Asia-Pacific region in recent decades has resulted in a corresponding rise in motorization and consequently, an increase in the ownership of motorized two- and four-wheeler vehicles, in particular in urban centres. Cities in the Asia-Pacific region are responsible for 75 per cent of the region’s greenhouse gas emissions, which is set to increase because of rapid urbanization. In the absence of integrated public transport systems and against the backdrop of rising income levels, privately owned motorized two- and four-wheelers have become the preferred choice for daily transport in many cities in the region. This has put a strain on urban transport infrastructure, which in some cases has shown that it has been unable to keep pace with the increase in private vehicles. In a study conducted in 2014 on transport infrastructure in Manila, traffic demand in Metro Manila was estimated at 12.8 million trips a day and six million in the adjoining provinces in 2012, and that public transport was used for 69 per cent of the trips. A smaller share of the trips was done by private vehicles as mentioned in the same study, which were responsible for occupying 78 per cent of the road space. Traffic jams are a daily occurrence in most major cities of the region, presenting policymakers with the challenge of meeting the growing transport needs of city dwellers, while reducing the carbon footprint of the transport sector. As part of efforts towards achieving low-carbon mobility, policymakers are considering a mix of technology improvements and policy measures, such as improving vehicle technology and efficiency; promoting a modal shift from private to public transport and non-motorized transport; and reducing individual travel demand through congestion pricing. Technology plays an important role in the process, as advances in information communications technologies (ICT) have resulted in increased deployment of them in the transport sector. Smart transport systems, including intelligent transport systems, is the umbrella term, which embraces a range of technology applications that integrate drivers, vehicles and transport infrastructure in a way that improves overall transport efficiency. The Economic and Social Commission for Asia and the Pacific (ESCAP) has defined intelligent transport systems within the scope of the 2030 Agenda for Sustainable Development and the diverse nature of smart transport technologies: “Intelligent transport systems are an agglomeration of diverse technologies that enhance the sustainability of transport systems in a safer, smarter and greener way.”

2 E/ESCAP/73/16.
4 Economic and Social Commission for Asia and the Pacific, “Guidelines for the regulatory frameworks of intelligent transport systems in Asia and the Pacific” (Bangkok, ESCAP, 2019).
1.1.1 Transport and the Paris Agreement on Climate Change

In 2015, countries participating in the Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris at its twenty-first session adopted an international climate agreement, which has come to be known as the Paris Agreement. Following the entry into force of the Agreement in 2016, countries that have ratified the Agreement are required to submit their nationally determined contributions. The climate actions contained in those contributions, if implemented, will determine whether the world will achieve the goals of the Paris Agreement to maintain global average temperatures below 2°C and closer to 1.5°C. Actions aimed at the transport sector appear in several of the nationally determined contributions submitted by ESCAP member countries, reflecting the importance of mitigating transport sector greenhouse gas emissions. Also, the potential use of smart transport systems as a greenhouse gas mitigation strategy has been highlighted in nationally determined contributions submitted by ESCAP member countries from the Asia-Pacific region.

In accordance with the Agreement, countries are required to submit subsequent nationally determined contributions every five years from 2015 with subsequent contributions due in 2020 and 2025. The Agreement also requires that subsequent nationally determined contributions submitted to UNFCCC build upon previous efforts and be more ambitious than prior commitments.

5 Nationally determined contributions with references to smart transport including intelligent transport systems as a mitigation strategy were submitted by Azerbaijan, Bhutan, Cambodia, China, Cook Islands, Japan, New Zealand, Sri Lanka and Tuvalu.


7 A/RES/70/1.

8 E/ESCAP/MCT(3)/11.

1.1.2 Transport and the 2030 Agenda for Sustainable Development

The 2030 Agenda for Sustainable Development, adopted by the General Assembly in 2015, consists of 17 Sustainable Development Goals and 169 targets. The Goals apply to all countries and require governments to work towards ending all forms of poverty, fighting inequalities and tackling climate change, while ensuring no one is left behind. The goals are integrated and balance the three dimensions of sustainable development: economic, social and environmental. While there is no goal dedicated to sustainable transport in the 2030 Agenda, it has been mainstreamed in several of the Goals, as transport is a key enabler of social and economic development. Moreover, several of the targets are directly linked to transport, such as target 3.6 which deals with reducing the number of deaths as a result of road traffic crashes, 7.3 which requires the doubling of the global rate of improvement in energy efficiency, 9.1 on sustainable and resilient infrastructure in support of economic development and 11.2 on safe, accessible and sustainable transport systems. Transport is also indirectly linked to several Goals, such as those related to climate change and health, which highlights the cross-sectoral nature of transport and its importance in achieving the Sustainable Development Goals. In this regard, smart transport systems play an important role to move towards sustainable transport systems, as they improve the overall efficiency of transport systems by optimizing transport networks and reducing environmental externalities. This was also highlighted by the ministers of transport and representatives of the members and associate members of ESCAP in a declaration adopted at the Ministerial Conference on Transport at its third session, held in Moscow from 5 to 9 December 2016, which recognized “the role of new technologies, including intelligent transport systems, to increase the efficiency, safety and effectiveness of transport systems”.

5 Nationally determined contributions with references to smart transport including intelligent transport systems as a mitigation strategy were submitted by Azerbaijan, Bhutan, Cambodia, China, Cook Islands, Japan, New Zealand, Sri Lanka and Tuvalu.


7 A/RES/70/1.

8 E/ESCAP/MCT(3)/11.
1.1.3 Smart transport systems and low carbon mobility

Smart transport systems can be fully integrated into the overall transport ecosystem as part of vehicle systems, road infrastructure, and management and operational strategies. These systems can directly and indirectly affect efforts to mitigate greenhouse gas emissions. Just to name a few, in vehicle systems, by using satellite navigation systems, drivers are able to optimize their travel routes and avoid incidents along their trip, which improve the overall efficiency of the transport ecosystem. Similarly, eco-driving systems installed in vehicles help drivers to reduce the fuel usage and associated costs by providing trip information. Smart transport systems can also be installed in road infrastructure along highways, arterial or feeder roads and major intersections to provide real-time traffic information to users. Variable message signs and mobile applications are representative tools used to broadcast traffic information gathered from detecting equipment. Electronic toll collection systems that automatically collect tolls without the need for a vehicle to come to a halt or weigh in motion systems that calculate vehicle loads on the go without the need for queuing at dedicated weigh stations are other examples. In addition to improving the overall driving experience, smart transport systems can contribute towards managing and operating traffic conditions in an effective way. Congestion pricing mechanisms are increasingly relying on smart transport technologies to enforce congestion policies. Vehicles entering predefined areas at certain hours can be automatically charged a congestion tax by deploying sensors in vehicles that track their movements. Congestion pricing is a strategy being used in cities to reduce individual travel demand during peak hours and encourage the modal shift to public transport. Supporting shared mobility using smart transport applications is another way to influence individual travel demand and, in some cases, make possible a shift to greener transport modes, such as e-scooter sharing or electric vehicle sharing.

1.2 Purpose of the study

It has been proven that smart transport systems can be used effectively to address traffic issues, improve transport efficiency and reduce greenhouse gas emissions. The beauty of such systems is their potential to generate quick results without the need for significant transport infrastructure investment. Nonetheless, despite the potential benefits of these new technologies, many countries in Asia and the Pacific are not leveraging them to improve the overall efficiency of their transport systems and reduce related greenhouse gas emissions. This is primarily because of limited awareness and understanding of these technologies, and low technical capacity to deploy them in support of greener transport systems. In this regard, this study is intended to increase the technical capacity of policymakers by providing details on smart transport systems to mitigate greenhouse gas emissions. In addition, it is expected to be a bridge between low awareness and understanding of such systems, and their actual benefits in reducing greenhouse gas emissions. This will eventually strengthen the technical capacity of policymakers in member countries in the region to use smart transport systems.

1.3 Scope of the study

The following information is included in the study in order to attain its main objective:

a An overview of nationally determined contributions for the transport sector focusing on the Asia-Pacific region;

b A review of smart transport applications that can contribute towards mitigating greenhouse gas emissions;

c Highlights and assessments of successful cases of smart transport applications in the Asia-Pacific region and other regions (the United States and Europe) to draw meaningful lessons learned;
d An impact analysis of selected smart transport strategies in given areas at the subregional level (South-East Asia, and North and Central Asia);

e A list of contributions and policy recommendations that may be useful for policymakers in the region.

In terms of smart transport systems covered in this study, the following are the scope of the areas:

a All smart transport applications (i) deployed within vehicles that can improve vehicle efficiency to reduce greenhouse gas emissions, (ii) embedded in transport infrastructure that can increase overall efficiency of transport systems, and (iii) used as strategies to optimize traffic conditions and efficiency.

b All smart transport technologies that (i) have been applied in the beginning stage of development (i.e., traditional intelligent transport systems) and (ii) have become known because of new techniques (emerging technologies), such as cooperative-intelligent transport systems, connected vehicles, autonomous vehicles and smart mobility.

Although various benefits can be obtained from smart transport systems, considering the main goal of this study, benefits relevant to environmental issues, such as greenhouse gas emissions, are of major interest. Other benefits are also explored to increase the general awareness and understanding of the advantages of smart transport systems. To be clear, although many aspects of smart transport systems are considered in this study, only the above-mentioned points are covered; others points, such as institutional or regulatory perspectives, are beyond the scope of this study.
CHAPTER 2

Nationally determined contributions and the transport sector
2.1 Introduction

In 2015, countries participating in the Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, adopted the international climate agreement, which has come to be known as the Paris Agreement, and entered into force in 2016. In the run-up to COP21, several countries submitted their intended nationally determined contributions aimed at reducing greenhouse gas emissions. Following the entry into force of the Paris Agreement and in accordance with the agreement, countries that have ratified the agreement are required to submit their nationally determined contributions. As of September 2019, 185 countries had ratified the agreement. The climate actions contained in the nationally determined contributions, if implemented, will determine whether the world will achieve the key goal of the Paris Agreement: to maintain global average temperatures below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C.9

Nationally determined contributions are one of the main elements of the Paris Agreement. Through them, countries put forward the national climate actions, and climate targets that they expect to contribute towards the goal of keeping global average temperatures below 2°C above pre-industrial levels. The nationally determined contributions should ideally also detail measures to improve the country’s resilience to the negative impacts of climate change.

While there is no pre-defined format for preparing nationally determined contributions, each one contains the mitigation and adaptation measures that are expected to be taken and the priority sectors across which the mitigation efforts will be undertaken. The contributions are to be revised every five years from 2015 onwards. Accordingly, they will be revised in 2020 and 2025. As of November 2019, one country has already submitted its second nationally determined contribution to the UNFCCC. The Paris Agreement requires that revised nationally determined contributions submitted to UNFCCC build upon previous efforts and be more ambitious than prior commitments.

2.2 Greenhouse gas emissions by sector in the Asia-Pacific region

In the Asia-Pacific region, emissions from the energy sector accounted for the bulk of the carbon dioxide (CO₂) emissions, 39 per cent, followed by the industrial and agricultural sectors; emissions from the transport sector accounted for 6 per cent of the emissions in 2010 (Figure I).10 The East and North East Asia region is the largest emitter of CO₂ in the region, accounting for 55 per cent of the total emissions, while Pacific countries as a whole were responsible for 3 per cent of the region’s emissions in 2010.11

FIGURE I Greenhouse gas emissions in the Asia-Pacific region (million tonnes of CO₂ equivalent), 2010

10 Economic and Social Commission for Asia and the Pacific, Responding to the Climate Challenge in Asia and the Pacific: Achieving Nationally Determined Contributions (NDCs) (Bangkok, United Nations, 2017).
11 Ibid.
2.3 Nationally determined contributions in the Asia-Pacific region

As of October 2019, 48 countries in the Asia-Pacific region had ratified the Paris Agreement (Figure II). 12 To date, 43 nationally determined contributions and eight intended nationally determined contributions have been submitted to UNFCCC by ESCAP member countries. 13

As mentioned earlier, there is no predefined format for preparing nationally determined contributions and they vary from country to country in terms of priorities and focus areas. The energy sector and electricity generation, more specifically, were the priority areas in many of the nationally determined contributions from countries in the Asia-Pacific region. Notably, 38 countries in the Asia-Pacific region have submitted nationally determined contributions that contain references to the transport sector. 14 The measures in many of the contributions, however, lack details on specific transport emissions reductions targets or the contribution of mitigation actions in the transport sector to overall emissions reduction targets.

In addition, the level of detail on transport specific mitigation actions in nationally determined contributions varies between countries. Although the transport sector is referenced in contributions submitted by countries in the Asia-Pacific region, revealing the importance of the sector, details on how the transport sector will be decarbonized is missing.

A study 15 on transport and nationally determined contributions in a few countries experiencing rapid motorization has found that there was in some cases limited involvement of transport ministries in the preparation of nationally determined contributions. It indicated that this was, in some

\[ \text{FIGURE II} \]
The Asia-Pacific region: status of ratification of the Paris Agreement

<table>
<thead>
<tr>
<th>STATUS OF RATIFICATION OF THE PARIS AGREEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of countries that have not ratified the Paris Agreement</td>
</tr>
<tr>
<td>Number of countries that have ratified the Paris Agreement</td>
</tr>
</tbody>
</table>

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\[ \text{FIGURE III} \]
Transport mitigation measures by passenger and freight transport from nationally determined contributions in Asia and the Pacific

<table>
<thead>
<tr>
<th>NUMBER OF NATIONALLY DETERMINED CONTRIBUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger</td>
</tr>
<tr>
<td>East and North-East Asia</td>
</tr>
<tr>
<td>South-East Asia</td>
</tr>
<tr>
<td>South and South-West Asia</td>
</tr>
<tr>
<td>North and Central Asia</td>
</tr>
<tr>
<td>Pacific</td>
</tr>
</tbody>
</table>

Source: Based on data extracted from Partnership of Sustainable, Low Carbon Transport, “Transport Knowledge Base” Version 0.2.

13 Based on data extracted from Partnership of Sustainable, Low Carbon Transport, “Transport Knowledge Base” Version 0.2 and the NDC Registry (interim) Available at https://www4.unfccc.int/sites/NDCStaging/Pages/Home.aspx.
14 Based on data extracted from Partnership of Sustainable, Low Carbon Transport, “Transport Knowledge Base” Version 0.2.
15 E. Lohr, N. Perara, and N. Hill (2017), Transport in Nationally Determined Contributions (NDCs): lessons learnt from case studies of rapidly motorising countries, synthesis report (Bonn, Germany, German Agency for International Cooperation).
cases, the result of lack of climate change modelling expertise in transport ministries, and limited availability of data on emissions from the transport sector, and mitigation potential, which affected the modelling processes. Some of the transport sector recommendations of the study were: to improve emissions data collection in the transport sector; to develop nationally determined contributions implementation plans for transport; and to mainstream nationally determined contributions into national transport policies.

In terms of mitigation measures by transport modes, in the 38 nationally determined contributions with transport sector references, the focus has been most predominately on passenger transport, which is featured in more than 20 thereof, and to a lesser extent on freight transport, which has been referenced in more than 10 thereof. In terms of transport subsectors, the bulk of the mitigation measures focus on urban transport, which consists of public transport and road transport for passengers (figure IV). This is followed by measures aimed at heavy rail, inland waterways, and walking and cycling.

In terms of mitigation strategies in the transport sector (figure V), promoting public bus transport and inducing a shift towards public transport are the first priority mitigation measures in East and North-East Asia, South and South-West Asia, and South-East Asia. Using alternative energy, such as bio fuels, liquefied petroleum gas and liquefied natural gas, is the preferred strategy in the Pacific, and South and South-West Asia. Promoting e-mobility is also a major priority action in Pacific, East and North-East Asia, and South and South-West Asia.

Apart from this, strategies that focus on improving and developing road infrastructure are highlighted in the nationally determined contributions submitted by countries in South and South-West Asia, and North and Central Asia. Mitigation measures targeting regular maintenance and inspection of vehicles are also a priority in the Pacific, while green freight measures are another priority in South and South-West Asia, and South-East Asia.

**FIGURE IV**
Transport mitigation measures by sub-sectors from nationally determined contributions in Asia and the Pacific

![Graph showing transport mitigation measures by sub-sectors](image-url)

Source: Based on data extracted from Partnership of Sustainable, Low Carbon Transport, “Transport Knowledge Base” Version 0.2.
2.4 Smart transport systems and nationally determined contributions

As many countries have acknowledged the advantages of smart transport systems in mitigating greenhouse gas emissions, such systems are included in some of the nationally determined contributions and intended nationally determined contributions. Table 1 shows some examples that are directly excerpted from the relevant sources.16

As can be seen from table 1, although the terminologies used are varied, at least nine out of 38 countries have made references to smart transport technologies as a mitigation measure in their nationally determined contributions.

CHAPTER 3

Lessons learned from state-of-art practices
3.1 Overall approach

To understand the current situation of smart transport-related practices and their benefits in mitigating greenhouse gas emissions, results from cases available in the public domain are being collated, analysed and compared. In addition, some cases are being explored through the country inputs, which were directly provided by national experts. More than 100 sources have been reviewed to extract relevant information from the Asia-Pacific region, the United States and Europe. Regardless of methodologies used in previous studies cited here, in this chapter, only the results that have not been recalculated or requantified to generate new results are used.

Although the approach has been to find quantitative benefits from smart transport applications, some benefits referred to in this chapter are measured in qualitative terms, which may be useful to provide preliminary ideas about the advantages of smart transport applications in the transport sector. To make the cases more applicable, a brief overview and contributing cases are provided with a range of diverse applications from the traditional to most recent ones, and an overall assessment is also conducted as a result of the review. The selection of countries in this chapter is determined by the available information and data in order to draw lessons learned.

3.2 Cases from the Asia-Pacific region

3.2.1 Australia

(A) Overview

Although major cities in Australia are well populated, the extensiveness of the country’s territories lowers the population density, resulting in a large average on-commuting distance. Over the period January, 2013–June, 2018, average driving speeds declined significantly in major cities. In Sydney and Brisbane, they decreased by 3.6 and 3.7 per cent, respectively, and in Melbourne, they declined by an even greater degree (8.2 per cent). Such an extensive reduction in average driving speeds is often indicative of an increase in traffic congestion, which results in higher business costs, decreasing productivity and increases in vehicle emissions and fuel consumption. The cost of congestion in Australia in 2015 was estimated at approximately $16.5 billion Australian dollars ($A) (US$11.3 billion) and was projected to reach approximately $A 20 billion in 2020. In terms of the environmental impact, as of 2012, road transport accounted for 14 per cent of total greenhouse gas emissions in Australia. The Government of Australia has focused its efforts on development and utilization of smart transport technologies to solve its traffic problems. Cities, such as Adelaide, Brisbane, Melbourne, Perth and Sydney, are implementing smart transport-related projects and pooling resources and knowledge from experience with previous projects, so that they may be reborn as smart cities. Also, the resources at hand are extensive, as there is a long history connected with intelligent transport systems in Australia. In 1992, ITS Australia was set

17 Australian Automobile Association, “Road congestion in Australia” (Melbourne, Australia, Australian Automobile Association, 2018) p. 4.
20 Ibid.
up to promote the development of intelligent transport systems. More recently, the ITS Australia Strategic Plan 2018–2021 was launched to propose activities in focus areas, which will be implemented during the next couple of years. As of August 2019, approximately 80 projects related to smart transport are being implemented in Australia. Among them, 40 projects are related to connected and automated vehicles, 38 projects are in the domain of technology and policy enhancing efficiency, 18 projects pertain to data analytics and 12 projects are related to Mobility-as-a-Service. Two cases seen as providing benefits are reviewed.

(B) CONTRIBUTING CASES

Sydney Coordinated Adaptive Traffic System (SCATS)

SCATS is an advanced traffic signal optimization system that adjusts traffic parameters, including signal phase, sequence, and offset, based on a real-time traffic data collection capability, such as traffic volume. The traffic signal optimization capability of SCATS was initially developed by the New South Wales Roads and Traffic Authority and is currently being used in 42 countries and 142 cities around the world, including, among them, Sydney, Singapore, Kuala Lumpur, Jakarta, Manila, Shanghai, Hong Kong, Teheran, Doha, Mexico City, Detroit, Minneapolis, Dublin and Auckland. SCATS automatically adapts to changing traffic conditions continuously during the day and night. This enables the system to respond to changes in traffic volume at intersection approaches and compute optimum traffic signal parameters at every time step. While SCATS basically functions to optimize independent intersections, it also provides optimized traffic parameters for multiple intersections to coordinate traffic signals on consecutive intersections in the same link. A study conducted in 2011 in which 21 SCATS-controlled intersections in Sydney, the state capital of New South Wales, were reviewed, shows that SCATS reduced travel time by 28 per cent and traffic stops by 25 per cent. This improvement in traffic flows and consequent reduction in fuel combustion is expected to lead to a 15 per cent reduction in CO₂ and particle matter (PM10) emissions, and a 13 per cent reduction in nitrogen (NOₓ) emissions from vehicles, resulting in a total savings of $A 142,051 by reducing abrupt decelerations and accelerations. These reductions in physical terms are equal to 5,266 hours of travel time, 157,581 stops, 34,240 kg of CO₂, 109 kg of NOₓ and 2,418 kg of PM10-emissions.

Connected and automated vehicles trials

Given that the concept of connected and automated vehicles has attracted a lot of interest in Australia, approximately 30 related pilots, trials and case studies are being conducted. For example, connected and automated vehicle trials are being deployed and tested on the South East Queensland highway networks. In October 2018, a short-term trial was conducted of partially automated vehicles on the highways in Brisbane. The trial is to be used to evaluate the performance of advanced...
driver assistance systems, such as lane departure warning, adaptive cruise control and traffic sign recognition, in response to the road infrastructure in Brisbane.36 The trial data were collected by a smartphone application, which was developed for tracking and storing experimental data, including vehicle trajectories.37 The findings extracted from these experimental data are being used by automotive manufacturers, road-traffic operators, and government for better decision-making, and are expected to accelerate the commercialization of connected and automated vehicles.38 Another connected and automated vehicle trial is being run in the State of Victoria to evaluate the performance of connected and automated vehicle technologies in response to the motorway infrastructure in Victoria.39 This trial consists of three phases: in the first phase, an assessment is made to determine how partially automated vehicles perform with the road geometries and other external factors, such as traffic signs, toll gates, lane markings, entry-and-exit ramps, road objects, merging vehicles, illumination and weather conditions, road construction and maintenance works.40 The second and third phases are being implemented using a higher level of connected and automated technologies.41

Based on these trials, some potential benefits from connected and automated vehicles technologies can be noted. Estimated benefits of using cooperative-intelligent transport systems in South-East Queensland range from $A 575.7 million in the pessimistic scenario to $A 3.95 billion in the optimistic scenario from 2020 to 2050. In terms of fuel savings and emissions, cooperative-intelligent transport systems can contribute $A 448.3 million and $A 298.2 million in savings in the moderate scenario, respectively.42 They are also seen to be cost-effective based on showing a good cost-benefit ratio, ranging from 2.1 to 3.8 from 2020 to 2050.43 In New South Wales, early results of the implementation of cooperative intelligent transport systems for warning drivers indicate that using smart traffic signals with cooperative vehicles can potentially save up to 15 per cent in fuel consumption and corresponding emissions.44 With regard to autonomous vehicles or automated vehicles, estimates from the trial run in Victoria show a reduction of 27 million tonnes of greenhouse gas emissions, $A 706 million in health benefits, a 91 per cent increase in road efficiency, and a $A 15 billion annual boost to economic growth.45

3.2.2 China46

(A) OVERVIEW

China is experiencing rapid changes in the transport sector. As of 2017, the highway distance coverage in the country spanned 4,773,500 km and railway distance coverage totaled 127,000 km, including that of high-speed railways of 25,000 km. China has one of the largest automobile markets; in 2017, there were 217.43 million motor vehicles in the country. Owing to a rapid increase in vehicle ownership and infrastructure development, China...
has been experiencing severe traffic congestion, road crashes, increasing fuel consumption for transport and vehicle emissions. To tackle these issues, the Government initiated the 9th Five-Year (1996–2000) Plan and the 2010 Long-term Plan for the Development of Highway and Water Transportation Technology in 1995, which supported the development and establishment of intelligent transport systems developments, including the establishment of an intelligent transport system. With strong support from the Government, private sector investments in this area in China have been growing rapidly. In 2011, the overall market size of intelligent transport systems reached 25.3 billion Chinese yuan (RMB) ($3.62 billion), an increase of 25.21 per cent from 2010. It reached RMB 40.8 billion in 2013 and is expected to increase to RMB 200 billion by 2020.

In recent years, China has been actively pursuing various projects related to smart transport systems. Among them, two cases are reviewed.

(B) CONTRIBUTING CASES

Shanghai integrated intelligent transport systems

In 2010, Shanghai integrated intelligent transport systems were initiated to support the operation of transport systems for the Shanghai World Expo, which received 70 million visitors. An urban road monitoring system, transport hub travel information system, traffic emergency incident management system and traffic routing system were incorporated in the Shanghai integrated intelligent transport systems. The systems have contributed to an increase in the average speed of the central area by 3 per cent and average time for gridlock-free traffic by 7 per cent, while reducing vehicle emissions by 3 per cent. The processing time for real-time traffic information is less than one minute, with approximately 92 per cent accuracy. Based on the practices and experiences of Shanghai integrated intelligent transport systems, standards and specifications have been developed, which has affected intelligent transport management systems in more than 200 Chinese cities.

Electronic toll collection systems in expressways

With support from the Government, technical studies and pilot projects for electronic toll collection on expressway were conducted, and the Chinese standard for electronic toll collection systems was released. By 2015, electronic toll collection was operating in 29 provinces, covering 30,000 km. In total, more than 59 million drivers use roads covered by electronic toll collection systems. After adopting this system, various benefits have been observed.

Given that the traffic capacity of one electronic toll collection lane is equivalent to five manual toll collection lanes, electronic toll collection in China has led to a reduction in the average transit time at toll stations from 14 seconds to 3 seconds, which has alleviated traffic congestion on expressways. The environmental protection department has found that this positive impact has resulted in reduced fuel consumption by 0.0314 litre/vehicle, CO compound by 4.7 g/vehicle and NO compound by 0.3 g/vehicle. In other words, electronic toll collection on expressways can reduce fuel consumption by 20 per cent, CO₂ discharge by 50 per cent and carbon monoxide discharge by 70 per cent, on average. In monetary terms, it is estimated that fuel savings from electronic toll collection is about RMB 430 million, and savings from annual environment pollution control cost is approximately RMB 150 million. As electronic toll collection can improve traffic capacity without the need to extend manual toll stations for increasing traffic volumes, it can also contribute to indirect savings by reducing land acquisition costs and toll station construction costs; regarding the latter, toll station extension costs can be reduced by up to 87 per cent, along with a reduction of approximately 20 per cent in labour and service costs.

47 W. Huang, and others, “Next-generation innovation and development of intelligent transportation system in China”, Science China Information Sciences, vol. 60, No. 11.
3.2.3 Japan

(A) OVERVIEW

Japan has been experiencing economic losses resulting from traffic congestion and crashes. In the past, traffic congestion resulted in an annual time loss of 5.3 billion hours, which amounted to an economic loss of 12 trillion Japanese yen (¥) ($109.8 billion). In response, Japan recognized the need to deploy new forms of intelligent transport systems technologies to help resolve these problems by reducing the time wasted by traffic congestion and crashes. A year after the second ITS World Congress in Yokohama in 1995, five government ministries set up the “Grand Plan to Promote Intelligent Transport Systems (ITS)” as a means to foster the development of intelligent transport systems and to expand their scope in transport systems within the country.

These efforts have paid off; as of 2014, Japan is promoting 21 different intelligent transport services, including, among them, a Vehicle Information and Communication System (VICS) and an electronic toll collection system.

More recently, Japan has established the “Public-Private ITS Initiative/Roadmaps 2018”, with the objective to realize autonomous driving by means of accelerating the commercialization of autonomous driving technologies on highways for private vehicles and trucks by 2025, and the service of autonomous driving transport services in specified areas by 2020. The Government of Japan is also targeting application of the findings and technological advances for low-speed autonomous driving services in the suburban areas. Based on this information, three cases across the traditional and emerging technologies in Japan are investigated.

(B) CONTRIBUTING CASES

Vehicle Information and Communication System (VICS)

Japan initiated a VICS service on 23 April 1996 to provide real-time road and traffic information to the navigation screen of vehicles through radio wave beacon, infrared beacons, and FM multiplex broadcasts. The service areas were Tokyo, Kanagawa, Saitama and Chiba, and Tomei and Meishin expressways. In April 2015, a new service, called “VICS WIDE”, was launched, which involved increasing the transmission capacity of FM multiplex broadcasting from the previous VICS service. As of 2017, a cumulative total of 58.9 million VICS units were installed in vehicles. New VICS WIDE provides additional functions, including route search using link travel time, pop-up display of emergency warning and display of heavy rain areas. It was estimated that the VICS can reduce the socioeconomic cost from traffic congestion by 12 per cent, and that the VICS WIDE service can contribute an additional reduction by 11 per cent. The first 10 years of using the VICS had a positive effect on the economy values of about ¥ 3.71 trillion. In terms of environmental impacts, VICS service contributed to a decrease in annual CO2 emissions by 2.4 million tonnes in 2009.
Electronic Toll Collection 2.0

Electronic toll collection has been deployed in Japan for a number of decades. It evolved into electronic toll collection 2.0 in 2015, with the objective to support mitigation of traffic congestion and safe driving, and provide route recommendations. Electronic toll collection 2.0 runs by means of a high-speed, high-capacity bidirectional communication between the intelligent transport systems stations at the infrastructure side and the vehicle communication devices, one of the most recent practices of road-vehicle cooperation. Penetration of the electronic toll collection into the mainstream is exhibited using data collected within a one-week period in October 2015, during which more than 90 per cent of vehicles travelling on the expressways were found to be using electronic toll collection services on a daily basis, a figure that is equivalent to approximately 7.1 million total vehicles. Because of the technological benefits, which allows for seamless movement of vehicles through the toll gates with no need for start or stop the vehicle, the utilization of electronic toll collection has brought environmental improvements by alleviation of bottlenecks at toll stations, and accordingly, contributing to a 40 per cent decrease in expressway traffic-related CO2 emissions. The extent of this can be understood in the context that such bottlenecks were once responsible for approximately 30 per cent of the traffic congestion occurring on the country’s expressways. By the end of 2017, approximately 85 million vehicles were equipped with electronic toll collection units.

The Government of Japan has been looking into using the electronic toll collection 2.0 not only as an effective toll collection technology, but also as a means to support mitigation of traffic congestion, safe driving, countermeasures for natural disasters and private business models based on the electronic toll collection data.

Autonomous driving

With the advent of the 2020 Olympics, Japan is gearing for a rejuvenation of the transport environment through the commercialization and realization of semi- and fully-automated mobility services on its roadways. In this endeavour, a joint industry-academia-government collaboration called the “Cross-ministerial Strategic Innovation Promotion Program”, which focuses on a collaborative approach to the development and propagation of automated driving technologies, allocated ¥ 336.5 billion in 2017 to carry out large-scale field operational tests for automated driving for universal services to verify automated driving technologies. These tests took place between October 2017 and March 2019. The overall project is expected to roll into its second phase for universal services through the expansion of the operational domain of autonomous driving services into arterial and general public roads, so
that full automation can be achieved by 2025.\footnote{S. Hayashi, “SIP automated driving for universal services (SIP-adus) R&D Plans” (2018). Available at https://www.nedo.go.jp/content/100887563.pdf.} With regard to emissions impact, CO\textsubscript{2} emissions and traffic flow estimation models using traffic simulations, created through the programme for specific automated components, indicate that the introduction of the truck automated driving system on a platoon of four vehicles travelling at midnight and during 24 hours on the Shin-Tomei route at a speed of 80 km/h in less congested weekdays would reduce CO\textsubscript{2} emissions from the base case (no automated driving system) by 0.3 per cent and 0.8 per cent, respectively.\footnote{D. Oshima, and T. Kurisu, “Development of basic technologies to reduce traffic accident fatalities and congestion, and initiatives to raise social acceptance: development of tool for assessing impact of automated driving systems on traffic flow and CO\textsubscript{2} emissions” . In SID-adus: project reports, 2014–2018, Cross-ministerial Innovation Promotion Project (2018). Available at http://en.sip-adus.go.jp/file/Chapter2_s.pdf.} In addition, the project is intended to reduce traffic induced fatalities to 2,500 or less per year.\footnote{Cross-ministerial Strategic Innovation Promotion Project, “Automated Driving for Universal Services” ,SID-adus: project reports, 2014–2018 (2018). Available at http://en.sip-adus.go.jp/file/Cover-Overview_s.pdf.}

3.2.4 Republic of Korea

(A) OVERVIEW

After the Seoul Olympics in 1988, the Republic of Korea experienced rapid economic growth and a rise in social, economic and cultural activities, which resulted in greater demand for transport services. Traffic-related problems naturally followed. In response, the intelligent transport systems market has been expanding to deal with these problems. When intelligent transport systems were introduced, the cost from traffic congestion had increased by two trillion Korean won (₩) ($863 million) annually from ₩18.5 trillion in 1997.\footnote{Kyeong Pyo Kang, “ITS Country Report”, report prepared for ESCAP, May 2018.} The logistics costs accounted for 16.5 per cent of gross domestic product (GDP), which was higher than those in the United States (10.1 per cent) and Japan (9.5 per cent) because of severe traffic congestion in 1998. In the same year, deaths from traffic crashes per 10,000 cars were 8.3, which was also higher than those recorded in the United States and Japan, at 2 and 1.4, respectively.\footnote{Ibid.} Both of these statistics underscore the need for smart transport solutions to resolve the issues emanating from an inefficient and unsafe transport environment. In response, as of 2017, 13 local governments have implemented intelligent transport systems projects with subsidies from the Government of the Republic of Korea. In addition, ₩76 billion was invested in six wide-area bus information systems deployment projects in 2017, and ₩84 billion was invested in eight bus information systems projects in 2018.\footnote{Oh Dong-seop (Special report) Analysis on the Performance and Trends of Domestic ITS Project Implementation (2017–2019). Monthly ITS. 2019.04.} It was found that intelligent transport systems can generate benefits worth of ₩11.8 trillion by reducing traffic congestion, crashes and logistics costs, and result in a 12 per cent reduction in greenhouse gas emissions when compared with the business as usual scenario of 2020.\footnote{Kyeong Pyo Kang, “ITS Country Report”, report prepared for ESCAP, May 2018.} Among the applications implemented, four cases are reviewed which help to understand the benefits of smart transport systems to the environment in the Republic of Korea.

(B) CONTRIBUTING CASES

Bus information systems

Bus information systems are being provided not only inside cities but also in intercity operations. For an intercity trip, a bus information system is referred to as a wide-area bus information service, highlighting the expanded coverage domain. To expand the bus information services to the wider area, 28 primary and secondary regionally based bus information systems deployment projects were implemented in 2016–2017, and additional secondary projects are ongoing, as of June 2018. For the primary regions, which consist of 12 cities in Gangwon Province and two cities in Jeollanam Province, the bus information systems project deployed 63 bus information systems.
panels, 350 vehicle on-board units, and one central system. The secondary deployment projects, being carried out in five cities in Gangwon Province, six cities in Jeollanam Province, three cities in Chungcheongnam Province and in Gyeongsangbuk Province, include distribution of 333 bus information panels, 616 vehicle on-board units, 270 automatic passenger counters, 62 bus route information systems, and one central system. The provision of these technologies through the deployment projects has allowed for bus users living in small- and medium-sized cities to obtain information on bus arrival and passenger capacity, among other information that is relevant to their needs, which can be accessed through the bus information terminal. For safe operation of buses, a digital tacho graph is installed inside them to record bus operations, such as driving trajectories, in real-time, allowing for bus operation information to be transmitted to an electronic tachograph analysis system. In terms of environmental impact, a study has indicated that implementation of bus information systems in the 8.3 km section between Daejeon and Chungju led to an estimated reduction in CO2 of 39.45 tCO2/km. In addition, the installation of bus information systems has resulted in an improvement in the punctuality of the bus service by 35 per cent, a reduction in bus waiting time by an average of three minutes, and a decrease in bus-related crashes by 24 per cent.

Traffic information centre

A traffic information centre, referred to as “Seoul Transport Operation & Information Service”, was set up in Seoul in 2004 to collect and process a vast amount of traffic data and public transport operations data, and to provide public transport information, road-traffic information, such as congestion and road maintenance, and automated traffic enforcement, such as for speeding, signal violation, illegal parking, and exclusive lane violation services. The TOPIS is based on an integrated service platform for multiple public transport services, and consists of six unit platforms, including a central platform that controls overall unit platforms, a bus information platform that controls buses and provides bus arrival information in real-time, an urban expressway and arterial road traffic management platform to collect and control the traffic information and operate traffic signals, an unmanned enforcement platform to control illegal parking and speeding, and a transport big data analysis platform that supports transport policy establishment based on the abundant transport data collected in the platform. It has been working to increase the utilization ratio of public transport, and as a result, 1.4 million people use the provided public transport information per day; accuracy of bus arrival information is approximately 98 per cent; and user satisfaction has reached 96 per cent. Furthermore, the utilization ratio of the transport card is 100 per cent for subways and 98.17 per cent for buses, which means that almost all citizens using public transport use the transport card. An annual savings of W146.2 billion is estimated to be achieved in reduced transport time, crashes, and environmental pollution on intelligent transport systems-equipped roads, which span all expressways and 14 per cent of national highways, as a result of advanced traffic management through traffic information centres, such as the TOPIS, from which real-time traffic information is gathered, processed, and disseminated through various outlets for public use, such as the Internet and variable message signs.

80 Ibid.
82 See http://www.korea.kr/archive/expDocView.do;JSESSIONID_KOREA=hGBvcl0JskblHnvwLRLWxyCTLvPc1NGVTSmfo7LStsvpTMvPmpgy21-19445175871920210111&docId=10767.
86 Seoul Metropolitan Government, “A people-oriented safe and comfortable transportation for Seoul” Available at https://seoulsolution.kr/
87 Institute for Transport and Development Policy, “Intelligent transportation systems”, ADB knowledge Asia case studies project (Seoul and New York: Institute for Transportation and Development Policy, 2013).
Hi-pass system on the expressways

The Republic of Korea introduced and deployed Hi-pass, an electronic toll collection system, in 2007. Hi-pass is intended to reduce toll-gate gridlock and increase convenience for drivers by allowing non-stop toll collection at toll-gate. A Hi-pass unit, which is installed at each toll-gate lane in the initial Hi-pass system, has been upgraded to a smart tolling system, allowing coverage of multiple lanes and all vehicles passing through the toll collection road section. The smart tolling system is also being deployed on the expressways. According to an emission assessment result, a one-tonne cargo truck with a Hi-pass device could reduce the waiting time at a tollgate by 20 to 42 seconds, corresponding to a reduction in CO₂ emissions by 38 to 99 grams, and fuel costs by ₩25 to ₩66. The market penetration rate of Hi-pass is approximately 60 per cent of all registered vehicles in the Republic of Korea. Lower CO₂ emissions by 15,300 tonnes and fuel costs by ₩12.3 billion can be attributed to the deployment of the Hi-pass system annually.

Cooperative-intelligent transport systems demonstration

Cooperative-intelligent transport systems are an advanced form of existing intelligent transport systems that utilizes vehicular wireless communications, such as vehicle-to-infrastructure and vehicle-to-vehicle communications. Recently, the Government of the Republic of Korea defined 15 traffic safety services based on the cooperative-intelligent transport systems and initiated pilot projects. The objectives of the pilot projects are to test the performance of cooperative-intelligent transport systems, in line with the advancement of the self-driving system, to develop any related regulations in roads and traffic, and to support and promote the private sector in the cooperative-intelligent transport systems domain. The Seoul Metropolitan Government and the Jeju Special Self-Governing Province are the locations chosen for the cooperative-intelligent transport systems pilots. For the pilots, the cooperative-intelligent transport systems infrastructure will be deployed on 300 km of the roads in Jeju and 121 km of the bus rapid transit routes and urban expressways in Seoul. The implementations of the pilots are being carried out on expressways. Cooperative-intelligent transport systems infrastructure is being deployed on 85 km of road sections. Furthermore, to promote the cooperative-intelligent transport systems, an on-board unit has been distributed to 500 commercial vehicles. By 2020, the expansion of intelligent transport systems is expected to enter into the second phase, or intelligent transport systems 2.0, during which 30 per cent of roads are expected to be vehicle-to-everything based. Through this, services such as bidirectional communication and cognitive functions will be provided on these roads, leading to an estimated reduction of 2.2 million tCO₂ per year. The Ministry of Land, Infrastructure and Transport expects to reduce the annual traffic congestion cost by ₩800 billion, increase traffic speeds in the city centre by 30 per cent, and reduce traffic crashes by 46 per cent, as a result of the full utilization of the cooperative-intelligent transport systems on the roadways in the Republic of Korea.
3.2.5 
Singapore 

(A) OVERVIEW 

The transport systems in Singapore consist of roads, subways and maritime travel, however, most parts of the country are connected by road, including the areas of Sentosa and Jurong. The country’s growing population and shortage of available physical space has become an obstacle for seamless traffic management and operation. Travel demand is expected to increase from 8.9 million trips per day to about 14.3 million by 2020, and approximately 12 per cent of the land is taken up by the 3,300 km-road network and another 15 per cent is occupied by housing. As expanding road networks to address such problems is not a sustainable option because Singapore has a land area of only 718.3 km\(^2\), the Government of Singapore is dedicated to using intelligent transport systems technologies to maximize the efficiency of the current transport systems by balancing travel demand and supply. Since 1995, the Government has constantly leveraged intelligent transport systems to benefit from technologies, and the first ITS Master Plan was developed in 2006. Singapore is the front-runner in South-East Asia in adopting new intelligent transport systems. The first electronic road pricing system was implemented in the country to control travel demand in response to traffic flows and the time of day. Various novel applications, such as the Green Link Determining system to provide seamless green time along main roads, TrafficScan to collect traffic information from a taxi’s global positioning system (GPS), and Green Man+ to extend green time for the elderly and disabled to cross the road, have also been introduced. New concepts of smart mobility and autonomous vehicles are actively being implemented. Among such applications, two cases are reviewed to understand the benefits of smart transport systems in Singapore. 

(B) CONTRIBUTING CASES 

Electronic road pricing 

An electronic road pricing system was initially introduced in Singapore in 1998. Under the system, a fee is charged to road users for passage through a particular road with the objective to reduce vehicle use during periods of high congestion. The fee is charged through a cash card placed inside a vehicle using short-range radio communication whenever a vehicle passes through an electronic road pricing checkpoint. The rate varies by the type of vehicle, time of day, traffic conditions, and charges can change at every half hour. The system enables the country’s traffic management systems to collect abundant reliable and accurate traffic data, which can be used for decision-making by government and for providing traffic status information to road users. Singapore is considering the deployment of the next generation of electronic road pricing, which allows charging by a GPS signal produced from vehicles passing through the electronic road pricing checkpoint without any physical gantries. According to an estimate based on an emission assessment in Singapore, the electronic road

98 See https://www.geography.org.uk/teaching-resources/singapore-malaysia/is-Singapores-transport-system-fit-for-purpose. 
105 Ibid. 
106 See https://www.onemotoring.com.sg/content/onemotoring/home/driving/ERP.html. 
108 Ibid.
A pricing system has reduced CO₂ emissions by 103 kilo-tonnes. The initial assessment indicated that traffic volume and speed were also found to be positively affected during electronic road pricing hours, with speeds increasing from 35 to 55 kph and traffic volumes decreasing by 15 per cent.

Autonomous driving test bed

The Centre of Excellence for Testing and Research of Autonomous Vehicles recently developed a test-bed and the experimental facilities for testing automated vehicles. This facility is intended to support the development of test requirements and standards to deploy automated vehicles in Singapore. Consequently, the performance of many experiment-related automated vehicles are being actively examined on the test-bed before being introduced on public roads in Singapore. The test-bed is approximately 18,000 m² and provides a virtual road environment, including signalized intersections. In addition, vehicle-to-everything wireless roadside equipment, lidar equipment for test monitoring and rainmaking facilities are provided for testing automated vehicles in a variety of road-traffic situations. Recently, a self-driving shuttle was purchased and operated for a variety of experiments, including the recognition of obstacles, linking with signal controllers, and providing the capability to cope with traffic conditions through vehicle-to-everything wireless communication, because the self-driving shuttle has been spotlighted as the next-generation transport system in Singapore. Beyond the test-bed experiment, a real road demonstration is being operated in the One-north area in Singapore. The One-north section connects Biopolis, Fusionopolis, and Mediapolis. Its acceptance level of self-driving vehicles is relatively higher than that of other regions, as the location has major research institutes and companies. To test automated vehicles in this region, advanced infrastructure, including high-definition CCTVs and vehicle-to-everything communications (roadside units), and electronic high-definition maps have been equipped. This is promoting public and private sectors for testing automated vehicles in this area.

3.3 Cases from the United States and Europe

3.3.1 United States

(A) OVERVIEW

Traffic issues have been a major threat to economic growth and quality of the life in the United States. To tackle them, the application of new technologies in transport systems has been considered since the 1960s, when the first deployments of dynamic message signs and North American traffic management centres occurred. Under the leadership of the United States Department of Transportation, a national intelligent transport systems programme was developed over a twenty-year period to improve safety and mobility, reduce environmental externalities, and increase productivity. Intelligent transport systems have been providing substantial benefits to users. The societal benefits are estimated at more than $2.3 billion annually. Given that traffic congestion is still a large problem, resulting in loss...
of productivity estimated at $87 billion in 2018.\textsuperscript{116} the United States is leaning towards adopting various concepts of smart transport technologies with a focus on five strategic themes, as indicated in the ITS Strategic Plan 2015–2019\textsuperscript{117} – (i) enable safer vehicles; (ii) enhance mobility; (iii) limit environmental impacts; (iv) promote innovation; and (v) support transport system information sharing. Considering that the United States is one of the leaders in the field of smart transport systems and had some good experience in terms of reducing greenhouse gas emissions, four cases across the traditional and emerging technologies are reviewed.

\section*{(B) CONTRIBUTING CASES}

\textit{Traffic management centre}

The traffic management centre is the focal point where all intelligent transport subsystems are connected, and all data collected from the intelligent transport systems sensors are transmitted. State departments of transportation have continued to establish such centres in order to focus on the operations of their systems.\textsuperscript{118} As the traffic management centre is the point for operations and maintenance of city traffic, new and advanced traffic management systems, such as integrated corridor management, and active traffic and demand management have been integrated into the centre to facilitate more responsive or even predictive traffic operation strategies.\textsuperscript{119} The traffic management centre is beneficial for real-time traffic management based on these integrated corridor management and active traffic and demand management. Accordingly, the centre can help to reduce incident clearance time, delays, queue, crashes, and travel time.\textsuperscript{120} For example, the New York City Department of Transportation achieved a 10 per cent reduction in travel times through the initial corridor, by applying this real-time traffic congestion management system.\textsuperscript{121} In addition, traffic management strategies under the Greenhouse Gas Toolkit projects in Oregon indicated that through the traffic management centre, total transport sector greenhouse gas emissions can be decreased by a range of 0.07 to 1.3 per cent by 2030.\textsuperscript{122}

\textit{Traveller information systems}

Traveller information is useful for road users, as it provides information on traffic delays, inclement weather conditions affecting road conditions, special events requiring detours or caution, road work zones and road closures. In the United States, traveller information is provided prior to a trip and en route through information dissemination tools such as radio, television, highway advisory radio, websites, mobile applications, and dynamic message signs.\textsuperscript{123} Beyond this spot-based traveller information service, the traveller information system is evolving into in-vehicle traveller information through connected vehicle technologies, such as vehicle-to-everything communications and other “infotainment” applications.\textsuperscript{124} According to the Washington Department of Transportation, road users change their travel route once every 4.2 times that traveller...
information is provided, based on the test results of in-vehicle traveller information systems over a six month period. The results of this test also show that users who change their route can save 30 minutes in travel time. In another vein, a decrease in the range of 66,000 to 99,000 in vehicle miles driven and fuel consumption in the range of 2,600 to 2,800 gallons has been observed through the deployment of highway advisory radio and a portable dynamic message sign in the Grand Canyon National Park in a pilot shuttle bus programme to test the effectiveness of the combination of the two sources for travel information.

Connected and automated vehicle pilots

The Connected Vehicle Pilot Deployment Program is being implemented with the objective to realize services designed to maximize safety and mobility, and reduce environment externalities by developing vehicle-to-vehicle and vehicle-to-infrastructure communication systems and infrastructure. Under the programme, the United States Department of Transportation is deploying connected vehicles in three areas – New York, Tampa, and Wyoming. Connected vehicle technologies are specialized and customized based on the social and traffic characteristics of each region. In New York, technology related to intersection communication for vehicle-to-vehicle, improved vehicle flow, and pedestrian safety at early level is being applied; vehicle-to-infrastructure and vehicle-to-vehicle technologies and data utilization are being applied to variable highways and nearby roads in Tampa, Florida; and vehicle-to-vehicle, and vehicle-to-infrastructure and infrastructure-to-vehicle technologies are being applied to the I-80 corridors (402 miles) passing through Southern Wyoming focusing on commercial trucks. The main focus of these projects is to improve safety on roadways, but they are also expected to affect vehicle emissions and fuel efficiency. As an example of the impact of connected vehicle technologies, one analysis showed that these technologies, such as adaptive cruise control combined with vehicle-to-vehicle communications, can minimize sudden braking and stopping, and smooth traffic flows on highways, which, in turn can increase fuel efficiency from 23 to 39 per cent. A comprehensive emission estimation based on connected vehicle technologies is being carried out with the change in emissions between the connected vehicle-implemented case (with the connected-vehicle demonstration projects) and a base case (as if those projects had not been implemented) being investigated with a seven-year timeframe.

In addition, as the Connected Vehicle Pilot Deployment Project moves into the final phase, which consists of deployment, and impact and performance evaluations, authorities in New York, Wyoming, and Tampa have each submitted “Mobility, Environment, and Public Agency Efficiency Refined Evaluation Plans”. Within these plans the expected impacts of the deployments in the form of testable hypotheses are summarized. These hypotheses are specific and tailored to each pilot project’s needs. Of the numerous hypotheses,
for instance, with regard to mobility, in the New York plan, it is hypothesized that deployment “will not adversely affect mobility for all vehicles while improving travel reliability, both equipped and unequipped, in the deployment corridors”\(^\text{135}\) while under the Wyoming plan, deployment is expected to “improve mobility for both equipped and non-equipped vehicles in the deployment corridor during inclement weather events”\(^\text{136}\). In the Tampa plan, there is no explicit reference to the expected mobility impacts, but instead, the focus is on safety benefits, one of which is that the deployment “will reduce vehicle-to-vehicle and vehicle-to-streetcar crashes and incidents (or other safety surrogate measures if crashes are rare) in the pilot deployment area”\(^\text{137}\). Testing and analysis of relevant data of the pilot deployments will allow for concrete results to be obtained with regard to these hypotheses.

**Smart city challenges\(^\text{138}\)**

The United States Department of Transportation launched the Smart City Challenge project in December 2015. This project is aimed at developing ideas for an integrated, first-of-its-kind, smart transport system that use data, applications, and technology to help people and goods move more quickly, cheaply, and efficiently, and finally invest funding for the selected ideas and cities. The challenge generated a lot of responses, and 78 cities submitted applications with the urban challenges they face and ideas on how to tackle them. The United States Department of Transportation selected seven finalists; each city received $100,000 for public outreach over a three-month period of deep discussion on their smart city vision. Among these cities, Columbus, Ohio was selected as a finalist. Columbus established five visions through the Smart City Challenge project: access to jobs; smart logistics; connected visitors; connected citizens; and sustainable transportation. After spending close to one year carrying out research, Columbus has begun to make notable progress regarding connected vehicles, access to mobility for low-income residents, and electric vehicle deployment\(^\text{139}\). With the intention to reduce greenhouse gas emissions emitted by its public fleet, Columbus has upped its purchase of electric vehicles by adding 93 vehicles to the city fleet in 2018, realizing more than 50 per cent of its procurement goal of 300 electric vehicles by 2020.\(^\text{140}\)

 проjected annual savings in fuel and maintenance costs of electric vehicles are estimated at between $31,000 and $46,000 per vehicle in comparison with diesel vehicles.\(^\text{141}\) Efforts to electrify the transport environment has also increased the general adoption of electric vehicles in the city by 65 per cent from 2017.\(^\text{142}\) Of the remaining finalists, four others received smaller grants to pursue parts of their applications. Pittsburgh obtained a grant of approximately $11 million\(^\text{143}\) to deploy, among other technologies, real-time adaptive traffic signal, and vehicle-to-vehicle communications at key intersections along its “Smart Spine” corridor.\(^\text{144}\) Through the Scalable Urban Traffic Control programme, an adaptive signal technology that manages traffic idling, such times for vehicles at intersections have been reduced by 40 per cent,
and emissions decreased by 21 per cent.\textsuperscript{145} Along with the projects pursued by Columbus and Pittsburgh, other cities that have received similar grants are also working to meet their own vision statements for their ideal mobility environment.

### 3.3.2 Europe

#### (A) OVERVIEW

The environmental and cost impacts of transport on the European economy and society are extensive. Transport accounts for approximately 25 per cent of greenhouse gas emissions in Europe, and road transport is responsible for approximately 70 per cent of total transport-related greenhouse gas emissions.\textsuperscript{146} Costs associated with road congestion were estimated at approximately 1 per cent of the GDP of Europe or more than 110 billion euros ($121 billion) a year.\textsuperscript{147} As such, intelligent transport systems are being pursued actively in Europe to increase safety, and reduce growing transport emissions and congestion problems. In the 1970s, the technology to broadcast messages to vehicles only was developed by several European companies; this may be considered the first phase of intelligent transport systems development in Europe.\textsuperscript{148} In 1991, the European Commission supported the creation of the European Road Transport Telematics Implementation Coordination Organization to strengthen private-public partnerships for intelligent transport systems development.\textsuperscript{149} To date, Europe is encountering a challenge to achieve a target to reduce greenhouse gas emissions by 20 per cent by 2020 compared to the level in 1990, and 60 per cent by 2050.\textsuperscript{150} As an integrated approach is required to achieve such an ambitious goal, new smart transport technologies have been deployed in Europe in various forms. In this regard, the European Union and European Road Transport Telematics Implementation Coordination Organization recently set up the 2030 blueprint, consisting of five areas – connected and automated driving, clean mobility, transport and logistics, urban mobility and cross-sector – to supplement traditional approaches from intelligent transport systems and to develop a new agenda.\textsuperscript{151} Because Europe is the forefront in the field of smart transport systems and has gained good experiences in terms of reducing greenhouse gas emissions, three cases have been selected to be explored to derive lessons learned.

#### (B) CONTRIBUTING CASES

**Traffic management and control systems**

Traffic management and control systems generally encompass a number of applications, such as traffic signal control, lane control and allocation, dynamic speed limits, parking management and ramp metering control. Because of the diversity of traffic management and control systems, many European countries have been able to apply them in various ways to tackle environmental issues. In Helmond, Netherlands, the use of the eCoMove dynamic green wave for traffic lights results in a 4.1 per cent reduction in CO\textsubscript{2} emission during peak periods and a 3.6 per cent reduction during off-peak periods. In 2013, a trial in Ingolstadt, Germany indicated that the adaptive traffic control system has a pollutant reduction potential of 15 per cent on average for fuel economy and reductions in emissions of CO\textsubscript{2} by 15 per cent, NO\textsubscript{X} by 33 per cent, NO\textsubscript{2} by 27 per cent, particulate matter by 27 per cent and hydrocarbons

\textsuperscript{145} Ibid.


\textsuperscript{149} Ibid.


\textsuperscript{151} See http://ertico.com/its-innovation-deployment/.
by 13 per cent. In addition, in Turin, Italy, the trial on urban traffic control shows significant savings in travel times of up to 25 per cent, which results in an 8 per cent decrease in CO₂ emissions under normal traffic conditions and a 4.5 per cent reduction under congested conditions.

Eco-driving applications

Eco-driving is a system that provides support to drivers required to reduce fuel usage and associated costs, emissions and other pollution effects. In general, eco-driving applications are divided into pre-trip, such as trip planning, during the trip, and post-trip, such as a review of trip data. In 2011, 6,500 buses in the United Kingdom of Great Britain and Northern Ireland had telematics systems to support eco-driving and 13,800 drivers could use them with the goal of reducing fuel consumption by 4 per cent and the number of crashes. The Committee on Climate Change estimated that the application of telematics systems in the United Kingdom could reduce CO₂ emission by 0.3 million tonnes by 2020. As a result of the eco-driving Europe initiative, the fuel consumption of 350 service vehicles of the Canon Company in Switzerland declined by 6.1 per cent, the kilometres per traffic crashes increased by 22 per cent and total crashes declined by 35 per cent. In the Netherlands, the initiative's eco-driving programme led to a reduction in costs of five euros avoided per tonne of CO₂ over a 10 year period.

In addition to local initiatives, the European Union is involved in a number of efforts to implement eco-driving. ecoDriver is an integrated project funded by the European Commission to optimize eco-driving strategies. Trials related to this project have been carried out in France, Germany, Italy, Spain, Sweden, the Netherlands and the United Kingdom. Based on quantitative evaluations, the ecoDriver system can reduce fuel consumption and CO₂ emissions by an average of 4.2 per cent and NOₓ emissions by an average of 4 per cent. In addition, Europe has conducted the first large-scale naturalistic driving study entitled “European naturalistic driving and riding for infrastructure and vehicle safety end environment (UDRIVE)”, to identify approaches for reducing emissions and fuel consumption. It was revealed that an eco-driving application could reduce fuel consumption by up to 25 per cent. Such benefits for reduced fuel consumption could directly lead to the reduction of environmental externalities.

Cooperative-intelligent transport systems pilots

Compass4D is a European project to support the practical utilization of cooperative-intelligent transport system and connected and automated vehicles technologies by developing a test bed in the road environments of seven European cities including, among them, Bordeaux, Copenhagen, Helmut, Newcastle, Thessaloniki, Verona, and Vigo. These seven test-beds are intended to be used for performing independent and mutually collaborative studies during the project period (January 2013 to December 2015). A total of 44 organizations, including European automakers and automotive parts suppliers, are participating in this research. The major trial services to be tested are road hazard warnings, a red-light violation warning, and an energy efficient intersection.

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153 Ibid.
155 Ibid.
156 Ibid.
158 Ibid.
160 Ibid.
<table>
<thead>
<tr>
<th>COUNTRIES</th>
<th>INTELLIGENT TRANSPORT SERVICES</th>
<th>BENEFITS IN SUSTAINABILITY (ESTIMATED POSSIBLE EMISSION)</th>
<th>BENEFITS IN OTHERS (SAFETY, TRAVEL TIME, AMONG OTHERS)</th>
</tr>
</thead>
</table>
| Australia | SCATS (21 SCATS-controlled intersections in Sydney) | • Reduction of 15 per cent of CO₂ and PM10, and 13 per cent of NO₅*  
  *Corresponding to the saving of 3A142 051 | • Reduction of 28 per cent of travel time  
  • Reduction of 25 per cent of traffic stops |
|          | Connected and automated vehicle trials | • Reduction of 15 per cent of fuel consumption (New South Wales)  
  • Reduction of 27 million tonnes of greenhouse gas emissions (Victoria) | • Increase of 91 per cent of road efficiency*  
  • US$515 billion of annual economic boost (growth) |
| China    | Shanghai intelligent transport services | • Reduction of 3 per cent of greenhouse gas emissions | • Increase of 3 per cent of average speed  
  • Reduction of 7 per cent of travel time in central area |
|          | Electronic toll collection | • Reduction of 20 per cent of fuel consumption, 50 per cent of CO₂, and 70 per cent of carbon monoxide  
  (0.0314 liter/vehicle, CH by 0.7 g/vehicle, CO by 4.7 g/vehicle, and NO by 0.3 g/vehicle)*  
  *Corresponding to the saving of RMB 430 million (monetary value of the emission reduction) | • Reduction of average time of passing through a toll-gate from 14 seconds to 3 seconds |
| Japan    | VICS | • Reduction of 2.4 million tonnes of CO₂ (in 2009) | • Reduction of 12 per cent of socioeconomic cost (congestion cost)  
  • Savings of ¥3.71 trillion yen (during the first 10 years) |
|          | Electronic toll collection 2.0 | • Reduction of 40 per cent in CO₂ | • Near elimination of bottlenecks at toll stations in expressways (once accounted for about 30 per cent of total congestion on expressways) |
|          | Autonomous driving | • Reduction of CO₂ by 0.3 per cent at midnight and 0.8 per cent during a period of 24 hours from the base case (four truck platoon automated driving system) | • Expected reduction of annual traffic fatalities to 2,500 or less  
  • Ensure mobility to rural and vulnerable populations  
  • Alleviation of traffic congestion  
  • Resolution of logistics issues arising from labor pool decrease |
| Republic of Korea | Wide-area bus information systems | • Reduction of 39.45 tCO₂/km annually (8.3 km section between Daejeon and Chungju) | • Increase of bus punctuality by 35 per cent  
  • Reduction of bus waiting time by an average of three minutes  
  • Reduction of bus related crashes by 24 per cent |
|          | Traffic information centre | • Annual reduction of ¥146.2 million in transport time, crashes, and environmental pollution (traffic management systems) | • Attainment of 96 per cent of the users’ satisfaction  
  • Attainment of 100 per cent and 98.17 per cent of the utilization ratio for subways and buses, respectively |
|          | Hi-pass | • Reduction of CO₂ in the range of 38 and 99 grams (per range in reduction of waiting time for one-tonne cargo truck)  
  • Reduction of 15,300 tonnes of CO₂ annually*  
  * ¥12.3 billion annually | • Reduction of the waiting time at a toll-gate in by 20 to 42 seconds (one-tonne cargo truck) |
|          | Cooperative-intelligent transport systems C-ITS | • Estimated reduction of 2.2 million tCO₂ per year by 2020 | • Increase of travel speed by 30 per cent  
  • Reduction of traffic crashes by 46 per cent  
  • Reduction of ¥800 billion of traffic congestion cost |
| Singapore | Electronic road pricing | • Reduction of 103 kilotonne of CO₂ | • Increase of travel speed from 35 kph to 55 kph (initial assessment)  
  • Reduction of 15 per cent in traffic volume (initial assessment) |
| United States | Transport management centre | • Reduction of 0.07–1.3 per cent in total transportation sector baseline greenhouse gas emissions in 2030 (traffic management strategies) | • Reduction of 10 per cent in travel time (New York City) |
|          | Traveller information systems | • Reduction of between 2,600 and 2,800 gallons in fuel consumption (Grand Canyon National Park) | • Rough change at every 4.2 times of traveller information provisions  
  • Reduction of 30 minutes in travel time on average (for the persons who changed their routes) (Washington State) |
|          | Connected vehicle pilot | • Increase of fuel efficiency by between 23 and 39 per cent*  
  *The emission impact is currently being investigated. (i.e., including CO₂, volatile organic compounds, NO₅, PM10, SO₅, and CO) | • Expected to "not adversely affect mobility for all vehicles while improving travel reliability, both equipped and unequipped, in the deployment corridors" (New York City)*  
  • Expected to “improve mobility for both equipped and non-equipped vehicles in the deployment corridor during inclement weather events” (Wyoming)*  
  • Expected to "reduce vehicle-to-vehicle and vehicle-to-streetcar crashes and incidents (or other safety surrogate measures if crashes are rare) in the pilot deployment area" (Tampa, Florida)*  
  * Impacts are being investigated. |
|          | Smart City challenge | • Reduction of 21 per cent in emissions at intersections (Pittsburgh, Pennsylvania) | • Increase of 65 per cent in adoption of electric vehicles compared to 2017  
  • Reduction of 40 per cent in idling time at intersections (Pittsburgh, Pennsylvania) |
| Europe   | Traffic management and control systems | • Reduction of 4.1 per cent of CO₂ in peak period and 3.6 per cent of CO₂ in non-peak period (eCoMove, Helmond, Netherlands)  
  • Reduction of 15 per cent of CO₂ and fuel consumption, 33 per cent of NOₓ  
  • Reduction of 27 per cent of CO₂, 27 per cent of particulate matter emissions, and 13 per cent of hydrocarbons  
  (Adaptive traffic control, Ingolstadt, Germany)  
  • Reduction of 8 per cent of CO₂ in normal conditions, 4.5 per cent of CO₂ in congested conditions (Urban traffic control, Turin, Italy) | • Reduction of 25 per cent in travel time (Urban traffic control, Turin, Italy)  
  • Reduction of 35 per cent in total crashes (Canon company, Switzerland)  
  • Avoidance of 5 euros per tonne of CO₂ saved for a 10 year period (Netherlands) |
|          | Eco-driving applications | • Reduction of 4.2 per cent of fuel consumption and CO₂, 4 per cent of NO₅ | • Reduction of 35 per cent in total crashes (Canon company, Switzerland)  
  • Avoidance of 5 euros per tonne of CO₂ saved for a 10 year period (Netherlands)  
  • Increase of 2–6 per cent of fuel efficiency (light and heavy vehicles)  
  • Reduction of 200 grams of CO₂ per bus route/trip (bus)  
  • Reduction of 7 per cent in fatalities and serious and minor crashes |
Through this project, Copenhagen has targeted to reduce carbon emissions by 20 per cent in 2015 and achieve the first carbon neutral city in the world by 2025. One study indicated that the energy efficient intersection can increase fuel efficiency by 2 to 6 per cent for light and heavy vehicles, and an energy efficient intersection-equipped bus can save more than 200g CO₂ per bus route per trip. In terms of the societal impact, according to a benefit-cost analysis conducted by the cooperative-intelligent transport systems services, safety related services that include, but are not limited to, hazardous location warnings, in-vehicle speed limits, and intersection safety are expected to decrease fatalities, and serious and minor injuries by an additional 7 per cent from the baseline scenario.

3.4 Overall assessment

As a result of rapid advancement of ICT and an increase in transport demand, smart transport applications are being deployed in the Asia-Pacific region, the United States and Europe. Beyond conventional applications, emerging technologies, such as cooperative-intelligent transport systems, connected and automated vehicles and smart city, are being initiated and tested to respond to diverse economic, social and environmental issues generated from transport systems.

More than 100 sources have been reviewed in this chapter to identify environmental benefits from smart transport systems. Although the focus area is related to greenhouse gas emissions, other benefits, such as congestion, safety, and socioeconomic costs, are also discussed. Major lessons learned from the reviewed cases are as follows:

1. The cost-effectiveness of traditional smart transport applications: Traditional smart transport applications are effective in reducing greenhouse gas emissions – SCATS in Australia, VICS in Japan, electronic road pricing in Singapore, electronic toll collection in China, Japan and the Republic of Korea, and traffic management and control systems in Europe. Although the extent of their effectiveness varies by location and application, from 3.6 per cent to 70 per cent, it is obvious that there is a reason why such applications have been used over time. In some cases, these traditional applications have performed better when compared to the emerging technologies (although the performance assessment for emerging technologies has been conducted through simulation tools or scenario-based estimations). Given that the cost of implementing these traditional applications is steadily diminishing with the advancement of ICT, they are a good option to consider to mitigate greenhouse emissions in developing countries in a cost-effective way.

2. The environmental-friendliness of emerging smart transport technologies: Although emerging technologies are in the testing stage, as expected, they have performed well in terms of mitigating greenhouse gas emissions in various locations where they have been tested. It is too early to give a judgement about the emerging technologies’ benefits for the environment, however in some cases, such as connected and automated vehicle trials in Australia, connected vehicle pilots in the United States and cooperative-intelligent transport systems pilots in Europe, the benefits of such technologies to increase fuel efficiency and reduce greenhouse gas emissions are evident. Given that such technologies are still in their infancy in the Asia-Pacific region, potential benefits for the environment thereof should be considered in a timely manner.


3 **The environmental benefits of in-vehicle applications:** According to the definition of intelligent transport systems, in particular the definition given by ESCAP, smart transport technologies also include in-vehicle technologies. Even though there are limited sources regarding the effectiveness of in-vehicle technologies on the environment, eco-driving applications in Europe provide a good reference for the decrease in fuel consumption (up to 25 per cent) and the reduction of greenhouse gas emissions. As generally known, manufacturing vehicles are predominantly led by the private sector, which is very sensitive to technology trends. With governments’ continuous encouragement and support of environmental issues, in-vehicle technologies, such as eco-driving applications, could be widely deployed to tackle greenhouse gas emissions.

4 **Wide extent of benefits by smart transport technologies:** It is observed that the range of estimated benefits varies with a wide extent. This is because this type of assessment is generally based on many assumptions. At the same time, the magnitude and extent of effectiveness may differ according to smart transport applications and deployed locations. Although the range may vary on a case-by-case basis, it is very clear that smart transport systems have shown the positive impact in reducing greenhouse gas emissions regardless of where they have been implemented.

5 **Indirect indicators of benefits from smart transport systems:** In addition to environmental benefits, there are other types of benefits, including, for example, the reduction of travel time, traffic stops, crashes and socioeconomic costs, and the increase in travel speed and user satisfaction. Although environmental benefits are not directly estimated with quantified numbers, some benefits (reductions of travel time, stops and travel speed) are related to greenhouse gas emissions and can show the positive capability of specific applications tested in those studies.

6 **Multi-purposed smart transport applications:** In line with the above point, smart transport applications can be introduced with multiple purposes depending on the demands. One application, such as advanced traveller information systems, may be adopted to reduce travel time in a specific target area. This application can reduce traffic congestion, increase user satisfaction and also decrease associated socioeconomic costs.

In addition to the summarized benefits from the literature review, the key limitations are as follows:

1 **Lack of quality data:** Many studies on performance evaluations for smart transport systems do not focus on environmental issues, such as greenhouse gas or fuel consumption. This is because when the decision is made to apply smart transport applications, the impact on environmental externalities is not always the primary objective. Instead, the focus tends to be on increasing mobility and safety. Given that many policymakers still consider the environmental benefits of smart transport systems as a secondary effect, their assessments are not properly conducted, even though there may be positive impacts on the environment from such technologies.

2 **Lack of assessment validation:** Even though some studies investigate the environmental impact of smart transport applications, few field studies on the actual change in greenhouse gas emissions have been conducted. For any study, an analogical approach has been taken, which uses the variation of vehicle’s performance, including speeds and acceleration rates.
3 **Limited assessment scope:** In terms of the scope of assessment for the environmental impacts, many studies have focused on a specific location at the city level or even in a smaller jurisdiction. Considering that transport systems are interconnected and interoperated, an approach that takes into account a temporal-spatial scope would be better to examine more accurately the impact on the environment. One simple example can support this rationale. Generally, a traffic management centre is introduced to optimize traffic conditions in a given area, but the increased traffic flow can affect the traffic conditions not only in a target area but also in the adjacent areas surrounding the target area.

4 **Limited geographical scope:** In line with the above point, almost all previous analyses are limited to a city-level assessment or, to a broader extent, a country-level assessment. However, international movements of passenger and freight on roads are significantly increasing in the Asia-Pacific region. Furthermore, various smart transport applications, which could have broader impacts on the environment across countries have been developed, such as cross-border applications. In this regard, previous approaches with a limited geographical scope need to be reconsidered to capture the accurate impacts of smart transport systems on the environment.

5 **Lack of evaluation criteria:** As mentioned earlier, the literature review showed a large variation in the percentage of reduction in greenhouse gas emissions (3 per cent to 50 per cent). Such figures are obviously a good reference to examine the impacts of smart transport systems on the environment, but they cannot provide a solid criterion to determine the viability of smart transport-related projects. Given that, from time to time, policymakers like to see the exact criteria to decide their priorities, the type of results showing the impacts of smart transport systems may need to be reconsidered with intuitive forms.

6 **Lack of published assessment findings:** In the literature review, an attempt was made to find as many as possible relevant cases involving ESCAP member countries. The results are limited. They are from a few countries, which are already well known as leaders in the deployment of smart transport systems. As pointed out in chapters 1 and 2, in reviewing the nationally determined contributions, the utilization of such technologies to reduce greenhouse gas emissions is not the mitigation measure. For example, Azerbaijan and Bhutan state specifically the role of smart transport technologies in their contribution. However, relevant assessments for those countries were difficult to find from existing studies, which would be one of the weaknesses to support their intentions for nationally determined contributions.
CHAPTER 4

Impact analysis of smart transport systems on the environment
4.1 Overview

Although smart transport systems have shown great potential in addressing traffic issues, in particular with regard to reducing greenhouse gas emissions, the use of such technologies remains limited in the Asia-Pacific region. Most of the successful cases discussed in chapter 3 are from technology-leading countries in the region, where these technologies have been deployed at the country level. This makes it difficult to estimate the overall benefits including for developing countries at the (sub)regional level. It is well known that smart transport technologies generate diverse levels of impacts, which can be corridor-specific or area-wide. As noted earlier, one of the major objectives of this study is to bridge the gap between low awareness and understanding of smart technologies' benefits and their actual contributions towards reducing greenhouse gas emissions. Considering the limitations of previous studies in the region (chapter 3), an impact analysis needs to be conducted on the implementation of selected strategies to determine their viability for the benefits in given areas. In this regard, the impact analysis is conducted which will be an initial feasibility study of the potential deployments at the macrolevel in the target areas.

4.2 Analysis approach

To provide a meaningful comprehensive analysis, the most suitable method or tool, such as sketch planning, post-processing and multi-resolution or multi-scenario, needs to be decided, taking into account data availability and the expected level of analysis required to support the estimation of impacts.

b Considering the limitations observed from previous studies, target areas need to be set up to achieve the objectives of this study. In Asia and the Pacific, the target subregion must be selected among the five in the region, with consideration of socioeconomic status, smart transport-related situations, and existing supportive policies and plans.

c Smart transport strategies that are most suitable for the target areas are formulated by using a systems engineering process, a top-down approach that enables the understanding of the needs of each subregion and the selection of goals in target areas, and performance measures that can quantify the effectiveness of smart transport systems.

d The benefits and costs of the chosen strategies are analysed using a selected method or tool through which the degrees of benefits, focusing on mobility, safety and sustainability, are determined in respective target areas.

4.2.1 Systems engineering process for the impact analysis

A systems engineering process\textsuperscript{165} is an interdisciplinary process that focuses on managing the risks in the design, deployment, and maintenance from an array of complex interacting elements over the system's life cycle. The individual outcome will be a combination of components that work in synergy to collectively perform a useful function. The

The systems engineering process involves the top-down development of a system’s functional and physical requirements from a basic set of mission objectives. The purpose is to organize information and knowledge to assist those who manage, direct and control the planning, development, and operation of the systems necessary to accomplish the mission. In line with this, the systems engineering process with smart transport systems starts with regional planning and a feasibility study to understand how smart transport technologies will fit into the existing infrastructure and to identify the requirements to deploy additional systems in the target areas. This is best exhibited using the “Vee” diagram, as illustrated in figure VI, for generic smart transport-related (specifically, in this case intelligent transport systems) strategies, which shows the progression of steps that go from a regional plan in the upper left of the diagram to a deployed system in the upper right of the diagram. In this respect, the left side of the Vee diagram designs the system while the right-side builds, tests, implements and maintains it. As for this study, the concept of the systems engineering process is followed, and an initial analysis of (sub)regional needs is conducted. The analysis stops at smart transport systems design. It should be noted, however, that in future formal planning of smart transport strategies, a full follow-through of the systems engineering process is recommended.

The systems engineering process is applied in the analysis to understand the status quo and stakeholder needs, and to identify corresponding goals and objectives of smart transport systems deployments based on which actual strategies can
be selected and deployed in different situations. The selections of strategies will subsequently be analysed individually by using Benefit/Cost (B/C) analysis to determine their viability.

The first step in the systems engineering process for smart transport strategies is to determine regional needs and specific objectives. Then, the regional architecture for smart transport systems, if non-existing, is developed from which the set of strategies that will satisfy those needs and objectives is identified. The regional architecture identifies the integration opportunities that should be implemented (and are agreed to by the stakeholders). This step also includes a feasibility study that considers smart transport-related stakeholder elements, their functional requirements, and information dependencies on other elements in the regional architecture. Also, as part of the feasibility study, the goals, expected performance, and potential technologies are identified. The detailed cost and benefit estimates, and high-level technology choices for the smart transport elements guided by local environmental and institutional considerations are also investigated.

4.2.2 Details of B/C analysis

In general, the B/C analysis is defined as a systematic process for calculating and comparing benefits and costs of a strategy to determine if it is a sound investment (justification/feasibility); and to see how it compares with alternate strategies (ranking/priority assignment).166

B/C analysis first estimates the costs and benefits of a strategy and then calculates the relative value in monetized estimates. B/C analysis determines the value of a strategy by dividing the incremental monetized benefits related to a strategy by the incremental costs of that strategy. The result is called the B/C ratio and is often the primary output of the analysis process. If the B/C ratio is greater than one, the project is deemed to be an “efficient investment” in that each dollar invested in the project returns more than $1.00 in benefits. If the B/C ratio is less than one, the project is deemed to be an “inefficient investment” in that the costs of the strategy are greater than the incremental benefits.

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| TABLE 3 | Application attributes of analysis, modelling and simulation tools |
| --- | --- | --- |
| **CATEGORIES** | **APPROPRIATE GEOGRAPHIC SCOPE** | **RESOURCES REQUIRED** |
| Sketch-planning methods | Isolated location | Budget – low ($1 000 to $25 000) |
| | Corridor | Schedule – 1 week to 8 weeks |
| | Sub-area | Staff expertise – medium |
| | Regionwide | Data availability – low |
| Post-processing methods | Corridor | Budget – medium/high ($5 000 to $50 000) |
| | Sub-area | Schedule – 2 months to 1 year |
| | Regionwide | Staff expertise – medium/high |
| | | Data availability – medium |
| Multiresolution/multiscenario methods | Corridor | Budget – high ($50 000 to $1.5 million) |
| | Sub-area | Schedule – 3 months to 1.5 years |
| | | Staff expertise – high |
| | | Data availability – high |
B/C analysis provides several capabilities that are key in supporting different planning needs throughout an operations planning process in selecting various transport strategies. It is invaluable in supporting planning activities throughout the entire cycle of the process thereof.

4.2.3 Comparison of methods for B/C analysis

B/C analysis may be performed at a simple sketch-planning level to provide an order of magnitude estimate of benefits and costs appropriate for early screening of strategies. It also can be made much more rigorous to meet the more detailed analysis demands of later prioritization or design activities of the strategies. There are many analytical methodologies, and modelling and simulation tools designed for conducting a transport analysis. These methods and tools can generally be segmented into three broad categories, as follows:

- Sketch-planning methods provide a simple, quick and low-cost estimation of costs and benefits of transport strategies. These methods often rely on generally available input data and static default relationships between the strategies and their impact on a limited number of measurements of effectiveness to estimate the benefits of the strategy.

- Post-processing methods seek to more directly link the B/C analysis with the travel demand, network data, and performance measure outputs from regional travel demand or simulation models, making the methods more robust than sketch planning tools. The tools then provide additional analysis within their framework to assess impacts to measurements of effectiveness outside the capabilities of typical travel demand models. These methods are often more capable of assessing the impacts of route, mode, or temporal shifts than sketch-planning methods.

- Multiresolution/multiscenario methods are the most complex of the methods. They are typically applied when a high level of confidence in the accuracy of the results is required. These methods are most often applied during the final rounds of alternatives analysis or during the design phases when detailed information is required to prioritize and optimize the proposed strategies. They usually concern the use of simulation and similar analytical tools to understand the key design and operational parameters of transport strategies.

In addition to concerning the principles on each method and tool, the geographic scope and resources are critical in selecting appropriate methods or tools for use. Table 3 shows the details of each of the three types for analysis, modelling and simulation tools.

Considering all attributes of the methods and tools, sketch planning tools are selected for this study for two reasons: first, the main consideration of this chapter is the initial feasibility analysis of smart transport systems at the (sub)regional level, which requires the highest level of analysis scope; and second, many of the selected areas or corridors of interest lack detailed historical traffic data for model development. The sketch-planning method, which relies on similar real-world experience of smart transport systems deployment at other places, is a good fit under this condition to infer potential benefits and costs of deployment. TOPS-BC is one of the most comprehensive sketch-planning tools available; it was developed recently by the United States Department of Transportation and is used in the B/C analysis in this study. The tool is also flexibly applicable for corridor-specific


and area-wide strategies, and the analysis is dependent by requiring only generic inputs on the deployment sites.

In terms of data required for B/C analysis, TOPS-BC has compiled a large database of deployments of smart transport systems (specifically intelligent transport systems here) around the world and summarized the effectiveness based on available data, usually in the form of before and after analyses conducted by different agencies. The required user input for TOPS-BC usually involves general socioeconomic and traffic data, such as population and average daily traffic volume that are relatively easy to obtain or estimate. The analysis module in TOPS-BC then applies “effectiveness factors” in different forms to the selected cases to evaluate benefits by the strategies. A similar database is maintained by TOPS-BC to estimate cost of smart transport systems deployment in an itemized manner; accordingly, the user input concerns the number of equipment sets based on the actual case study condition. The tool also provides recommended default values for other factors required in the analysis, such as discount rate and deployment lifetime. These default values are directly adopted for this study.

### 4.2.5 Selection of target areas

To overcome the limitations found from previous studies, two subregions (South-East Asia, and North and Central Asia) from the Asia-Pacific region were selected for consideration of their respective socioeconomic status, smart transport-related situations and existing supportive policies and plans.

Urbanization is expanding rapidly in the Asia-Pacific region, which will lead to critical traffic issues and associated environmental externalities. It has been projected that the world’s population could add another 2.5 billion people to urban areas by 2050, in which approximately 90 per cent of the increase is expected to be in Asia and Africa.\(^{169}\) Reviewing motorization, there was rapid growth in many countries in South-East Asia, and North and Central Asia from 2014 to 2015. For example, the rates of motorization in Azerbaijan, Kyrgyzstan and Thailand increased to 133 (from 132), 224 (from 214) and to 228 (from 219), respectively.\(^{170}\) In terms of greenhouse gas emissions, for the period 2008–2013, of the 20 countries from South-East Asia, and North and Central Asia that recorded data on PM 2.5 levels in cities, many had not met the annual mean concentration level recommended by WHO.\(^{171}\) In more detail, countries in South-East Asia, and North and Central Asia (except for Uzbekistan) indicated that there was significant growth of contributions from dangerous and fine particle matter from the transport sector to greenhouse gas emissions.

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\(^{170}\) See http://www.oica.net/category/vehicles-in-use/.

\(^{171}\) Statistical Yearbook for Asia and the Pacific 2016 (United Nations publication, Sales No. E.17.II.F.1).
The growth of CO₂ emissions from transport in 10 countries of South-East Asia was approximately 68 per cent during the period 1990–2012, while during the period 2000–2012 in eight countries of North and Central Asia, it was approximately 43 per cent.¹⁷²

To address such issues, countries in South-East Asia and North and Central Asia are actively deploying smart transport systems in their policies and plans. Using South-East Asia as an example, the Association of Southeast Asian Nations (ASEAN) secretariat developed the Intelligent Transport System (ITS) Policy Framework¹⁷³ to guide principles for planning, evaluating and prioritizing relevant programmes, projects, and activities for member countries. In addition, in the ASEAN Transport Strategic Plan 2016–2025¹⁷⁴ greater emphasis is placed on utilizing intelligent transport systems in the mobility and transport sector. Even though smart transport systems have only recently been adopted in North and Central Asia (except for Russian Federation) and it is difficult to find a common framework or plan, various attempts have been made to promote such systems to address traffic issues. In Azerbaijan, an order of the president in October 2007 includes the adoption of intelligent transport systems.¹⁷⁵ In Tajikistan, the Transport Sector Development Strategy until 2025 clearly outlines activities aimed at using modern technologies to develop the transport sector and solve problems related to it.¹⁷⁶

Considering the above circumstances, the B/C analysis on two subregions is meaningful in that it provides a better understanding of the benefits from smart transport systems. Given that many countries in the two subregions are still in their infancy regarding the development of smart transport systems, the results of B/C analysis at the subregional level will help policymakers increase the awareness of such systems.

The subsequent sections contain details on case studies of the deployment of smart transport strategies. Two corridors and two cities (table 4) are selected for case studies. The two cities are chosen to understand how smart transport strategies can relieve urban congestion and promote sustainability. Two corridors are chosen to understand how these strategies can improve the efficiency and sustainability of interregional transport and accordingly, ensure the economic growth of neighbouring regions and countries.

4.2.6 Selection of performance measures

The benefits in a B/C analysis are calculated by estimating the incremental change in various measurements of effectiveness and then applying an established value to the identified amount of change to monetize the benefits. The measurements may include a wide range of metrics, depending on the anticipated impacts of the various strategies being analysed. They should be identified during the analysis set up and must be sufficiently comprehensive to capture the full benefits (positive impacts) and disbenefits (negative impacts) of the identified strategies. Many traditional and non-traditional measurements of effectiveness are used in transport-related B/C analysis; typical measures often include the following:

- Congestion: travel time
- Reliability: travel time reliability
- Safety: crashes
- Sustainability: fuel use, emissions, air quality
- Others: nonfuel vehicle operating costs, agency efficiency

¹⁷² This was calculated by the ESCAP Transport Division based on the data from https://edgar.jrc.ec.europa.eu/archived_datasets.php.
¹⁷⁴ ASEAN secretariat, Kuala Lumpur Transport Strategic Plan (ASEAN Transport Strategic Plan) 2016–2025 (Jakarta, ASEAN secretariat, 2015).
Based on the above-mentioned needs in both subregions, identified objectives and performance measures are shown in Table 5.

**Table 5: Objectives and measurements of effectiveness for the analysis**

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Performance Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOBILITY/EFFICIENCY</strong></td>
<td></td>
</tr>
<tr>
<td>Improve (shorten) the travel time of public transit</td>
<td>Average minutes/trip</td>
</tr>
<tr>
<td>Improve the travel time reliability of public transit</td>
<td>Standard deviation of trip time (minutes/trip)</td>
</tr>
<tr>
<td>Increase the utilization of public transit</td>
<td>Per cent of trips using public transit</td>
</tr>
<tr>
<td>Reduce roadway recurring congestion and reduce congestion resulting from incidents or special events</td>
<td>Per cent of trips affected by recurring congestion Per cent of trips affected by special event congestion</td>
</tr>
<tr>
<td><strong>SAFETY</strong></td>
<td></td>
</tr>
<tr>
<td>Improve safety for highways and intersections</td>
<td>Average number of crashes per traveler kilometre</td>
</tr>
<tr>
<td>Improve passenger transport safety</td>
<td>Average passenger injuries per kilometre travelled</td>
</tr>
<tr>
<td>Enhance freight transport safety</td>
<td>Average number of commercial vehicle crashes per commercial vehicle kilometre travelled</td>
</tr>
<tr>
<td><strong>SUSTAINABILITY</strong></td>
<td></td>
</tr>
<tr>
<td>Increase the number of trips that use green modes of travel, such as public transit and non-motorized travel</td>
<td>Ratio of public transit trips and non-motorized travel trips/total number of trips</td>
</tr>
<tr>
<td>Reduce carbon and hazardous pollutant emissions through using advanced technologies</td>
<td>Average carbon pollution per trip Average particulate pollution per trip</td>
</tr>
<tr>
<td>Reduce overall energy or fuel consumption</td>
<td>Average fuel consumption per trip</td>
</tr>
</tbody>
</table>

4.2.7 Selection of strategies in target areas

Based on the selected measurements of effectiveness, appropriate smart transport strategies are presented according to the target areas. For city-level analysis, advanced traffic information systems, namely en route traveller information and pre-trip traveller information, are viewed as the most effective strategy to deal with urban traffic issues, while, for corridor-specific analysis, traffic incident management, road weather management, and truck parking and reservation systems are seen as the most essential strategies in response to potential negative impacts of incidents, freight traffic issues and adverse weather on highways.

It should be noted that selected strategies serve as examples of how certain smart transport strategies can positively affect target areas. There is no intention to list all possible strategies. As discussed above, an agency or a policy maker should follow the systems engineering process to understand needs and goals, which will then enable the identification of possible smart transport strategies to maximize their benefits.

(A) TRAFFIC INCIDENT MANAGEMENT SYSTEMS

Traffic incident management is a planned multi-disciplinary process for coordinating the resources of many partner agencies and private sector companies. It can detect, respond to and clear traffic incidents as quickly as possible to reduce the impacts of incidents on safety and congestion, while protecting the safety of on-scene responders and the general public. If effective, the duration and impacts of traffic incidents are reduced and the safety of motorists, crash victims and emergency responders are improved.

Traffic incident management entails using a variety of technologies and processes to monitor the operation of a freeway and arterial systems along a corridor, respond to incidents and disseminate traveller information. Its ultimate objective is to reduce traffic congestion caused by traffic incidents or secondary crashes that result from incident-related congestion,
which, in turn, reduces negative environmental impacts, namely excessive fuel consumption and pollutants emissions.

**(B) ROAD WEATHER MANAGEMENT SYSTEMS**

The objective of road weather management is to gain a better understanding of the impacts of weather on roadways, and to mitigate those impacts on safety, mobility and sustainability. More timely, accurate and relevant information about weather-related events that adversely affect roads enables transport managers and travellers to make more effective decisions. This includes the deployment of various types of sensors at weather stations, the collection and processing of the data in traffic management centres and the use of variable message signs to communicate the information to the motoring public.

**(C) TRUCK PARKING AND RESERVATION SYSTEMS**

Multiple freight-related smart transport strategies can be deployed to enhance the efficiency of freight transport, such as truck-only lanes, truck parking and reservation systems, climbing lanes, and off-hour delivery. For the selected corridors, truck parking and reservation systems, which can assist trucks in finding available parking spots by reducing idling time or reserving places in advance, are selected for evaluation to facilitate better traffic flow along the corridor by freight transport. This system includes roadside sensors, information signs and a traffic management centre. The strategy can also significaently enhance safety by using information to organize truck traffic, such as locations to park efficiently. This is particularly relevant from the user perspective, which is in line with WHO Global road safety performance targets (target 11, which covers professional drivers).

**(D) ADVANCED TRAFFIC INFORMATION SYSTEMS**

Advanced traffic information systems can be placed into two broad categories: pre-trip and en route. Pre-trip information is the traffic condition-related information that the travellers obtain from various sources, including, among others, websites, mobile applications and advisory radio. The travellers use this information to plan various aspects of their trip, such as selecting travel routes, modes, or departure times. En-route traveller information provides real-time updates to travellers while they are on the road through such channels as variable message signs, mobile applications and advisory radio. It enables them to make real-time decisions on routes and modes, particularly in response to non-recurring congestion caused by incidents, adverse weather, work zones or other special events.

This information may be distributed using several existing and evolving communications technologies. Public agencies have historically collected the real-time information, although distribution of information may be through either public or private channels. Both pre-trip and en-route traveller information generally have positive impacts. The availability of pre-trip information increases driver confidence to use freeways and allows commuters to make better-informed mode choices. En-route information and guidance save travel time, help a traveller avoid congestion, can improve traffic network performance, and are more efficient than paper maps or written instructions.

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4.3 Case studies

Following the selection of the target areas, smart transport strategies and performance measures, four case studies are conducted at two corridors, one in South-East Asia and the other in North and Central Asia, and two cities, Baku and Bangkok.

4.3.1 Case Study 1 – A corridor in South-East Asia

The first case study deals with South-East Asian countries. A corridor in South-East Asia connecting three cities – Vientiane, Laos; Bangkok, Thailand; Kuala Lumpur, Malaysia – is selected (see figure VII) because it covers a large area of the subregion and can show regional impacts of selected strategies owing to its importance with regard to its location and area coverage. In addition, it should be noted that the selected corridor, in particular the segment from Bangkok to Kuala Lumpur, does not have many alternative routes for travellers. Any conditions that occur on the corridor, such as traffic incidents or adverse weather, may have a significant impact on the intercity passenger and freight transport. Accordingly, traffic incident management systems, road weather management systems and truck parking and reservation systems are selected for the analysis of this corridor. For traffic incident management and road weather management systems, general strategies are incorporated, namely the deployment of various types of sensors (for road weather management systems at weather stations), collection and processing of the data in traffic management centres, and the use of variable message signs to communicate the information to the general public. In addition, as freight transport critically affects the economic and

FIGURE VII
Map of the selected corridor in South-East Asia

Source: South East Asia map, Geospatial Information Section, DOS, OICT, United Nations.
Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
trade collaborations among countries in South-East Asia, truck parking and reservation systems are evaluated in this case study.

For the cost analysis, detailed costs of each strategy are as shown in table 6, and a detailed benefit and cost analysis is made using the TOPS-BC tool (table 7), as selected earlier.

Five categories of benefits are identified as performance measures, travel time savings (recurring delay and non-recurring delay), safety (number of various types of crashes), reliability, energy (fuel consumption) and emissions of pollutants. However, because of the relevance of energy (fuel consumption) and emissions of pollutants, the combined energy and emissions benefits are presented.

The B/C analysis generates a B/C ratio of 4.89 for traffic incident management systems, 3.52 for truck parking and reservation systems and 10.57 for road weather management systems, an average B/C ratio of 8.78, indicating good cost-effectiveness resulting from implementing all strategies along the corridor. In terms of monetized benefits, the majority of the benefits come from travel time savings (46.3 per cent of total benefits). Approximately, a total of $58.3 million ($8 million from traffic incident management systems, $1.7 million from truck parking and reservation systems, and $48.5 million from road weather management systems) is expected from travel time savings. In more detail, it is shown that traffic incident management systems generate significant benefits in reducing non-recurring delay, while truck parking and reservation, and road weather management systems produce more benefits in reducing recurring delay. These benefits, in turn, save energy consumption and decrease emissions. The combined energy and emissions benefits account for 10.7 per cent of total benefits, approximately $13.4 million.
4.3.2
Case study 2 – Bangkok, Thailand

Bangkok, Thailand, suffers from several traffic congestion, which can be attributed to many factors, including, among them, increasing travel demand, construction and work zones, and roadway crashes. The INRIX Global Traffic Scorecard rated Bangkok the twelfth most congested of the cities in a report released in 2017, considerably worse than the rating of thirtieth attained in 2015. Its scorecard rating was 11, down from 20 in 2015. Bangkok drivers spent an average of 64.1 hours a year in traffic jams, according to the scorecard – 23 per cent of overall time and an average of 33 per cent of their time during peak hours. In this case study, advanced traveller information systems, including both pre-trip and en-route information systems, are proposed to test their viability in Bangkok. It is assumed that traveller information may be distributed using several existing and evolving communications technologies. For example, the en-route traveller information specifically refers to variable message signs that give travel time information and traffic conditions on highways, arterials and feeders while the pre-trip information refers to websites or call line from which travellers obtain travel time information and traffic conditions before their travel and a transit schedule using other services. The items of costs and assumptions to estimate benefits in this study are explained in table 8.

As indicated in table 9, the analysis results indicate a B/C ratio of 8.37 for en-route traveller information and 39.42 for pre-trip traveller information, an average B/C ratio of 37.51, indicating good cost-effectiveness resulting from implementing advanced traveller information systems in Bangkok. Although the majority of the benefits come from travel time savings (98.5 per cent of total benefits), the combined energy and emissions benefits account for 1.5 per cent of total benefits, amounting to approximately $1.5 million from both strategies, which can greatly contribute to reduce energy consumption and emissions.

### Table 8
Details of costs and assumptions used in the case study

<table>
<thead>
<tr>
<th>STRATEGIES</th>
<th>COSTS</th>
<th>ASSUMPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>En-route traveller information</td>
<td>Traffic management centre hardware and software for information dissemination, system integration, archived data management systems, communication lines, variable message signs, and variable message sign tower</td>
<td>• Per cent of time the device is providing useful information (25 per cent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Per cent of drivers acting on the information (10 per cent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Average time saved by drivers acting on the information (4 minutes)</td>
</tr>
<tr>
<td>Pre-trip traveller information</td>
<td>Traffic management centre hardware and software for information dissemination, system integration, archived data management systems, communication lines, hardware and software/labour in the transit centre, information service centre software and hardware, map database and software</td>
<td>• Per cent of people accessing the traveller information (10 per cent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Per cent of people acting on the information (22 per cent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Average time saved by drivers using the information (7 minutes)</td>
</tr>
</tbody>
</table>

### Table 9
Results of B/C analysis of Bangkok, Thailand

<table>
<thead>
<tr>
<th></th>
<th>EN-ROUTE TRAVELLER INFORMATION</th>
<th>PRE-TRIP TRAVELLER INFORMATION</th>
<th>TOTAL BENEFITS</th>
<th>PROPORTION (PER CENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual benefits</td>
<td>$1 420 850</td>
<td>$102 350 059</td>
<td>$103 770 909</td>
<td>100</td>
</tr>
<tr>
<td>Travel time savings</td>
<td>$864 070</td>
<td>$101 384 227</td>
<td>$102 248 297</td>
<td>98.5</td>
</tr>
<tr>
<td>Recurring delay</td>
<td>$864 070</td>
<td>$101 384 227</td>
<td>$102 248 297</td>
<td>-</td>
</tr>
<tr>
<td>Non-recurring delay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Energy and emissions</td>
<td>$556 780</td>
<td>$965 832</td>
<td>$1 522 612</td>
<td>1.5</td>
</tr>
<tr>
<td>Total annual costs</td>
<td>$169 726</td>
<td>$2 596 606</td>
<td>$2 766 332</td>
<td>-</td>
</tr>
<tr>
<td>Net benefits</td>
<td>$1 251 124</td>
<td>$997 53 452</td>
<td>$1 010 4 577</td>
<td>-</td>
</tr>
<tr>
<td>B/C ratio</td>
<td>8.37</td>
<td>39.42</td>
<td>37.51</td>
<td></td>
</tr>
</tbody>
</table>

4.3.3 Case study 3 – A corridor in North and Central Asia

For the analysis, the North and Central Asia corridor, which connects three cities – Baku, Azerbaijan; Tbilisi, Georgia; Yerevan, Armenia – is selected (see figure VIII) because of its important role in the transport of freight and people among the three countries. For the same reasons considered for case study 1, three strategies are tested for their viability, traffic incident management, road weather management, and truck parking and reservation systems. The details of the costs employed in this case study are the same as the ones in case study 1 (see table 6). However, because of the difference in the corridors (such as corridor length, traffic volume and number of lanes), different inputs from case study 1 to TOPS-BC are used.

The results of the B/C analysis show good cost-effectiveness from all strategies (a B/C ratio of 4.2 for traffic incident management systems, 2.84 for truck parking and reservation systems, and 8.19 for road weather management systems, an average B/C ratio of 6.32). Approximately, a total of $27.6 million in monetized benefits is estimated with the majority of travel time savings (47.0 per cent of total benefits) (table 10). Specifically, traffic incident management systems can reduce non-recurring delay by approximately $6.9 million, while truck parking and reservation, and road weather management systems can reduce recurring delay by approximately $1.1 million and $19.5 million, respectively. As for the combined energy and emission benefits, 10.8 per cent of total benefits, approximately $6.3 million, is expected by deploying the strategies along this corridor.

4.3.4 Case study 4 – Baku, Azerbaijan

Baku, Azerbaijan, is challenged by traffic congestion and air quality issues, as the result of several factors, including, among them, increasing travel demand, construction and work zones, and roadway crashes. While a couple of smart transport

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**FIGURE VIII**

Map of the selected corridor in North and Central Asia

Source: Central Asia map, Geospatial Information Section, DOS, OICT, United Nations.
Note: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
strategies have been deployed to tackle the issues, the results of impact analysis by such strategies in Baku are not readily available. In this case study, advanced traveller information systems that can inform travellers about the conditions that cause congestion before and during their trips are used to determine their benefits in the city. It is also assumed that traveller information may be distributed using several existing and evolving communications technologies. Detailed costs and assumptions incorporated in this case study are same as the ones deployed in case study 2 (see table 8).

As shown in table 11, the analysis results in a B/C ratio of 10.95 for en-route traveller information and 29.70 for pre-trip traveller information, an average B/C ratio of 28.55, indicating good cost-effectiveness of implementing advanced traveller information systems in Baku. It is noted that while the majority of the benefits come from travel time savings (98.2 per cent of total benefits), the strategy also contributes significant savings to energy and emissions, which account for 1.8 per cent of total benefits, amounting to approximately $482,675 from both strategies in Baku.

### TABLE 10  Results of B/C analysis of the corridor in North and Central Asia

<table>
<thead>
<tr>
<th></th>
<th>Traffic Incident Management</th>
<th>Truck Parking and Reservation</th>
<th>Road Weather Management</th>
<th>Total Benefits</th>
<th>Proportion (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual benefits</td>
<td>$12,598,413</td>
<td>$2,876,273</td>
<td>$43,311,068</td>
<td>$58,785,754</td>
<td>100</td>
</tr>
<tr>
<td>Travel time savings</td>
<td>$6,902,670</td>
<td>$1,137,712</td>
<td>$19,561,949</td>
<td>$27,602,331</td>
<td>47</td>
</tr>
<tr>
<td>Recurring delay</td>
<td>-</td>
<td>$1,137,712</td>
<td>$19,550,612</td>
<td>$20,688,324</td>
<td>-</td>
</tr>
<tr>
<td>Non-recurring delay</td>
<td>$6,902,670</td>
<td>-</td>
<td>$11,337</td>
<td>$6,914,007</td>
<td>-</td>
</tr>
<tr>
<td>Safety</td>
<td>$5,185,949</td>
<td>$590,729</td>
<td>$14,465,084</td>
<td>$20,241,762</td>
<td>34.4</td>
</tr>
<tr>
<td>Reliability</td>
<td>-</td>
<td>$64,432</td>
<td>$4,512,318</td>
<td>$4,576,750</td>
<td>7.8</td>
</tr>
<tr>
<td>Energy and emissions</td>
<td>$509,794</td>
<td>$1,083,400</td>
<td>$4,771,717</td>
<td>$6,364,911</td>
<td>10.8</td>
</tr>
<tr>
<td>Total annual costs</td>
<td>$3,002,802</td>
<td>$1,011,384</td>
<td>$5,286,844</td>
<td>$9,301,030</td>
<td></td>
</tr>
<tr>
<td>Net benefits</td>
<td>$9,595,611</td>
<td>$1,864,889</td>
<td>$38,024,224</td>
<td>$49,484,724</td>
<td></td>
</tr>
<tr>
<td>B/C ratio</td>
<td>4.2</td>
<td>2.84</td>
<td>8.19</td>
<td>6.32</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 11  Results of B/C analysis of Baku, Azerbaijan

<table>
<thead>
<tr>
<th></th>
<th>En-Route Traveller Information</th>
<th>Pre-Trip Traveller Information</th>
<th>Total Benefits</th>
<th>Proportion (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual benefits</td>
<td>$619,630</td>
<td>$25,702,856</td>
<td>$26,322,486</td>
<td>100</td>
</tr>
<tr>
<td>Travel time savings</td>
<td>$493,754</td>
<td>$25,346,057</td>
<td>$25,839,811</td>
<td>98.2</td>
</tr>
<tr>
<td>Recurring delay</td>
<td>$493,754</td>
<td>$25,346,057</td>
<td>$25,839,811</td>
<td>-</td>
</tr>
<tr>
<td>Non-recurring delay</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Energy and emissions</td>
<td>$125,876</td>
<td>$356,799</td>
<td>$482,675</td>
<td>1.8</td>
</tr>
<tr>
<td>Total annual costs</td>
<td>$56,575</td>
<td>$865,535</td>
<td>$922,111</td>
<td></td>
</tr>
<tr>
<td>Net benefits</td>
<td>$563,055</td>
<td>$24,837,320</td>
<td>$25,400,375</td>
<td></td>
</tr>
<tr>
<td>B/C ratio</td>
<td>10.95</td>
<td>29.70</td>
<td>28.55</td>
<td></td>
</tr>
</tbody>
</table>
4.4 Findings

To overcome the limitations found in the literature review (chapter 3), the B/C analysis in this chapter is conducted by focusing on subregional-level benefits of smart transport strategies. The systems engineering process is first applied at a high level to determine suitable measurements of effectiveness and smart transport strategies for the target areas. Based on this, four categories of smart transport strategies are selected and evaluated for four case studies – two corridor-specific and two city-wide target areas. Various types of benefits are observed among which sustainability-related benefits (energy consumption and emissions) are the main focus points for the B/C ratio in this study. Table 12 contains a summary of the results of the four case studies.

On average, smart transport strategies show a B/C ratio of 12.27 and approximately $2.1 million of monetized benefits in energy/emissions through the four case studies. For only energy/mission benefits, approximately, a total of $21 million is estimated from smart transport strategies in the four target areas. In more detail, for corridor-specific analysis, the B/C ratio ranges from 6.32 to 8.78, while the combined energy and emissions benefits range from approximately $6.3 million to $13.4 million in terms of the monetized value. For city-wide analysis, the B/C ratio ranges from 28.55 to 37.51, while the combined energy and emission benefits range from $482,675 to approximately $1.5 million in terms of the monetized value.

### TABLE 12 Summary of case study results

<table>
<thead>
<tr>
<th>TARGET AREAS</th>
<th>STRATEGIES</th>
<th>B/C RATIOS</th>
<th>ENERGY/EMISSION BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case study 1</td>
<td>Corridor in South-East Asia (Vientiane - Bangkok - Kuala Lumpur)</td>
<td>Traffic incident management 4.89</td>
<td>$509 794</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freight parking and reservation 3.52</td>
<td>$1 582 600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road weather management 10.57</td>
<td>$11 342 275</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall 8.78</td>
<td>$13 434 669</td>
</tr>
<tr>
<td>Case study 2</td>
<td>Bangkok, Thailand</td>
<td>En-route traveller information 8.37</td>
<td>$556 780</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pre-trip traveller information 39.42</td>
<td>$965 832</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall 37.51</td>
<td>$1 522 612</td>
</tr>
<tr>
<td>Case study 3</td>
<td>Corridor in North and Central Asia (Baku - Tbilisi - Yerevan)</td>
<td>Traffic incident management 4.2</td>
<td>$509 794</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Freight parking and reservation 2.84</td>
<td>$1 083 400</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road weather management 8.19</td>
<td>$4 771 717</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall 6.32</td>
<td>$6 364 911</td>
</tr>
<tr>
<td>Case study 4</td>
<td>Baku, Azerbaijan</td>
<td>En-route traveller information 10.95</td>
<td>$125 876</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pre-trip traveller information 29.7</td>
<td>$356 799</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall 28.55</td>
<td>$482 675</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>12.27</td>
<td>$2 180 487</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>$21 804 867</td>
</tr>
</tbody>
</table>
CHAPTER 5

Conclusions
5.1 Noticeable contributions

Because of various advantages, smart transport systems including intelligent transport systems, have been adopted for many years around the world. The Asia-Pacific region is not an exception, although the advances in deploying smart transport technologies, in general, are relatively slow and fragmented among countries in the region. Social and environmental needs of such technologies are quite simple; they increase traffic efficiency and safety, thereby mitigating associated negative externalities to society.

Unlike previous studies about smart transport systems, this study was triggered by some fundamental questions: (a) What is the status of nationally determined contributions with regard to the transport sector in the region? (b) Do smart transport systems, including traditional and emerging ones, generate positive benefits to the environment? (c) To what extent can smart transport systems positively affect the environment by focusing on their potential to mitigate greenhouse gas emissions? (d) From the subregional perspective, what are the tangible benefits of smart transport systems in terms of mitigating greenhouse gas emissions? and (e) To what extent can smart transport systems contribute to nationally determined contributions in the region?

Bearing these questions in mind, this study provides meaningful contributions:

a Nationally determined contributions for the transport sector focusing on the Asia-Pacific region were specifically reviewed for the analysis. As of October 2019, 48 ESCAP member countries had ratified the Paris Agreement. A total of 44 nationally determined contributions and eight intended nationally determined contributions have been submitted to UNFCCC by ESCAP member countries, and 38 countries in the region have submitted nationally determined contributions, which contain actions intended for the transport sector.¹⁷⁹

b A review was conducted to investigate the benefits from smart transport systems, with a focus on the reduction of greenhouse gas emissions. More than 100 sources covering various applications were reviewed to identify potential benefits. In addition, extensive cases were reviewed from not only the Asia-Pacific region but from other regions, such as the United States and Europe, to overcome the limitations of just focusing on a specific region. The result was summarized in table 2 in chapter 3.

c To attain meaningful lessons learned from the literature review, the overall assessment was conducted from five viewpoints, followed by a review of their limitations. In short, (i) traditional smart transport applications contribute with varying success with regard to the reduction of greenhouse gas emissions, (ii) although emerging technologies are in the test stage, they are effective in helping to mitigate greenhouse gas emissions in various locations, (iii) there are limited sources for reviewing the effectiveness of in-vehicle technologies on the environment, however, eco-driving applications have proven to be effective in decreasing fuel consumption and reducing greenhouse gas emissions, (iv) the magnitude and extent of effectiveness may differ according to smart transport applications and locations where they are deployed, and (v) in addition to benefits for the environment, these technologies also contribute towards the reduction of travel time, traffic stops, crashes and socioeconomic costs, and increase travel speed and user’s satisfaction, among others.

d Given that smart transport systems are usually deployed along corridors and/or well-defined areas, within a country or across different countries, the benefits to greenhouse gas emissions from such systems should be investigated from this aspect. As can be seen from the review (chapter 3), an analysis across different countries was not available. Case studies were performed for South-East Asia, and North and Central Asia countries with a focus on the specific

¹⁷⁹ Based on data extracted from the Transport Knowledge Base (TraKB) Version 0.2.
corridors across the countries and two major cities from each subregion. Case studies showed that smart transport strategies could provide good B/C ratios (from 2.84 through a freight parking and reservation system to 39.42 through a pre-trip traveller information system).

5.2 Policy recommendations

As can be seen from the literature review in chapter 3 and the corridor analysis in chapter 4, there is great potential in using smart transport systems to address transport issues by improving overall efficiency of the transport sector, which also leads to a reduction in greenhouse gas emissions. To maximize the benefits that can be derived from such systems, there is a need for timely intervention through policies that promote smart transport systems with the maximum potential for greenhouse gas reduction. In this regard, the following policy recommendations should be prioritized at the national, subregional and regional levels.

5.2.1 National level recommendations

(A) SPECIFICATION OF THE NEEDS

As explained, there are various expectations from the implementation of smart transport systems, including, among others, improvements in road safety, better mobility and reliability, increase in user’s convenience and energy efficiency. As reviewed in chapter 3, each application has different advantages. For example, eco-driving applications can contribute towards increasing fuel efficiency, while electronic toll collection systems can optimize traffic flows near toll gates on expressways. Although both applications may eventually lead to a reduction in greenhouse gas emissions from the environmental perspective, their primary objectives are different. Given that each city or country has different priorities and realities, the requirements at the city, province and national levels should be prioritized according to the issues faced, and social and environmental conditions. At the same time, such requirements should be determined with consideration of the overarching plans and/or strategies led by the responsible government agency at the national level.

(B) PRIORITIZATION OF THE SPECIFIC TARGET AREAS

Based on the analyses discussed in chapters 3 and 4, the degree, extent and effectiveness of smart transport applications in mitigating greenhouse gas emissions vary from case to case and depend on individual situations. For example, a traveller information system covers a limited area in a given city or state, whereas a road weather information system covers a much larger area. Similarly, considering the different issues affecting a city or country, the specific target areas need to be prioritized based on the national strategies or priorities. In some specific corridors, a response to severe weather conditions, such as recurrent flooding, may be required as quickly as possible because of the potential for unexpected traffic delays.

(C) CONDUCT OF PERFORMANCE EVALUATIONS

Adoption of new technologies in the transport sector is the result of the rapid advancement of ICT. Even though smart transport systems have been found to be relatively cost-effective tools in tackling transport environmental issues, they are not a panacea to address all environmental issues. A performance evaluation by an independent or external party is necessary in this regard in order to determine proper countermeasures to maximize the benefits of mitigating greenhouse gas emissions. As can be seen in chapter 3, although additional assessments need to be conducted, there is no guarantee that smart transport systems can resolve all transport problems adequately considering the associated high investments. Furthermore, in chapter 4, the analysis reveals that different applications provide a varying scale of benefits – the range of B/C ratio is 2.84–39.42.

In this sense, and in order to apply the most suitable strategy in a given area, city or country, performance evaluations are needed to identify the requirements for such evaluations to be effective.

(D) USING SMART TRANSPORT TECHNOLOGIES FOR NATIONALLY DETERMINED CONTRIBUTIONS

Among nationally determined contributions or intended nationally determined contributions, which were submitted by 52 countries in the Asia-Pacific region, 38 countries' detailed actions are aimed at the transport sector. Moreover, at least nine countries include references to smart transport-related technologies in their nationally determined contributions. As shown in chapters 3 and 4, smart transport systems can bring positive benefits in terms of reducing greenhouse gas emissions. Nationally determined contributions are one of the main elements of the Paris Agreement through which countries expect to contribute to the goal of keeping global average temperatures below 2°C above pre-industrial levels. Considering the effectiveness of smart transport systems with regard to the environment, the use of smart transport technologies to mitigate greenhouse gas emissions can be further explored in revised versions of the nationally determined contributions, due in 2020 and 2025. In addition, given that different ministries sometimes work on the nationally determined contributions and smart transport systems, respectively, proactive discussions and consultations for revised versions among different ministries are encouraged to incorporate the component of smart transport systems.

5.2.2 Subregional level recommendation

(E) COOPERATION AND COLLABORATION AMONG NEIGHBOURING COUNTRIES

As discussed in chapter 3, there is limited evidence at the (sub)regional levels of benefits from smart transport systems in the Asia-Pacific region. This is because only some countries have acknowledged the role of smart transport systems in mitigating greenhouse gas emissions. This gap makes countries underutilize smart transport systems where the necessity exists along the specific corridors. For example, in South-East Asia, and North and Central Asia, several corridors connecting cities are very popular for passenger and freight movements where smart transport systems could be applied to mitigate greenhouse gas emissions. With cooperation and collaboration among neighbouring countries, the development gap of technologies can be narrowed; thus, the use of smart transport systems can be enhanced to tackle greenhouse gas issues. Further, to support such cooperation and collaborations, the involvement of United Nations agencies and other development agencies with national ITS related associations is encouraged.

5.2.5 Regional-level recommendation

(F) PREPAREDNESS FOR THE EMERGING TECHNOLOGIES

Various forms of smart transport technologies are emerging, such as cooperative-intelligent transport systems, connected vehicles, autonomous vehicles and smart mobility. As reviewed in chapter 3, studies indicate that these emerging technologies affect the environment. Although emerging technologies are expected to bring unprecedented benefits to society and environment, the Asia-Pacific region is not adequately ready to adopt them. Strong policy support to prepare for the new era of automation is necessary to avoid conflicts and to incorporate these new technologies. It is, therefore, essential to plan for these new emerging technologies and to better integrate them into future transport planning in order to maximize their potential for mitigating greenhouse gas emission and reducing environmental externalities. Also, it is encouraged that the upcoming ESCAP Regional Action Programme for 2022–2027, and other relevant frameworks and strategies developed by ESCAP be considered for efficient preparedness of such emerging technologies.