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 snapshot of the advantages that a type of technology may bring to given areas upon its implementation, the appropriate approach needs to be determined in relation to the available data. Given the wide-ranging circumstances in the region, for the subsequent analysis, the following are key features related to the approach taken:

a To provide a meaningfully comprehensive analysis, the most suitable method or tool, such as sketch planning, post-processing and multiresolution 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.

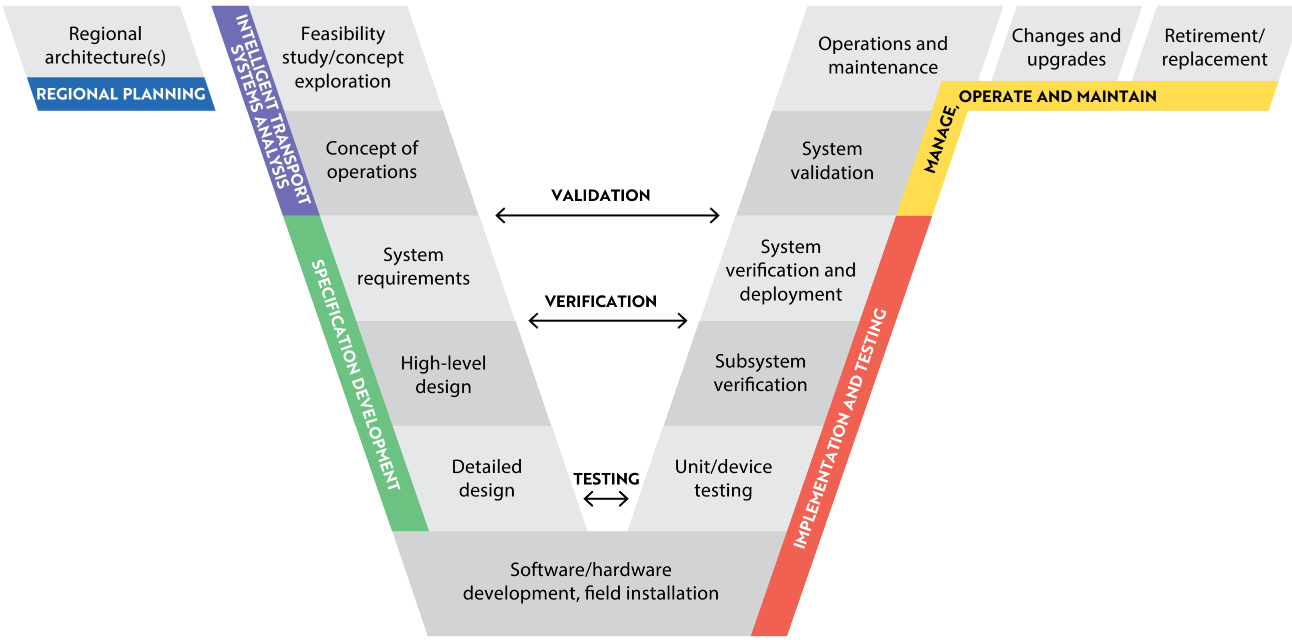
4.2.1 Systems engineering process for the impact analysis

A systems engineering process[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

165 A. Sage, *Systems Engineering*, vol. 6. (New York, John Wiley & Sons, 1992).

FIGURE VI

"Vee" diagram for smart transport systems (i.e., intelligent transport systems here) projects



Source: United States, Department of Transportation, "Systems Engineering for Intelligent Transportation Systems: An Introduction for Transportation Professionals" (Washington, D.C., Department of Transportation, 2007).

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

TABLE 3 Application attributes of analysis, modelling and simulation tools

CATEGORIES	APPROPRIATE GEOGRAPHIC SCOPE	RESOURCES REQUIRED
Sketch-planning methods	Isolated location Corridor Sub-area Regionwide	Budget – low ($ 1 000 to $ 25 000)) Schedule – 1 week to 8 weeks Staff expertise – medium Data availability – low
Post-processing methods	Corridor Sub-area Regionwide	Budget – medium/high ($ 5 000 to $ 50 000) Schedule – 2 months to 1 year Staff expertise – medium/high Data availability – medium
Multiresolution/multiscenario methods	Corridor Sub-area	Budget – high ($ 50 000 to $ 1.5 million) Schedule – 3 months to 1.5 years Staff expertise – high Data availability – high

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.

166 National Academies Transportation Research Board Economics Committee, “Transportation benefit-cost analysis”. Available at http://bca.transportationeconomics.org/.

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:[167]

- 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[168] 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

167 J. Ma, and M. Demetsky, "Integration of travel demand models with operational analysis tools", (No. FHWA/VCTIR 14-R5). Virginia Center for Transportation Innovation and Research. Available at https://www.semanticscholar.org/paper/Integration-of-Travel-Demand-Models-with-Analysis-Ma-Demetsky/3f8228d595ebb40d0eba87565d398f5c1d671aef.

168 D. Sallman, and others. "Operations benefit/cost analysis desk reference", Report no FHWA-HOP-12-028 (Washington, D.C., United States Department of Transportation, 2012).

TABLE 4 Details of case studies

	ANALYSIS SUBREGION	ANALYSIS CITY/COUNTRY	ANALYSIS SCOPE
Case study 1	South-East Asia	Vientiane, Lao People's Democratic Republic; Bangkok, Thailand; Kuala Lumpur, Malaysia	Corridor
Case study 2		Bangkok, Thailand	City
Case study 3	North and Central Asia	Baku, Azerbaijan; Tbilisi, Georgia; Yerevan, Armenia	Corridor
Case study 4		Baku, Azerbaijan	City

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.

169 World Urbanization Prospects: The 2018 Revision. (United Nations publication, Sales No. E.19.XIII.7).
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 CO_2 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 Framework[173] to guide principles for planning, evaluating and prioritizing relevant programmes, projects, and activities for member countries. In addition, in the ASEAN Transport Strategic Plan 2016–2025[174] 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.
173 ASEAN secretariat, ASEAN Intelligent Transport System (ITS) Policy Framework, version 2 (Jakarta, ASEAN secretariat, 2017).
174 ASEAN secretariat, Kuala Lumpur Transport Strategic Plan (ASEAN Transport Strategic Plan) 2016–2025 (Jakarta, ASEAN secretariat, 2015).
175 V. Mammadzada, "Country study report", report prepared for ESCAP (May 2018).
176 F. Yoqubzoda, "Country study report", report prepared for ESCAP (May 2018).

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**

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

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 pollutant 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 significantly 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).[177]

(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.

177 See https://www.who.int/violence_injury_prevention/road_traffic/road-safety-targets/en/.

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.

TABLE 6 Details of costs used in the case study

STRATEGIES	DETAILED COSTS
Traffic incident management	Basic infrastructure equipment, such as traffic management centre hardware, and incremental infrastructure equipment, such as incident response vehicle and labour, and communication lines
Road weather management	Basic infrastructure equipment, such as traffic message channel hardware and software for information dissemination, system integration and labour for traffic information dissemination and communications, and incremental deployment equipment, such as communication line, variable message signs, variable message sign tower and remote weather stations
Truck parking and reservations	Weight station, rest area centre, communication line, detectors, sensors, variable message signs, network equipment, utilities, fibre optic cables, operational support, maintenance and software

TABLE 7 Results of B/C analysis of the corridor in South-East Asia

	TRAFFIC INCIDENT MANAGEMENT	TRUCK PARKING AND RESERVATION	ROAD WEATHER MANAGEMENT	TOTAL BENEFITS	PROPORTION (PER CENT)
Total annual benefits	$14 681 681	$4 271 909	$106 931,435	$125 885 025	100
Travel time savings	$8 092 228	$1 706 568	$48 519 507	$58 318 303	46.3
Recurring delay	-	$1 706 568	$48 491 387	$50 197 955	-
Non-recurring delay	$8 092 228	-	$28 120	$8 120 348	-
Safety	$6 079 659	$886 093	$35 877 750	$42 843 502	34
Reliability	-	$96 648	$11 191 902	$11 288 550	9
Energy and emissions	$509 794	$1 582 600	$11 342 275	$13 434 669	10.7
Total annual costs	$3 002 802	$1 213 661	$10 121 038	$14 337 501	
Net benefits	$11 678 879	$3 058 248	$96 810 397	$111 547 524	
B/C ratio	4.89	3.52	10.57	8.78	

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.[178] 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

STRATEGIES	COSTS	ASSUMPTIONS
En-route traveller information	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	• Per cent of time the device is providing useful information (25 per cent) • Per cent of drivers acting on the information (10 per cent) • Average time saved by drivers acting on the information (4 minutes)
Pre-trip traveller information	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	• Per cent of people accessing the traveller information (10 per cent) • Per cent of people acting on the information (22 per cent) • Average time saved by drivers using the information (7 minutes)

TABLE 9 Results of B/C analysis of Bangkok, Thailand

	EN-ROUTE TRAVELLER INFORMATION	PRE-TRIP TRAVELLER INFORMATION	TOTAL BENEFITS	PROPORTION (PER CENT)
Total annual benefits	$1 420 850	$102 350 059	$103 770 909	100
Travel time savings	$864 070	$101 384 227	$102 248 297	98.5
Recurring delay	$864 070	$101 384 227	$102 248 297	-
Non-recurring delay	-	-	-	-
Energy and emissions	$556 780	$965 832	$1 522 612	1.5
Total annual costs	$169 726	$2 596 606	$2 766 332	
Net benefits	$1 251 124	$99 753 452	$101 004 577	
B/C ratio	8.37	39.42	37.51	

178 J. Fernquest, "Bangkok traffic jams among world's worst", Reuters, 20 February 2017. Available at https://www.bangkokpost.com/learning/advanced/1201724/bangkok-traffic-jams-among-worlds-worst.

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

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 boundries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

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

	TRAFFIC INCIDENT MANAGEMENT	TRUCK PARKING AND RESERVATION	ROAD WEATHER MANAGEMENT	TOTAL BENEFITS	PROPORTION (PER CENT)
Total annual benefits	$12 598 413	$2 876 273	$43 311 068	$58 785 754	100
Travel time savings	$6 902 670	$1 137 712	$19 561 949	$27 602 331	47
Recurring delay	-	$1 137 712	$19 550 612	$20 688 324	-
Non-recurring delay	$6 902 670	-	$11 337	$6 914 007	-
Safety	$5 185 949	$590 729	$14 465 084	$20 241 762	34.4
Reliability	-	$64 432	$4 512 318	$4 576 750	7.8
Energy and emissions	$509 794	$1 083 400	$4 771 717	$6 364 911	10.8
Total annual costs	$3 002 802	$1 011 384	$5 286 844	$9 301 030	
Net benefits	$9 595 611	$1 864 889	$38 024 224	$49 484 724	
B/C ratio	4.2	2.84	8.19	6.32	

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 11 Results of B/C analysis of Baku, Azerbaijan

	EN-ROUTE TRAVELLER INFORMATION	PRE-TRIP TRAVELLER INFORMATION	TOTAL BENEFITS	PROPORTION (PER CENT)
Total annual benefits	$619 630	$25 702 856	$26 322 486	100
Travel time savings	$493 754	$25 346 057	$25 839 811	98.2
Recurring delay	$493 754	$25 346 057	$25 839 811	-
Non-recurring delay	-	-	-	-
Energy and emissions	$125 876	$356 799	$482 675	1.8
Total annual costs	$56 575	$865 535	$922 111	
Net benefits	$563 055	$24 837 320	$25 400 375	
B/C ratio	10.95	29.70	28.55	

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/emission 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

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