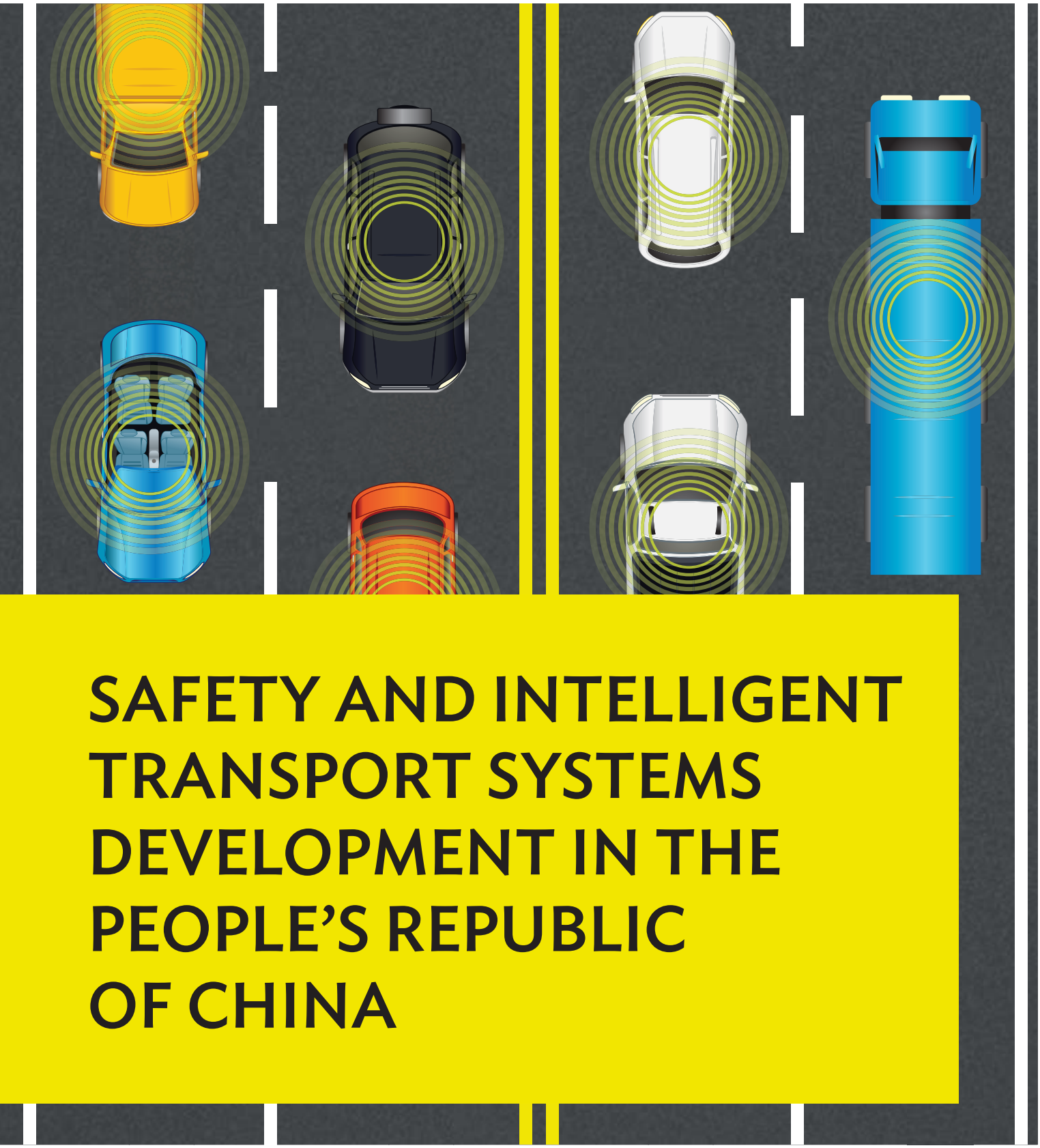

SAFETY AND INTELLIGENT TRANSPORT SYSTEMS DEVELOPMENT IN THE PEOPLE'S REPUBLIC OF CHINA

ASIAN DEVELOPMENT BANK

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ASIAN DEVELOPMENT BANK

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Foreword

Road fatalities in the People's Republic of China (PRC) have been decreasing steadily. However, the total number of road accidents in the PRC is still high. There is room for improvement that can lead to reduction of fatal accidents and decrease of near-miss events.

Now, after decades of applying traditional traffic engineering methods and law enforcement to improve road safety, many developed countries use Intelligent Transport Systems (ITS) technologies to improve road safety. ITS utilizes information and communication technology in transport infrastructure and vehicles to improve transport outcomes. ITS can (i) reduce overall risks, (ii) identify specific risks and minimize the chances of collision and serious injuries, and (iii) minimize delay of emergency response after an accident.

To help decision-makers in the PRC further understand the challenges and opportunities of using ITS for traffic management and road safety, the Ministry of Transport and the Asian Development Bank jointly launched a technical assistance project on road safety and ITS. The objectives were (i) to provide opportunities for establishing a policy framework for the development and implementation of mobile communication-based ITS, (ii) describe technologies, and (iii) offer recommendations for further development.

This study identifies the main factors that influence road safety in the PRC including rapid motorization combined with immature drivers and weak traffic management. The specific issues which contribute to collisions are speeding and fatigued driving. These road safety challenges can be overcome in part by the use of ITS.

The report then describes technologies being used in best performing countries and in the PRC. These include using vehicle-to-vehicle and vehicle-to-road infrastructure connected technologies. These are also referred to as cooperative ITS because benefit is derived when information passed from one entity to another can achieve advantageous results.

The report concludes by discussing the prospects and benefits of ITS application in the PRC and providing recommendations for the development and implementation of mobile communications-based ITS suitable for the PRC.

Through this technical assistance project, the Ministry of Transport and the Asian Development Bank have shown that deploying cooperative ITS on the National Trunk Highway System can support meaningful improvements in road safety in the PRC.

Ayumi Konishi
Director General
East Asia Department
Asian Development Bank

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This report has been prepared through the Asian Development Bank's technical assistance project, Highway Safety and Information System Development. Ki-Joon Kim led the implementation of the technical assistance. Tyrrell Duncan and Robert Guild provided overall guidance and supervision.

A team of international consultants from the Transport Research Laboratory and national consultants from the Research Institute of Highway produced this report through a combination of desk research and consultations. National experts and stakeholders in the People's Republic of China contributed through interviews and discussions.

This publication was reviewed by Andri Heriawan, Ko Sakamoto, Sharad Saxena, and Mitsuhiro Yao.

Abbreviations

2G	second generation of cellular networks for mobile phone communications
3G	third generation cellular networks for mobile phone communications
4G	fourth generation cellular networks
ACN	automatic crash notification
C-ITS	cooperative ITS (intelligent transportation systems)
CVRIA	connected vehicle reference implementation architecture
DSRC	dedicated short-range communications—an example of a wireless local area network (WLAN)
EasyWay	European Program for deployment of Intelligent Transport Systems on the Trans-European Road Network
EDA	enhanced driver awareness
ETC	electronic toll collection
ETSI	European Telecommunications Standards Institute
FVD	floating vehicle data
GPRS	general packet radio service
GPS	global positioning system
GSM	global system for mobile communications
HGV	heavy goods vehicle
HMI	human–machine interface
HMRC	highway monitoring and response center
HSDPA	high-speed downlink packet access
I2V	infrastructure to vehicle communications
ICT	information and communications technologies
ISA	intelligent speed adaptation
ISO	International Organization for Standardization
ITS	intelligent transportation systems
IVI	in-vehicle information
IVS	in-vehicle signage
LTE	long-term evolution
MOT	Ministry of Transport
MPS	Ministry of Public Security
NHTSA	National Highway Traffic Safety Administration
NTHS	National Trunk Highway System
OEM	original equipment manufacturer
RIOH	Research Institute of Highway
SAC	The Standardization Administration of the People's Republic of China
SAC/TC268	The National Technical Committee 268 on Intelligent Transport Systems of the Standardization Administration of the People's Republic of China
SAE	Society of Automotive Engineers

TC	technical committee
TS	technical standard
US DOT	United States Department of Transportation
V2I	vehicle-to-infrastructure communications
V2V	vehicle-to-vehicle communications
V2X	vehicle-to-anything (communications between vehicles and any other entity)
VMS	variable message sign
WAN	wide area network
WAVE	wireless access in vehicular environments
WiMax	worldwide interoperability for microwave access
WLAN	wireless local area network

Executive Summary

Introduction

This report examines opportunities for establishing a policy framework for the development and implementation of mobile communication-based Intelligent Transport Systems (ITS) using vehicle-to-vehicle (V2V) and vehicle-to-road infrastructure (V2I) connected technologies. This technology is referred to as cooperative ITS (C-ITS). C-ITS takes intelligent transport systems a stage further by taking advantage of the enhancements and additional services made possible by connecting these systems together.

The report focuses on deployment opportunities for C-ITS aimed at improving safety on the National Trunk Highway System (NTHS) in the People's Republic of China (PRC). It reviews safety data from the NTHS and evaluates the results with particular reference to potential improvements in road safety that C-ITS could offer. It then identifies the most relevant cooperative systems, and outlines the requirements for ITS infrastructure in terms of architecture, communication technologies, and equipment.

The report reviews the current C-ITS situation in the PRC from the perspective of various stakeholder groups including road operators, vehicle manufacturers, equipment and service suppliers, and communication providers. Based on interviews with stakeholders and further analysis, the report summarizes C-ITS services in the PRC, C-ITS operations and an overview of the readiness of the PRC to use C-ITS.

The report is structured as follows:

- **Chapter 1** gives an overview of the NTHS and its features.
- **Chapter 2** identifies the most relevant C-ITS application for initial deployment in the PRC. It includes an analysis of accident data to help identify which C-ITS would be most beneficial. The methodology for identifying the short list of C-ITS through a structured filtering process is explained.
- **Chapter 3** discusses the technical infrastructure required for implementation of C-ITS and reviews technical architectures and standards developments. In particular, it describes the communication options for implementation of C-ITS.
- **Chapter 4** identifies the main stakeholders that need to be involved in deployment of C-ITS on the NTHS. The chapter explores existing services and the processes and perspectives of the stakeholders.
- **Chapter 5** identifies a number of key operational issues that need to be addressed for successful deployment. These include technical issues such as security and performance as well as organizational and legal ones.
- **Chapter 6** provides a number of project conclusions which lead to a set of recommendations.

Road Safety on the National Trunk Highway System

Road accident data have helped identify the prevalence of some of the key factors which could be addressed by C-ITS aimed at improving safety on the NTHS. However, data collection, storage, and analysis could still be improved in the PRC to support current and future evidence-based policy making. While C-ITS certainly has

a role in improving safety on the NTHS, it cannot be expected to provide an efficient and effective means of addressing all identified safety issues. Conventional traffic safety engineering should also be undertaken on the NTHS in parallel with C-ITS development.

Identification of the Most Relevant Cooperative Intelligent Transport Systems for the National Trunk Highway System

A C-ITS service already widely deployed on the NTHS is the Electronic Toll Collection (ETC) system, but this does not provide a suitable basis for more general C-ITS. The most relevant C-ITS services with substantial safety benefits are those that warn drivers of excessive speed and services that provide warnings of various hazards on the road ahead.

C-ITS applications identified and considered relevant for the NTHS are grouped into the following applications:

- **Cooperative hazard warnings**—This group of applications warns drivers that they are approaching a hazard. This group of applications can reduce road fatalities by 1% to 5%.
- **Enhanced driver awareness and control**—This group of applications aim to improve safety by enhancing the driver's awareness of prevailing traffic and safety conditions. Benefits include reduction in road fatalities of about 4%–7%, and about 1% reduction in carbon emissions.
- **Automatic crash notification**—This system inside a vehicle can automatically make a telephone call to emergency services when a collision occurs. Road fatalities are reduced by about 5% by using this application.
- **Controlling congestion and maximizing efficient use of the road network**—This group, while not primarily for safety applications, can also have a safety benefit. Using dynamic route guidance, it can improve travel time by 2%–4% with corresponding benefits to the environment.
- **Tracking and tracing of dangerous or valuable goods**—These applications for tracking and tracing dangerous or valuable goods enable vehicles to communicate in-vehicle status to the infrastructure in real time.
- **Floating vehicle data**—This refers to the gathering of road usage statistics from road users. Vehicles can report their position and speed data to a central database allowing road managers to understand the state of the network. Using this database can improve traffic management by 2% and reduce emissions by 1%.

Cooperative Intelligent Transport Systems Infrastructure

The NTHS is equipped with a fiber-optic backbone, and there is virtually complete cellular network coverage on the NTHS. The fiber-optic communications network is owned by the road operator to provide high-speed data communications from the expressway data center to the roadside. It is currently used to connect Electronic Toll System tolling infrastructure, but has sufficient capacity to fulfill an extensively enhanced role, for instance, connecting other roadside equipment for incident detection, traffic management, etc. All roadside communications infrastructure is brought together in an expressway data center. Other roadside equipment may include Manual Toll Collection systems, closed-circuit cameras, and emergency telephones (every 500 meters on either side of expressways).

This is an excellent opportunity to introduce cooperative vehicle applications in the PRC.

Cooperative Intelligent Transport Systems Stakeholders for Services in the People's Republic of China

The government and the automobile industry are key stakeholders in realizing the deployment of C-ITS in the PRC. The industry is ready to develop ITS services if suitable business models can be found. The industry is also looking to government to take the lead, but direct and continued government funding for C-ITS is not expected. It is important to identify the relationship between government and the market to promote C-ITS development. Several approaches are available for stimulating deployment of C-ITS.

Skills and Experience for Cooperative Intelligent Transport Systems Deployment

The PRC has suitable arrangements for higher education, university teaching, and research. The industry has high skills and capabilities; nevertheless, ITS is a rapidly developing area which calls for continuous professional development. Additional attention to professional registration and continuous professional development could support future growth.

Recommendations

The following recommendations are made to support the overall objective of developing C-ITS for enhancing road safety in the PRC:

- The PRC should develop a national electronic collection, storage, and analysis system for road accident data.
- Conventional traffic safety engineering should be undertaken on the NTHS in parallel with C-ITS development. This should include better enforcement to prevent nonmotorized road users entering the NTHS, and better enforcement of overladen vehicles, speed, and driver distraction.
- Market solutions should be encouraged for C-ITS services such as Floating Vehicle Data collection, Dynamic Route Guidance, In-Vehicle Signage, and hazard warning ahead.
- Trials should be undertaken for the C-ITS service Automatic Crash Notification for cars and heavy trucks. This should investigate both technology and deployment issues.
- Road operators should be encouraged to make more use of Floating Vehicle Data to enhance and implement dynamic traffic management.
- The automobile industry should be encouraged to develop both autonomous and V2V safety systems (such as collision mitigation).
- The PRC should update and disseminate a state-of-the-art national ITS architecture and deployment plan for all stakeholders.
- Industrial companies should be encouraged to support professional registration, and continuous professional development of staff to assist future deployment of ITS.
- Consideration should be given to joining the European Union/United States/Japan Cooperative Systems International Task Force.
- Longer term C-ITS development should be explored within an appropriate research program.

[1]

INTRODUCTION

The application of Intelligent Transport Systems (ITS) to improve road safety in the People's Republic of China (PRC) began in the early 1990s. By the late 1990s, ITS represented by intelligent traffic signal control systems and automatic enforcement equipment were widely introduced in the PRC, and still plays an important role in improving urban road safety. At the start of the 21st century—with the acceleration of urbanization, highway construction, and vehicle growth—ITS have been more widely introduced. As a result of investment related to the PRC's hosting of the 2008 Olympic Games and World Expo 2010, risk reduction and accident prevention ITS applications have been increasingly used on urban roads, expressways, and commercial vehicles.

The PRC has become the world's largest car consumer since 2010. As manufacturing costs decrease, the use of pre-installed ITS in vehicles is rising and public awareness about them is improving. It can be predicted that there is potential for a broad spectrum of applications for vehicle-installed and vehicle-infrastructure cooperation systems in the future.

While some of these technologies are already in use and others are available on the market, there is still uncertainty as to which technologies will be implemented during the next decade or two.

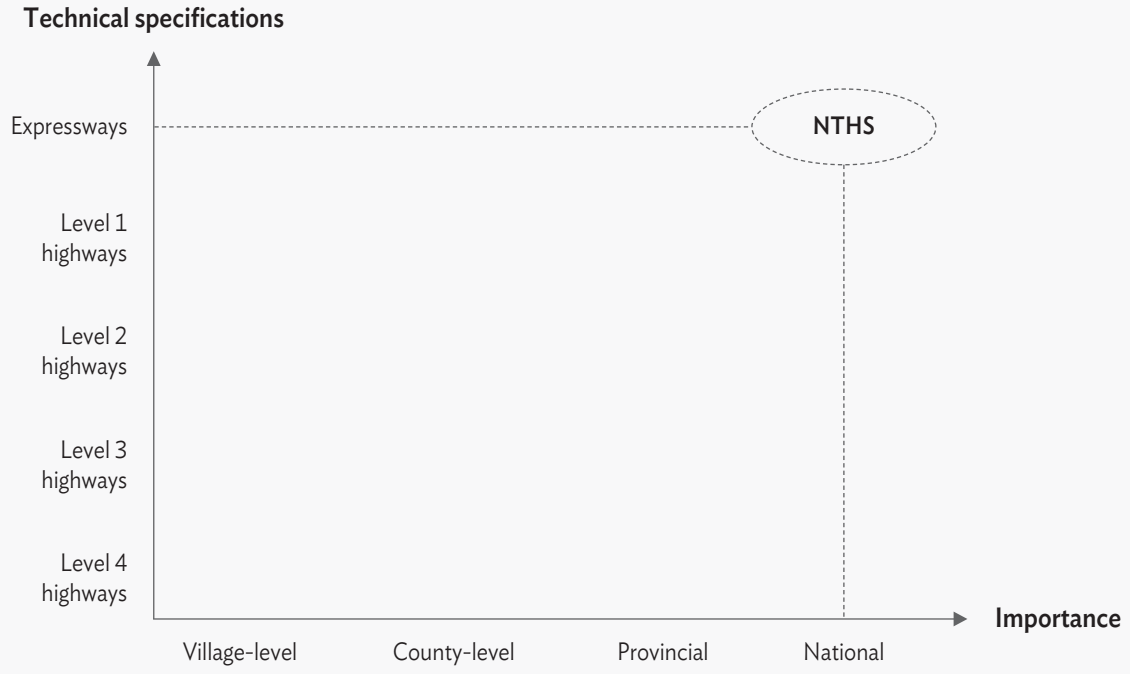
The main purpose of this study is to examine opportunities for establishing a policy framework for the development and implementation of mobile communication-based transport system, using vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connected vehicle technologies to improve safety. This technology is referred to as cooperative ITS (C-ITS). C-ITS takes ITS a stage further by taking advantage of enhancements and additional services made possible by interconnecting these systems.

The report particularly focuses on deployment opportunities on the National Trunk Highway System (NTHS) where C-ITS can support improvements in road safety. Nevertheless, C-ITS can also offer benefits in urban areas, and also support economic and environmental improvements.

1.1 The National Trunk Highway System—Road Facts

According to the Highways Law of the PRC, all highways can be categorized in two dimensions. The first dimension divides highways into four levels: (i) national, (ii) provisional, (iii) county, and (iv) village level, according to their importance in the overall highway network. The second dimension divides highways into five categories, including (i) expressways (highest level), (ii) Level 1 highways, (iii) Level 2 highways, (iv) Level 3 highways, and (v) Level 4 highways (lowest level), according to the technical specifications. The NTHS belongs to "national" and "expressway" as shown in Figure 1.

Figure 1: The Concept of the National Trunk Highway System



NTHS = National Trunk Highway System.

Source: Research Institute of Highways, the People's Republic of China.

The NTHS consists of seven radial expressways (from the capital, Beijing), nine North–South expressways, and 18 East–West expressways as the backbone, and some other national expressways as supplementary (known as the 7918 network). According to the National Highway Network Plan (2013–2030) published by the Ministry of Transport in June 2013, the total length of the planned NTHS in 2030 is 136,000 kilometers (km) of which 71,000 km have been built, 22,000 km are under construction, 25,000 km are to be built in the near future, and 18,000 km are to be built in the long-term (Figure 2).

The expressways (including the NTHS and regional expressways) have grown in length by about 20% each year since 2000 to the current projected length of 104,500 km at the beginning of 2014 (Figure 3).

In general, the construction of expressways is funded through the vehicle purchase tax, fees and taxes collected by local governments, state bonds, domestic investment, and foreign investment. Unlike other freeway systems, the majority of the roads on the NTHS are toll roads that are largely financed by private companies under contract from provincial governments. The private companies raise money through bond and stock offerings, and recover money through tolls.

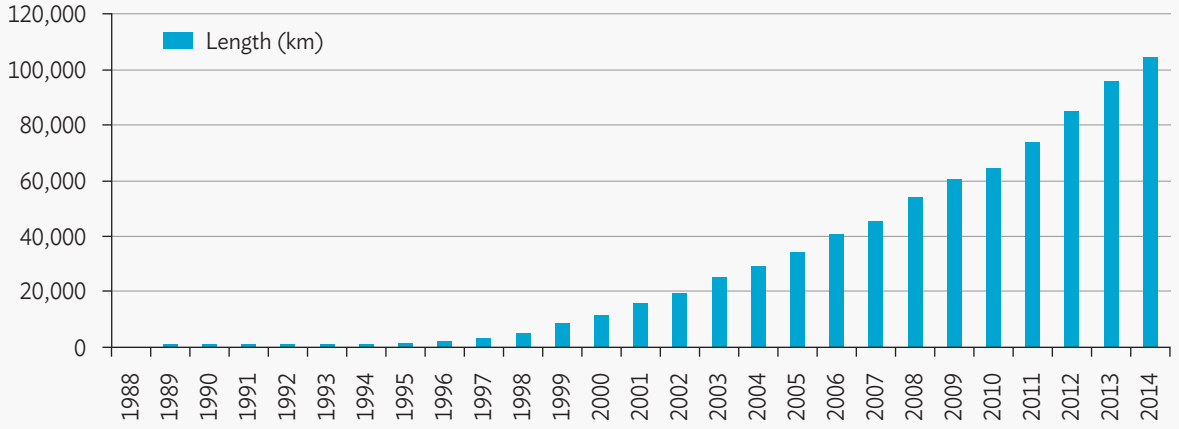
The funding for the NTHS is through a public–private partnership. The provinces, including the particular sections of the NTHS, provide 65%–95% of the capital required to construct and maintain the infrastructure. The concessions are issued based on a build–operate–transfer method.

Figure 2: The National Trunk Highway System Network in the People's Republic of China—Planned by 2030

Note: Solid lines to be constructed in the short term. Dashed lines to be constructed in the long term.

Source: Ministry of Transport, the People's Republic of China.

Figure 3: Length of Expressways in the People's Republic of China, 1998–2014



km = kilometer.

Source: National Bureau of Statistics, People's Republic of China.

1.2 Safety and Other Statistics

The factors that govern common safety on the NTHS are quality and maintenance of the infrastructure (including road surface, road markings, signages, and accident barriers), level of maintenance of the vehicles (tires, brakes, mirrors, and lights), and the behavior of drivers (ability to drive and adherence to speed limits).

To support road safety, the PRC has several standards relating to quality and maintenance of the infrastructure. The following national transport industry standards regarding the construction of expressways are in place:

- **General Specification of Freeway Traffic Engineering and Roadside Facilities** (JTG D80-2006). This standard is mandatory, currently effective, and experiencing revision.
- **Specification for Design of Highway Safety Facilities** (JTG D81-2006). This standard is mandatory and currently effective.

In addition, there are two more mandatory standards currently being developed:

- **Specification for Design and Construction of Expressway Management Appurtenances**
- **Specification for Design and Construction of Expressway Services Appurtenances**

Another relevant standard is the **Technical Specification for Construction of Highway Safety Facilities** (JTG F71-2006). According to these standards, it is not mandatory to install accident barriers on expressways, and such is only justified if certain criteria are met. However, the current situation is that almost all expressways in the PRC have barriers on both sides.

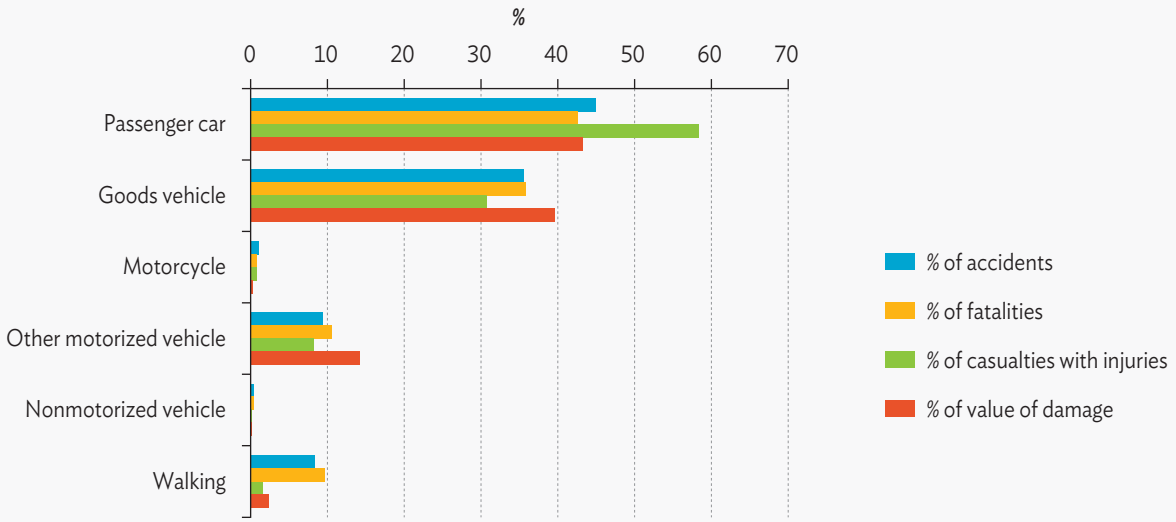
1.2.1 Analysis of Road Accident Data Relevant to the National Trunk Highway System

Published tables showing the national accident statistics for expressways in 2012 have been analyzed, with brief comparisons on key points with equivalent tables for each year since 2008. Since expressways include both the NTHS and other expressways, the analysis should be treated as indicative of the nature of the accidents on the NTHS. Due to the reliance on published tables, analyzing how different types of factors combine in the circumstances of accidents has not been possible. Thus, the analysis presented provides a general impression of the prevalence of some key factors which could be addressed by C-ITS aimed at improving safety on the NTHS; it is not possible to quantify the safety impacts of C-ITS on the basis of this data.

1.2.2 Road User Types

The statistics for expressways in Figure 4 show that 45% of accidents are attributed to car drivers, 36% are attributed to truck drivers, 8% to pedestrians, and 1% to motorcycle drivers. The rest involve various other types of motorized and nonmotorized vehicles such as tractors, animal-drawn vehicles, etc. Note that there are local laws or regulations banning motorcycles from the NTHS in certain provinces.

Figure 4: Types of Vehicles Involved in National Trunk Highway System Accidents, 2012



Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

The split of fatalities[1] is similar: 43% were in accidents where car drivers were to blame, 36% in accidents where truck drivers were to blame, 10% in accidents attributed to pedestrians, and less than 1% were in accidents attributed to motorcycle riders.

[1] A fatality is defined as a death occurring within 7 days of the accident.

The proportion of accidents recorded where truck drivers were to blame have decreased in recent years—from 45% in 2008 to 36% in 2012, while the proportion where car drivers were to blame have increased from 40% to 45% over the same period. Less than 1% of accidents, fatalities, and casualties involve vehicles transporting dangerous goods.

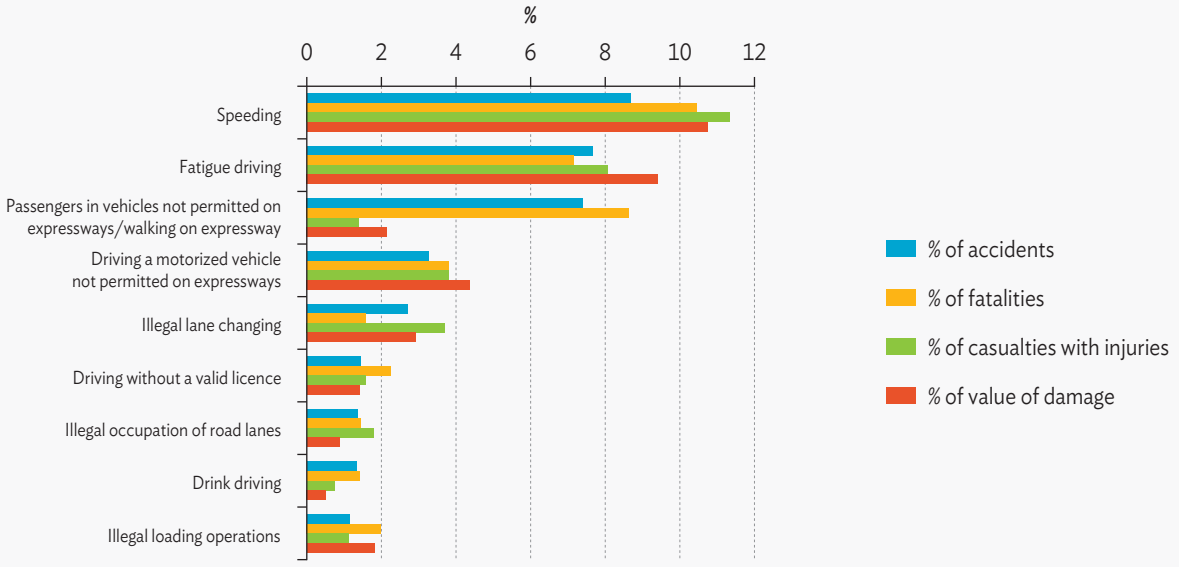
1.2.3 Main Causes of Accidents

The main causes of accidents on the PRC's national expressways can be divided into five main categories: (i) illegal behavior of motorized vehicles (80.2%), (ii) non-illegal behavior of motorized vehicles (10.5%), (iii) illegal behavior of nonmotorized vehicles (0.2%), (iv) illegal behavior of pedestrians and passengers (8.3%), and (v) others (0.8%).

Of all illegal behavior, common factors identified were: (i) speeding, (ii) fatigued driving, (iii) riding a vehicle prohibited on expressways, (iv) walking on the expressway, (v) driving a vehicle prohibited on expressways, (vi) illegal lane changing, (vii) driving without a valid license, (viii) illegal occupation of road lanes, (ix) drunk driving, and (x) illegal loading operations (Figure 5). It is important to note that this only provides a partial impression, because many accidents in the "illegal behavior of motor vehicles" group are classified as "other" (i.e., 47% are described as "other illegal behavior of motor vehicle").

Causes of individual accidents identified in the 2012 statistics, which account for at least 1% of accidents, are shown in Figure 5. The figures for the previous 4 years show a similar picture, but with some variation in the percentage of accidents with each of these causes recorded.

Figure 5: Factors Attributed to National Trunk Highway System Accidents, 2012

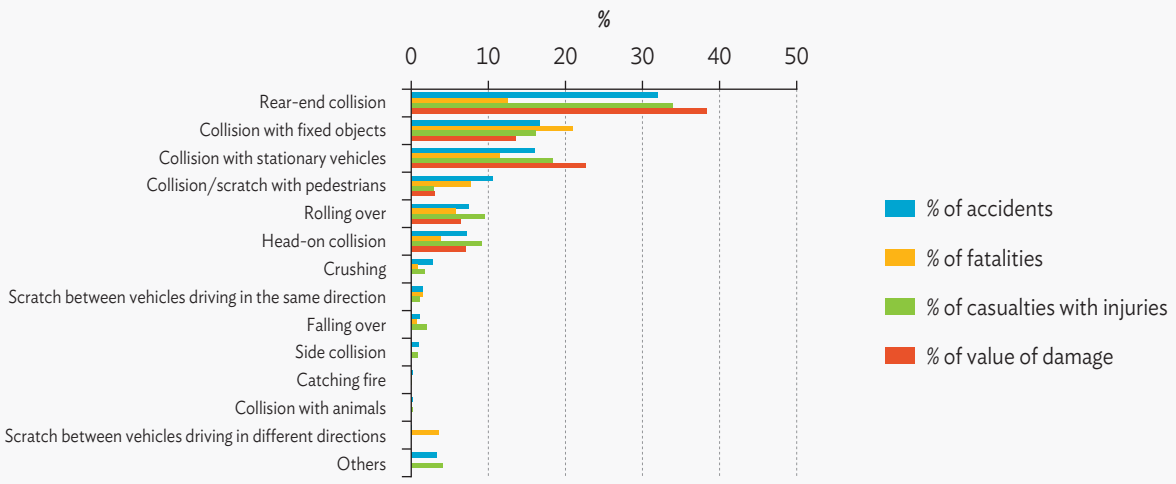


Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

1.2.4 Collision Types

The most common type of collisions recorded are (i) rear-end collisions, (ii) collisions with fixed objects, and (iii) collisions with stationary vehicles (Figure 6). These account for almost two-thirds of the accidents, and three-quarters of the value of property damage.

Figure 6: Types of Collision in National Trunk Highway System Accidents, 2012



Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

One other type of accident accounts for at least 10% of accidents—collision with pedestrians.

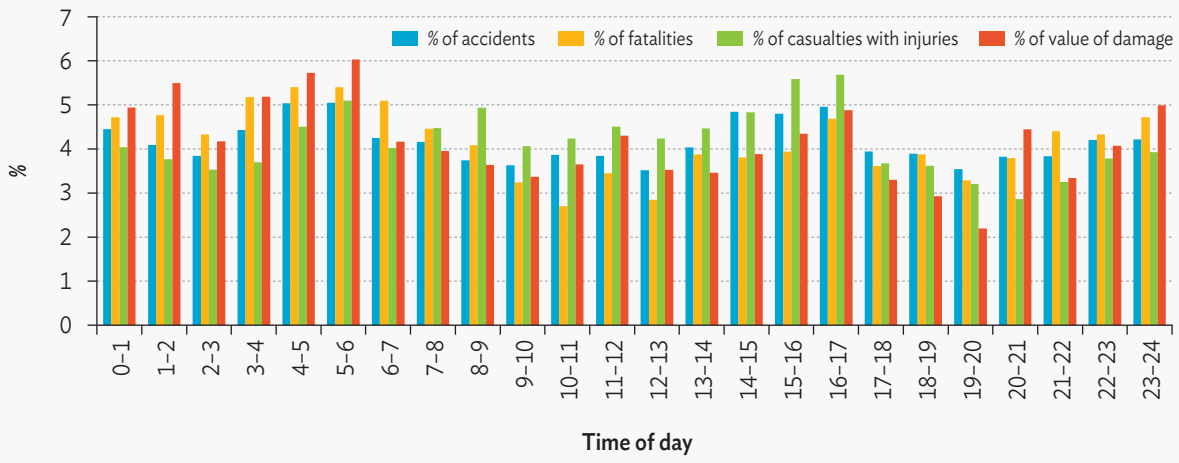
The percentage of accidents recorded as rear-end collisions have declined in recent years from 45% in 2008 to 32% in 2012, while the percentage recorded as collisions with stationary vehicles increased from 5% in 2008 to 16% in 2012. Significant changes over a relatively short period may reflect changes in the way accidents are recorded and classified, rather than differences in the nature of the accidents.

Head-on collisions (7%), side collisions (1%), and impacts between vehicles travelling in the same direction (less than 1%) are relatively less common accidents.

1.2.5 Time of Day

The distribution of accidents and casualties recorded by time of day shows peaks from 3 a.m. to 6 a.m., and from 2 a.m. to 5 p.m., with a relatively large proportion of accidents recorded at night—35% from 9 p.m. to 4 a.m. (Figure 7). However, since the PRC follows only a singular time zone, statistics of accidents recorded from 9 p.m. to 4 a.m. occurring during the hours of darkness are not clear.

Figure 7: National Trunk Highway System Accidents by Time of Day, 2012

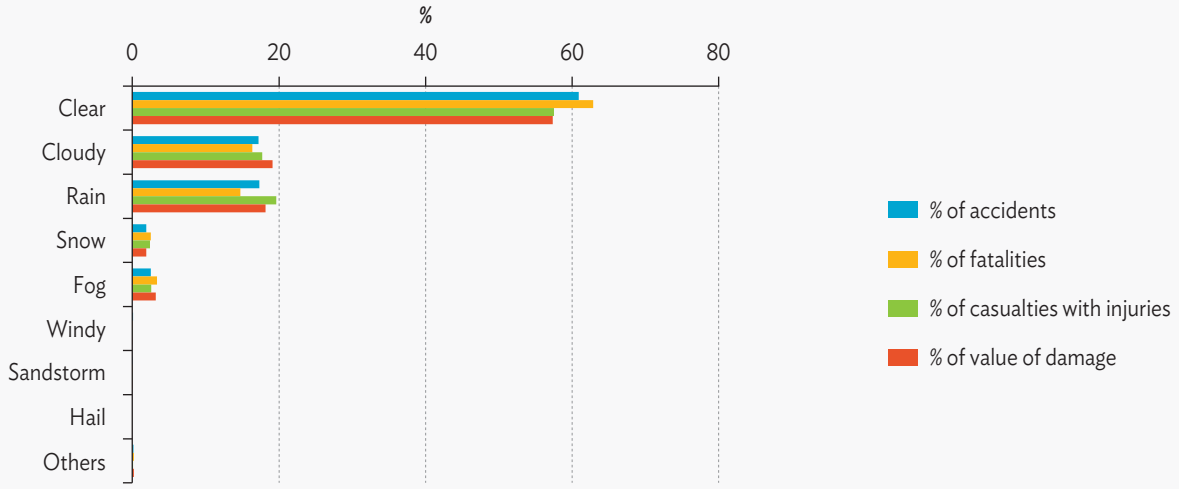


Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

1.2.6 Weather and Road Surface Conditions

Around 60% of accidents with casualties recorded were during clear weather conditions; around 18% in rain, and 2% in snow (Figure 8). The way in which accidents were recorded may underrepresent the influence of weather conditions as a cause of accidents.

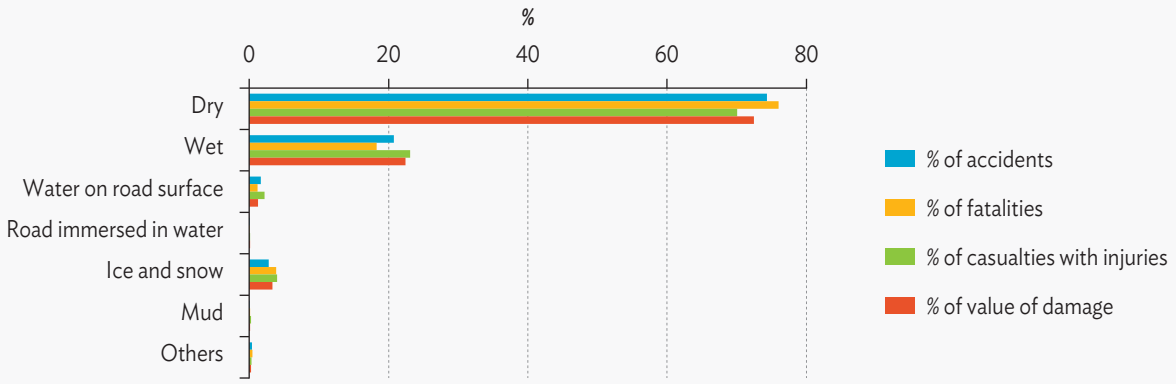
Figure 8: Weather Conditions During National Trunk Highway System Accidents, 2012



Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

Around 75% of accidents and casualties recorded were on dry roads, 20% on wet roads, and 3% on roads where there is ice or snow (Figure 9).

Figure 9: Road Surface Conditions During National Trunk Highway System Accidents, 2012



Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

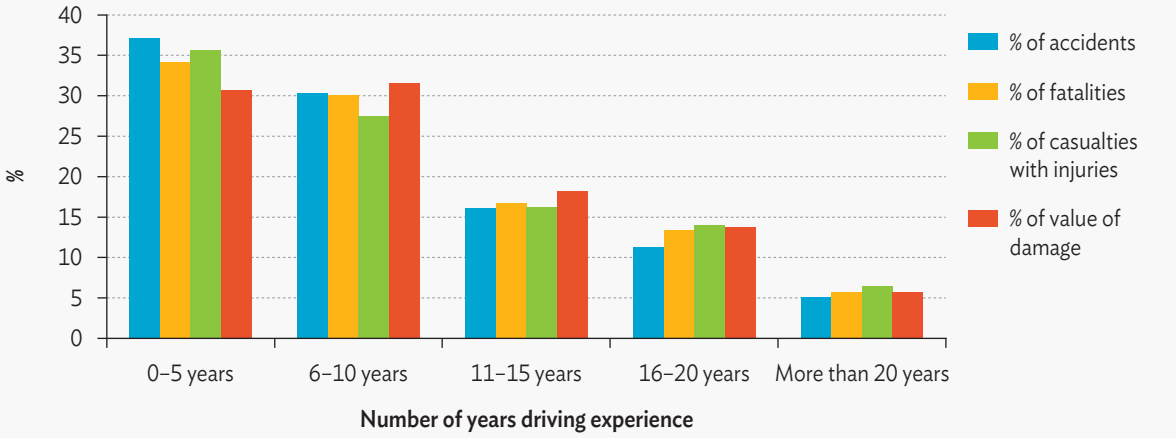
1.2.7 Driving Experience

Over a third of accidents and casualties occur in cases where drivers with less than 5 years driving experience are considered as "to blame," and 13% occur in cases where drivers with less than 1 year driving experience are considered to be at fault (Figure 10).

The proportion of accidents recorded in which the driver considered to be at fault with less than a year's experience, has increased to 13% in 2012 from 8% in 2008.

Accidents due to speeding, fatigued driving, roadway hazards, and vehicle-to-vehicle or vehicle-to-object collisions can be prevented or minimized through the use of V2V or V2I technologies. Chapter 2 identifies relevant C-ITS for the types of accidents in the PRC that can be minimized through the use of these technologies.

Figure 10: Driving Experience in National Trunk Highway System Accidents, 2012



Source: Traffic Management Bureau, Ministry of Public Security, People's Republic of China.

[2]

IDENTIFICATION OF MOST RELEVANT COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS

2.1 Cooperative Intelligent Transport Systems and Methodology

Cooperative Intelligent Transport Systems (C-ITS) is a term which covers a range of ITS applications and services. They are considered "cooperative" when a benefit is derived from using information passed from one entity (e.g., roadside infrastructure) to another (e.g., a vehicle) to achieve an advantageous result for at least one entity, and possibly both. Achieving this form of cooperation requires that the two entities involved are able to communicate. There are two types of communications in general use in C-ITS systems:

- **Vehicle-to-Infrastructure (V2I)**—communications between roadside or centralized infrastructure and vehicle. This could involve a range of communication channels, most commonly cellular data (long-range), and high-speed short-range microwave communication (similar to Wi-Fi).
- **Vehicle-to-Vehicle (V2V)**—communications between vehicles. This is usually short-range microwave.

This section identifies the most relevant C-ITS applications and services for improving safety on the National Trunk Highway System (NTHS) in the People's Republic of China (PRC). The methodology is as follows:

- Create a long list of C-ITS applications from existing research studies and literature (section 2.2)
- Undertake safety analysis based on accident data from the PRC (section 2.3)
- Identify other benefits which C-ITS may provide (section 2.4)
- Survey the literature to identify the impacts of C-ITS (section 2.5)
- Using the analysis of the road network and accident data from the PRC, those cooperative applications most relevant to the Chinese situation are identified, taking into account the safety analysis outputs (section 2.6.)

2.2 Analysis of Applications

A wide range of cooperative applications have been identified in a variety of international research projects. Inputs from a number of projects have been listed in Appendix A.

Unfortunately, the terminology used in different projects were not definitive, a range of different names were used for identifying cooperative applications, and there is significant overlap between individual applications.

The applications used in this report have been grouped into the following "overarching" applications, and are discussed in the following sections:

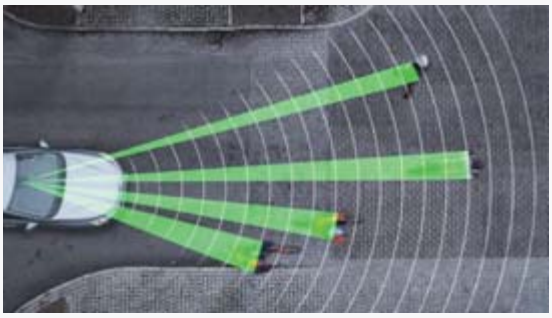
- Cooperative hazard warnings
- Enhanced driver awareness and control
- Automatic crash notification
- Controlling congestion and maximizing efficient use of the road network
- Tracking and tracing of dangerous/valuable goods
- Floating vehicle data

2.2.1 Cooperative Hazard Warnings

This group of applications warns drivers that they are approaching a hazard. Previous research into cooperative applications have identified a range of different services which may be provided, including:

- **Accident and/or collision warning:** Warns approaching vehicles that there has been a collision ahead. The collision may be detected in a number of ways, including notification by the crashed vehicle (section 2.2.3), or reporting by other vehicles, or sensors on the infrastructure. This is closely tied to the pre-accident sensing application.
- **Road condition and/or obstacle on driving surface:** Warns drivers of damage to or debris on the road surface detected by the infrastructure, by other vehicles, or by traffic management centers (via cameras). The warning message giving the position of the road surface damage or debris is then delivered to drivers via the cellular network or a close range communication option. Through this, drivers can adjust their speed and change lanes much further ahead of the obstacle. This application would have particular benefit in low visibility circumstances (e.g., fog, heavy rain, darkness, etc.).
- **Vehicle breakdown warning:** Warns drivers when approaching a vehicle that has broken down, either through the stranded vehicle itself, or by a following vehicle that detects a disabled vehicle (e.g., detecting zero velocity).
- **Ice warning and other weather warnings:** Warns drivers of poor weather conditions, particularly ice and fog. This can be a simple forecast-based warning, or more sophisticated with localized detection of ice on the road by vehicles or by the infrastructure.
- **Hazardous location warning:** Warns drivers about potential hazardous areas upon approach. These areas statistically have more collisions and incidents, and thus require more attention from the driver. This application would have a particular benefit in dynamic situations such as changing weather conditions.
- **Vulnerable road user warning:** Pedestrian safety systems can help reduce accidents by alerting drivers when they are approaching a crossing, together with any speed limit changes,

Figure 11: Vulnerable Road User Warning



Source: Volvo Cars.

then automatically activating in-pavement or overhead lighting to alert drivers if pedestrians are using the crossing. The driver can also be warned of other vulnerable road users in the vicinity, such as motorcyclists and cyclists.

- **Road work and/or work zone ahead:** Carrying out repairs on a live thoroughfare usually involves temporary speed limits, lane changes, lane merges, and counterflows which are managed by temporary signs and portable physical barriers to divide lanes. A linked V2I system offers much more flexibility, enabling faster reconfiguration of the work zone, allowing precise alerts and instructions to be sent to drivers regarding lane choices, speeds, too-close following of preceding vehicles, and others.
- **Traffic jam ahead warning:** In the event of a traffic jam, the infrastructure or the vehicles already stuck in the jam send warning signals to vehicles following them, alerting them to slow down in time. This application is especially useful in low visibility circumstances (e.g., fog, heavy rain, dark, etc.). It potentially reduces the need for queue protection infrastructure, and thus could potentially reduce costs.
- **Low bridge warning:** The approaches to an especially low bridge can be protected by installing roadside sensors to measure vehicle height then sending a warning to a driver via roadside signs, or directly to in-vehicle displays, and activating a red traffic signal to indicate that the vehicle needs to stop.
- **Curve speed warning:** Where there is a very tight bend on a road, the infrastructure can measure an approaching vehicle's speed and send a warning message directly to the driver, and/or trigger a roadside message display. Alternatively, the vehicle can broadcast its speed to the infrastructure and be ready to receive an excess speed warning.
- **Wrong-way driver:** About 400 people die each year from wrong-way drivers in the United States. In fact, 22% of wrong-way crashes are fatal, compared with less than 1% of all other crashes.[2] Such incidents frequently lead to serious accidents and create insecurity among other travellers. Systems have been designed to detect a driver going into a road on an exit ramp, activating flashing red lights in the road as a warning, sending messages and instructions to the driver and approaching drivers via roadside signs, or directly to an in-vehicle display.

2.2.2 Enhanced Driver Awareness and Control

Enhanced Driver Awareness (EDA) and Control is a group of applications that aims to improve safety by enhancing the driver's awareness of prevailing traffic and safety conditions.

- **In-vehicle signage (IVS):** A V2I link is used to give information or warning to a driver of the content of an upcoming roadside sign. This can be extended to inform drivers about other oncoming features of the road such as chicanes, roundabouts, traffic-calming installations, and road markings like segregated cycle lanes or bus lanes. This application is often referred to as visibility enhancement (giving the driver information about situations beyond or outside the direct line-of-sight).
- **Intelligent Speed Adaptation (ISA)** is a system that monitors vehicle speed and the speed limit of the road being used. It intervenes if a vehicle is detected as exceeding the speed limit. ISA acquires local speed information through several techniques: (i) matching the known position to an on-board digital map that

[2] National Transportation Safety Board. 2012. *Highway Special Investigation Report: Wrong Way Driving.* Washington, DC. http://www.ntsb.gov/safety/safety-studies/Documents/SIR1201.pdf

includes speed limit information, (ii) receiving a wireless broadcast from a roadside transponder that notifies speed limits and changes to them, or (iii) through feature recognition technology that detects and interprets speed limit signs. The level of intervention is variable, and is divided into three categories which may be seen as separate applications:

- **Advisory ISA** (ISA 1) wherein the driver is warned of speeding through visual and/or auditory alarms. These systems can be implemented as part of an IVS system, and may be considered a form of in-vehicle signage. This is also called Speed Alert.
- **Supportive or Warning ISA** (ISA 2) which uses haptic feedback (normally increasing the upward pressure on the accelerator pedal on reaching the prevailing speed limit) to encourage the driver to stay within the speed limit.
- **Intervening or Mandatory ISA** (ISA 3) which allows automatic control of the driving systems of the vehicle to reduce speed to the prevailing limit.

Figure 12: Driver Monitoring System

Source: Volvo Cars.

- **Lane change assistant or Blind spot warning, Highway merge assistant, Overtaking vehicle warning, and Lateral or longitudinal collision warning:** Most vehicles have a "blind spot" behind and to the side of them where an overtaking vehicle is rendered momentarily invisible. In the case of a large truck, this space can conceal a car for a time dependent on their relative velocities. This system monitors movements at the rear and alerts the driver to an approaching, overtaking vehicle together with a warning should the driver start to move sideways into the other vehicle's path. It can also alert the approaching vehicle of the intention of the vehicle in front to change lanes or, in case of overtaking, it can inform the vehicle being overtaken.

Figure 13: Collision Warning Systems

Source: Volvo Cars.

2.2.3 Automatic Crash Notification

If sensors in the vehicle detect that a collision has occurred, the vehicle can automatically call for emergency services to give the incident location, and provide information about the vehicle. The system activates voice and data channels enabling the emergency call center to communicate with the driver or any passenger or passengers if they are conscious. The postaccident warning part of the application warns drivers when approaching a crashed car, either via a message from the crashed car itself, or through a following car that detects a crashed vehicle warning ahead.

Source: Volvo Cars.

2.2.4 Controlling Congestion and Maximizing Efficient Use of the Roads

While not primarily safety applicators, the following applications can have a safety benefit as a side effect.

- **Traffic Information and Dynamic Route Guidance (DRG):** Live traffic information collected from floating data vehicles, traffic cameras, and loops is transmitted to the vehicle or satellite navigation device. Using this information and the details of the vehicle's final destination, the system plans the route dynamically. In case of high penetration and in case every equipped vehicle serves as a floating data vehicle, the quality and accuracy of the data provided can replace any additional data source, like loops and traffic counting. These services promote safety by reducing driver stress and distraction.
- **Dynamic Traffic Management (DTM):** Using information similar to the previous application, the road authority dynamically manages the network, for example, by using variable speed limits and hard shoulder running. The information can be relayed to in-vehicle systems through IVS and ISA applications. Smoother running traffic tends to reduce the incidence of accidents. While not strictly a cooperative application, DTM benefits from the use of accurate and up-to-date traffic information provided by floating vehicle data and incident detection systems like Automatic Crash Notification. DTM has both congestion reduction and safety benefits.
- **Cooperative Automatic and/or Adaptive Cruise Control:** Simple cruise control enables a vehicle to set a certain speed limit that can be kept automatically. Adaptive Cruise Control (ACC) monitors the distance of a vehicle to the vehicle in front and slows the host vehicle if it comes close too quickly, maintains a set gap, then automatically restores the set speed when it is already safe. Cooperative ACC takes this process a stage further and uses traffic flow reports from the infrastructure combined with real-time information from the lead vehicle to further optimize speed to prevailing road and traffic conditions. Cooperative ACC may be considered a form of ISA.
  - **Platooning:** Vehicles following each other closely and travelling at a constant speed maximize use of the road and reduce emissions. In this application, vehicles are electronically linked using V2V communications to form a platoon or convoy. The lead vehicle sets the speed of the platoon, with following vehicles automatically maintaining the speed and position in the platoon.
  - **Ecodriving Support:** This is an umbrella term for applications which assist drivers in reducing their carbon footprint by driving more economically. Cooperative applications can assist by encouraging driving techniques which use knowledge of local traffic and geographic conditions. The majority of

the communications functionality required can be delivered by cellular networks and short-range V2V communications. Some benefit may be achievable from short-range V2I, but it is very unlikely to be significant. Little safety benefit has been identified, but reduced traffic speeds can decrease accidents.

2.2.5 Tracking and Tracing of Dangerous or Valuable Goods

Vehicles transporting dangerous or valuable goods communicate critical in-vehicle information to the infrastructure in real-time. The infrastructure monitors the vehicle position and deploys intervention protocols in case of an emergency. Working in cooperation with other safety applications, particularly in the area of cooperative hazard warning and dynamic traffic management, this can be used to improve safety for all road users.

2.2.6 Floating Vehicle Data

Floating Vehicle Data (FVD) refers to gathering road usage statistics from road users directly. In its simplest form, vehicles regularly report their position or speed data to a central location, allowing road managers to understand the state of the network and detect upcoming problems such as congestion and incidents.

It is important to understand the strengths and limitations of using this type of data. FVD is able to provide accurate and timely data on journey times with only a low penetration rate (10% is sufficient on nearly all roads, but rather less for busy roads) and is potentially more accurate and faster than using fixed roadside or in-road detectors. It can also provide journey time data for lightly trafficked roads where it is not economically viable to install infrastructure-based detectors. However, infrastructure-based detectors are also used to detect traffic density and impending congestion. For FVD to be used for this type of application, the requirement is (i) either near 100% penetration or (ii) at least an accurate knowledge of what proportion of vehicles is reporting their presence.

FVD is already being collected by private operators and mobile service providers, and is widely used by on-board navigation systems to optimize routing and journey time predictions.

An enhanced form uses vehicles as “floating data vehicles” to collect real-time information about road conditions—accidents, temporary speed reduction zones, hazardous weather conditions (e.g., icy roads), operation of a vehicle’s stability control, etc.—for transmission to neighboring vehicles and the infrastructure operator. This could enable a vehicle to detect potholes and other road imperfections using the hub-accelerometers in the vehicle stability controls.

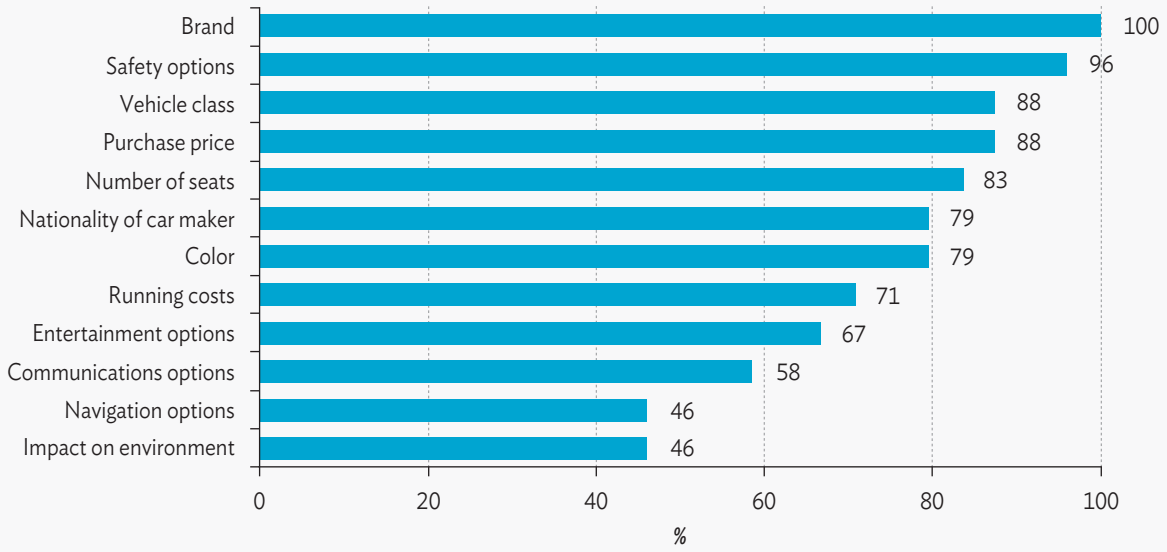
Enhanced FVD may include additional information like the condition of the vehicle, and could be used by vehicle dealerships to warn drivers that their vehicle is potentially unsafe and call them in for repair.

2.3 Safety Analysis

Previous work for the Asian Development Bank (ADB) on road safety in the PRC (Ono et al. 2013) have shown how road fatalities in the PRC have decreased since 2002 as a result of implementing wide-ranging policies and actions including establishing the National Inter-Ministerial Joint Conference on Road Safety. It noted that intelligent transport systems in general (not just C-ITS) could lead to further safety improvements by detecting hazards automatically, reminding and warning drivers in real time and assisting them with control of their vehicles.

It is believed that in-vehicle safety systems would get good user support and hence have a strong influence on the make and models of new vehicles purchased by consumers in the PRC. A survey carried out in 2011 by Strategy Analytics (Lanctot 2012), surveyed 2,000 vehicle owners in the PRC through a carefully sampled online survey, and followed up with focus groups in January 2012. It revealed that safety options were second only in importance to brand name when deciding on purchasing a new vehicle (Figure 14).

Figure 14: Factors Important in Vehicle Purchasing Decisions



Source: R. Lanctot. 2012. *"The Starting Point: Apps to Define the in-Car User Experience"* Strategic Analytics–Content & Apps for Automotive 2012, 18–19 April 2012, Kempinski Hotel, Munich, Germany.

The ADB paper identified areas wherein the PRC could accelerate the process of improving road safety by learning lessons from other countries and developing institutional arrangements, strategic planning and targets, data collection and sharing, and using ITS, as well as measures for vehicle and infrastructure safety, road user education, and enforcement (Ono et al. 2013). The focus of this report takes that work a step further by focusing specifically on C-ITS. The safety analysis presented in this study is concerned with identifying C-ITS which could address safety issues in the PRC.

Published tables showing the national accident statistics for expressways in 2012 have been analyzed, with brief comparisons on key points with equivalent tables for each year since 2008. The source of information is the translation by the Research Institute of Highway (RIOH) of the 2012 Annual Report of Road Transport Accidents Statistics in the People's Republic of China (Government of the PRC, Ministry of Public Security, Traffic Management Bureau 2013) and comparisons with reports for earlier years.

Since expressways include the National Trunk Highway System (NTHS) and other expressways, the analysis should be indicative of the nature of the accidents on the NTHS. Due to reliance on published tables—the only source of accident data available to the project—it has not been possible to analyze how different types of factors combine in the circumstances of accidents. Thus, the analysis provides a general impression of the prevalence of some key factors which could be addressed by C-ITS aimed at improving safety on the NTHS. However, it is not possible to quantify the safety impacts of C-ITS on the basis of this data. More detailed analyses and assessment of impacts would be possible if a national-level electronic database of accident data were available as part of an accident data management and analysis system. Appendix C outlines how road safety improvements could be supported with improved accident data.

Similarly, it is expected that ITS (other than C-ITS) is likely to provide substantial safety benefits at appropriate locations where not already deployed. For example, variable message signs (VMS) and supporting information infrastructure could be installed to warn drivers about incidents ahead, such as accidents and adverse weather. Although there are a number of VMS on expressways in the PRC, their potential to improve safety or efficiency is not fully utilized due to the following reasons. First, the locations where many VMS were set are not usually determined on the basis of in-depth studies or comprehensive justification. Second, the content and frequency of messages displayed on VMS are not carefully determined. VMS on expressways commonly display either insufficient or too much information and VMS are often misused. For example, many VMS on roads are only used to display slogans or other less-relevant information of limited use for improving traffic safety or efficiency.

The results of the accident analysis presented in section 1.2 shows the percentage of accidents, deaths (fatalities), injuries, and the value of damage. The analysis makes it possible to draw some broad conclusions about the types of C-ITS which may be most appropriate for improving safety on the NTHS:

- It is important to target both goods vehicles and cars.
- Rear-end collisions and collisions with stationary vehicles are two of the three most commonly recorded types of collision (the third being collisions with fixed objects), and could be addressed by hazard warning, cooperative ACC and vehicle platooning.
- Speed is clearly an issue which could be addressed by C-ITS (ISA with in-vehicle signage) but other methods of detection and enforcement may be more cost-effective in the short term.
- A large proportion of accidents occurred at night, although it is not clear how many happened in the hours of darkness. Hazard warning, ISA, and in-vehicle signage would be expected to contribute to reducing accidents after dark.
- Collisions with pedestrians account for 11% of accidents, indicating that vulnerable road user warning or pedestrian warning systems may be beneficial. However, more information on the circumstances of these accidents could help assess whether they would be addressed more effectively by measures to prevent pedestrians from using high-speed roads.

- Head-on collisions are recorded as representing a relatively small proportion of collisions (7%), so a wrong-way driver warning would not be a priority C-ITS service.
- Adverse weather conditions and icy roads are also recorded relatively infrequently. However, this appears to be a result of the way in which accidents are recorded because weather conditions are considered to be a significant contributor to accidents.[3] Thus, weather warning systems are recommended for inclusion in the list of C-ITS applications relevant to the PRC, possibly as one of the many functions included in a multifunction hazard warning system.
- Similarly, collisions with animals are recorded relatively infrequently, indicating that warnings of animals on the road are not high priority stand-alone systems.
- Less than 1% of accidents, fatalities, and injuries involve a vehicle transporting dangerous goods. However, when they do occur, they tend to be severe. There is already a requirement for vehicles carrying dangerous goods to be tracked, so ACN for vehicles carrying goods is suggested as a priority to improve the effectiveness and timeliness of incident response.

Other (non-C-ITS) measures for addressing safety issues may be more cost-effective in addressing some safety issues highlighted in the accident analysis:

- Driver fatigue is an issue which could be addressed by (i) driver education and additional provision of rest areas and (ii) increased enforcement of regulations on drivers' hours.
- Inexperienced drivers would benefit, possibly more than others, from some of the C-ITS discussed above, but could also be supported with improved driver education, (e.g., specific training on motorway driving) and with Advanced Driver Assistance Systems (ADAS) such as blind spot warning and merge assistant.
- Preventing vehicles not permitted on expressways is most effectively addressed by education and enforcement. However, a C-ITS hazard warning system could potentially include warnings of slow-moving vehicles and pedestrians or vulnerable road users.
- Overloaded vehicles carrying goods are understood to be a significant contributor to accidents, particularly in mountainous areas. However, C-ITS is not the most effective solution; it is likely to be more cost-effective to address the issue by two more traditional means: (i) overloading can be addressed by enforcing weight limits and taking illegally modified vehicles off the road and (ii) delays and the consequent rear-end collisions on two-lane roads caused by slow-moving vehicles overtaking each other could be addressed by banning heavy vehicles carrying goods from overtaking on steep gradients.

To assist in prioritization of safety measures, trials of safety measures should be considered in order to assess possible approaches to implementation and their effectiveness in the context of the NTHS. Existing trial facilities, such as the joint venture between Volvo and the China–Sweden Research Centre for Traffic Safety, may be suitable for undertaking such assessments (*Automotive Business Review 2014*).

[3] Approximately 22% of accidents in the US are weather-related. Federal Highway Administration, US Department of Transportation. http://www.ops.fhwa.dot.gov/weather/q1_roadimpact.htm (accessed April 2016).

2.4 Other Benefits of Cooperative Intelligent Transport Systems

Safety improvements brought about by C-ITS will lead to other benefits. The primary mechanism by which this occurs is that a reduction in accidents leads to a reduction in traffic delays. This, in turn, leads to two types of benefits. Economic or efficiency benefits arise through reduced journey times and improvements in journey time reliability for both travellers and goods. Environmental benefits arise through smoothing out vehicle flows, which reduces fuel consumption, emissions, and noise.

2.5 Review of Cooperative Intelligent Transport Systems Impacts

A brief review of European literature concerning the potential impacts of C-ITS was conducted. As this is a new and developing area, there is no universally agreed set of services. How they are described and how they are bundled together vary between projects and reports. It is important to emphasize that the information available is on potential, not actual, impacts. The experience of C-ITS in operation is largely limited to early pilot trials in Europe, the United States (US), and Japan which may not be transferable to the context of the PRC. Published information on potential impacts is largely based on estimates and extrapolations from services which are not based on connected vehicle technologies. Table 1 shows the benefits of ITS categorized according to the potential application in the PRC. Appendix B presents the full results of the literature review on benefits and impacts of C-ITS.

Table 1: Benefits and Impacts of Cooperative Intelligent Transport Systems

Application	Fatality Reduction	CO_2 reduction
Hazard Warning		
Accident Warning	< 1%–5%	< 1%
Ice and Weather Warnings	1%–7%	< 1%
Hazardous Location	4%–7%	< 1%
Road Works		< 1%
Traffic Jam	+1%–7%	< 1%
Curve Speed	7%	< 1%
Enhanced Driver Awareness		
IVS	7%	< 1%
Advisory ISA1	4%–7%	< 1%
Automatic Crash Notification (ACN)	5%	
ACN including HGV	4% for fatalities, 6% for injuries	
Dynamic Traffic Management		
Dynamic traffic management	<10%	< 1%
Data Gathering		
Floating Vehicle Data	2% (safety benefit)	< 1%

CO_2 = carbon dioxide, HGV = heavy goods vehicle, ISA = intelligent speed adaptation, IVS = in-vehicle signage.

Sources: SMART 63 project; COBRA project; iMobility Effects.

Projects should generally focus on the most realistic services providing the greatest benefits and that results are more readily available where there are large potential impacts (whereas small impacts will be more difficult to measure).

It is often possible to implement a C-ITS application, function, or service and present it to a driver in different ways. Choices of system architecture do not greatly affect the impact of the service (e.g., safety) but are likely to affect the Benefit–Cost Ratio (BCR) and rollout feasibility.

In summary, there appears to be good evidence for substantial safety benefits from services that warn drivers of excessive speed. There are benefits reported from services that provide warnings for various hazards on the road ahead. The only other substantially beneficial cooperative service is intersection collision warning, but this is more applicable to urban situations than the interurban links.

There is some evidence of benefits from ACN, but these are highly dependent on the context being considered. Although several V2V services, such as collision mitigation, are expected to provide substantial benefits, such services can also be provided using on-board sensors and are commercially available. Therefore, the incremental benefit of V2V here is small. For the future, platooning which requires V2V communication appears to offer considerable potential in removing human driving errors through automation as well as providing substantial fuel savings.

2.6 Identification of Key Cooperative Intelligent Transport Systems Relevant to the People's Republic of China

A significant number of cooperative applications have been identified in section 2.2. It is reasonable to assume that not all will be relevant for the PRC, or that the time scales to implementation are too long to be of benefit in the short to medium term. An analysis of the identified applications has been undertaken in Appendix D.

The analysis sought to identify those applications which will be relevant to the PRC in the short- (5-year) and medium-term (10-year) time scales. The analysis identified those which (i) provide a real safety benefit; (ii) address a known issue in the PRC, as determined by the safety analysis in section 2.3; and (iii) are expected to be market-ready in the relevant time scales.

The applications identified are listed in Tables 2 and 3 for the short- and medium-term applications, respectively. Those applications identified as "partially relevant" are those where only some versions of the applications address the issues.

For a significant number of applications, noncooperative solutions of applications are possible, and in some cases already exist. However, in most cases there are additional benefits from a cooperative solution.

It is possible to deliver an application to a driver in different ways. For example, warning of a hazard ahead may come from information passed on V2V or V2I channels, and then communicated to a driver within the vehicle via V2V, V2I, or from an infrastructure sign. Similarly, the V2I may be through cellular communications or from local beacons (dedicated short-range communications). These different architectural choices do not greatly affect the impact of the service (e.g., safety) but are likely to affect the benefit–cost ratio and rollout feasibility.

All of the applications in Table 2 can be readily implemented using V2I technology. These applications could also be implemented with V2V technology, although the service quality would depend on the number of equipped vehicles. These architecture options are discussed in the next chapter. In the 5-year time horizon, no application has been identified that can be implemented using V2V technology only because incremental

benefits of cooperative (V2V) ITS over autonomous ITS are small (extremely small in the initial stages) and the requirements of the technology which controls safety-critical vehicle functions are higher than the technology that provides information to the drivers. Such V2V technology is relatively immature, and may be costlier.

Within the 10-year horizon, the incremental benefits from cooperative over noncooperative systems would probably still be small but cooperative adaptive cruise control and platooning are identified as C-ITS where there is no equivalent autonomous ITS system.

It can also be noted that V2V safety applications (such as collision mitigation) can be implemented by automobile manufacturers without the need for other stakeholders, as a result the government has less need to act, than in the case of V2I services.

For those applications which *need* integration into the vehicle (ISA 2, ISA 3, cooperative adaptive cruise control, and platooning), the motor industry's involvement is crucial to ensure that common standards are adopted and, where appropriate, enforced.

Table 2: Applications Relevant in 5 Years

Application	Relevance	Comments
Hazard Warning		
Accident Warning	Relevant in 5 years	Noncooperative versions possible
Ice and Weather Warnings	Relevant in 5 years	Noncooperative versions possible
Hazardous Location	Relevant in 5 years	Noncooperative versions possible
Road Works	Partially relevant in 5 years	Noncooperative versions possible
Traffic Jam	Partially relevant in 5 years	Noncooperative versions possible
Curve Speed	Relevant in 5 years	Noncooperative versions possible
Enhanced Driver Awareness		
IVS	Relevant in 5 years	
Advisory ISA1	Relevant in 5 years	Noncooperative versions already available
Automatic Crash Notification including HGV	Relevant in 5 years	Being rolled out in Europe as eCall, private networks also exist
Dynamic Traffic Management	Relevant in 5 years	Noncooperative versions already available
Data Gathering		
Floating Vehicle Data	Relevant in 5 years	Commercial services already exist

HGV = heavy goods vehicle, ISA = intelligent speed adaptation, IVS = in-vehicle signage.

Sources: Transport Research Laboratory, UK and Research Institute of Highways, the People's Republic of China.

Table 3: Applications Relevant in 10 Years

Application	Relevance	Comments
Hazard Detection (pre-accident)	Relevant in 10 years	Noncooperative versions possible
Enhanced Driver Awareness		
Supportive or Warning ISA2	Relevant in 10 years	Require significant motor industry involvement
Intervening or Mandatory ISA3	Relevant in 10 years	Require significant motor industry involvement
Efficiency		
C-ACC	Relevant in 10 years	Require significant motor industry involvement
Platooning	Relevant in 10 years	Require significant motor industry involvement

C-ACC = cooperative adaptive cruise control, ISA = intelligent speed adaptation.

Sources: Transport Research Laboratory, UK and Research Institute of Highways, the People's Republic of China.

[3]

COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS INFRASTRUCTURE

3.1 Architectures

3.1.1 The People's Republic of China Context

Information on Intelligent Transport Systems (ITS) architecture in the People's Republic of China (PRC) is included in the PRC's National ITS Plan; the most recent version is the second edition which was developed from 2003 to 2005. This is likely to have been overtaken by more recent developments in technologies and services. The document itself is not published, but a research report available summarizes the main features as follows:

- user services (nine service domains),
- logical framework (10 functional domains),
- physical systems (10 systems), and
- applications (10 application domains).

Further details of the domains and systems within each of these four high-level areas are provided in Appendix E.

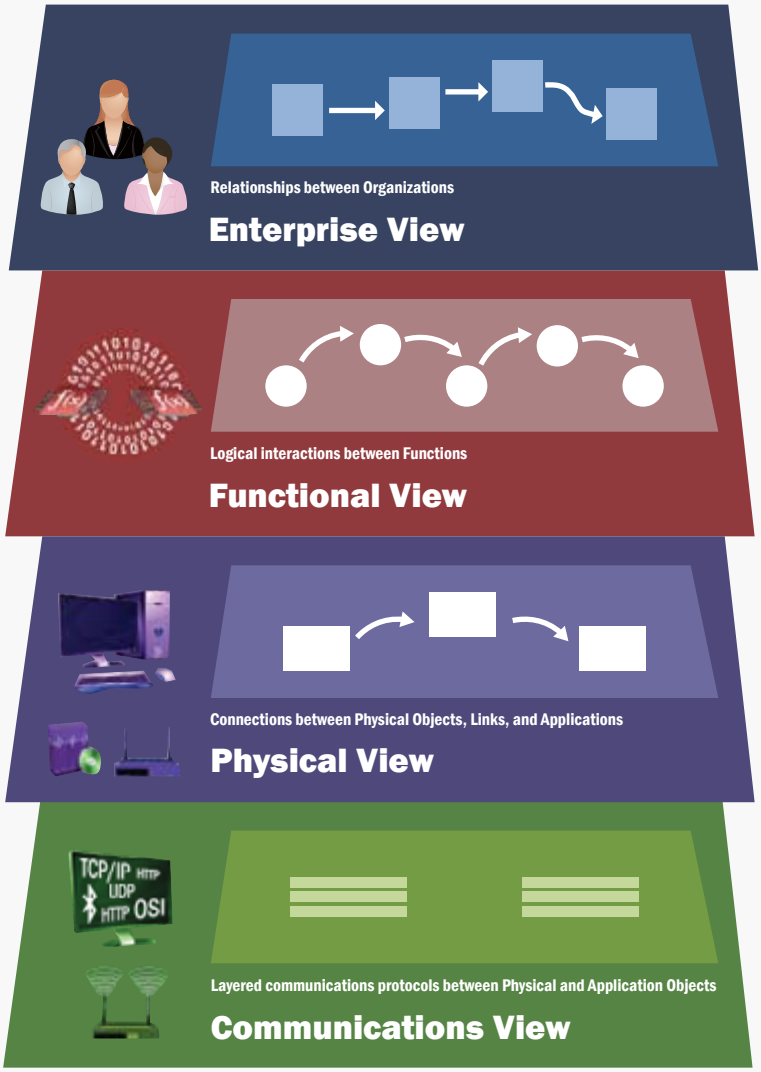
3.1.2 Connected Vehicle Reference Implementation Architecture in the United States

A recent development in the United States (US) relevant to this study is the Connected Vehicle Reference Implementation Architecture (CVRIA).[4]

The CVRIA development includes stakeholder engagement and development of an integrated standards strategy and action plan. Outputs of the project include a set of system architecture viewpoints that describe the functions, physical and logical interfaces, enterprise relationships, and application dependencies within the connected vehicle environment. This effort will produce a prioritized list of interfaces to be considered for standardization, and a connected vehicle standardization plan for the development, modification, and/or harmonization of the defined interfaces.

[4] http://www.iteris.com/cvria/ (accessed 12 May 2014).

Figure 15: Connected Vehicle Reference Implementation Architecture



Source: Connected Vehicle Reference Implementation Architecture. http://www.iteris.com/cvria/

CVRIA is being developed at four architecture levels (Figure 15). These are explored here in the PRC context:

Enterprise

The enterprise level describes the relationships between organizations and the roles they play within the connected vehicle environment. In the PRC context, the major stakeholders will be (i) the government (different departments such as public security department, transport department, industrial and commercial department, environmental department, and health care department), (ii) road operators, (iii) vehicle manufacturers, (iv) aftermarket suppliers to vehicle owners, and (v) mobile communication suppliers. Currently, most of the toll roads in the PRC, including expressways, apply the build–operate–transfer scheme for building and operation, and apply various types of investments. Stakeholders sign contracts to determine how to divide the benefits according to their investments, risks, and responsibilities. According to PRC law,

the roads are owned by the state, and the operating company only has rights to charge toll, advertising, and manage related commercial services, which are protected by laws.

From the safety viewpoint, more can be done with physical safety on the National Trunk Highway System (NTHS) through improved enforcement of speed limits, and vehicle safety checks. From the cooperative ITS (C-ITS) viewpoint, road operators would need to be involved if infrastructure (roadside equipment for communications I2V [infrastructure-to-vehicle communications] and V2I [vehicle-to-infrastructure communications] and back office data processing) is required. The government may need to invest in such infrastructure, as road operators may not see a business case for such investment. Standards for communication and safety-related application functionality will also be necessary to ensure that users can travel across roads run by different operators and obtain a safe level of service. Vehicle manufacturers and aftermarket equipment suppliers would also need to adhere to these same standards to ensure interoperability of any V2V or V2I applications.

Functional

The functional level describes abstract functional elements (processes) and their logical interactions (data flow) that satisfy the system requirements.

This part of the architecture will develop the types of applications which are both practical and useful in the PRC context, and within a reasonable time scale (next 5 years). Without going into technical detail of how a set of safety-related applications will be implemented, this level concentrates on defining the functions, and how users and other stakeholders will visualize the processes, and what data has to flow between the various parties in the process chain to achieve the functions required.

Physical

The physical level describes physical objects (systems and devices) and their application objects, as well as the high-level interfaces between those physical objects.

Given a number of diverse but interoperable solutions which are to be developed in C-ITS applications, this part of the architecture explores the types of infrastructure and in-vehicle equipment necessary to achieve the functional requirements. Although not ruled out, the installation of a large amount of roadside infrastructure is difficult to justify economically for long stretches of interurban road. However, given the availability of dedicated fiber-optic communications along the majority of the NTHS, the costs will mainly be restricted to the roadside V2I structures and devices, and new control equipment for back offices. The transfer of road user and road operator information between vehicles and infrastructure, where timing is not critical, is technically possible. In most cases, and certainly where safety critical applications require information to be guaranteed to be passed from vehicle-to-vehicle, V2V communications will be essential.

Communications

The communications level describes the layered sets of communications protocol required to support communications among physical objects that participate in the connected vehicle environment.

In order to implement interoperable and compatible solutions for a range of safety-related applications on the NTHS, the communications options for fixed and mobile data transfer must be agreed upon. It is possible that both V2V and V2I applications would require a mix of fixed and mobile communication options to be available to road users and operators. The government is in the best position to facilitate this through the support of standards bodies. The reuse of any existing standards, as highlighted in the following sections, would always be preferable to developing new ones.

3.2 Standards

3.2.1 Introduction and Related Standards Activities

Standardization is a vast topic, with a wide range of standards having some bearing on C-ITS activities including standards in information technology, security, and system architectures. There are specific standards for different ITS functions such as digital maps and the European eCall service. In this report, the focus is on the most relevant standards specifically connected with C-ITS.

C-ITS standardization in International Organization for Standardization (ISO) takes place through the ISO Technical Committee 204 (ISO/TC204). Details are provided in Appendix F.

3.2.2 Europe

ISO work on C-ITS is fully coordinated with the European Committee for Standardization as the European Community have supported development through their standardization mandate. Other relevant European standardization takes place within the European Telecommunications Standards Institute (ETSI).

3.2.3 United States

The ITS Joint Program Office of the US Department of Transportation (DOT) is developing a standards plan in support of the US DOT intelligent transport systems connected vehicle research and deployment program. The CVRIA will be used to identify likely candidate interfaces in a connected vehicle implementation. These interfaces will then be used to identify candidate standards that may be used to implement those interfaces.[5]

3.2.4 Asia and the Pacific Region

Japan is very active in international standardization through ISO. It has been developing and implementing action plans for standardization of ITS by areas since 2003. In Japan, the Japanese Industrial Standards Committee (JISC) participates as a member organization based on the approval of the cabinet. An international

[5] CVRIA Standards Plan. http://www.iteris.com/cvria/html/standards/cvstandardsplan.html

standardization committee (the national committee) set up in the Society of Automotive Engineers of Japan (JSAE) carries out the international standardization activities for ISO/TC204 on behalf of the JISC. Standardizations are set forward concerning items on agenda in ISO/TC204. The main actions of the national committee are to (1) take swift action in response to changes in the standardization environment, (2) implement standardization activities in accordance with the strategy, (3) assist registration of Japanese industrial standards for ITS technology, and (4) provide related parties with up-to-date information.[6]

The Standardization Administration of the People's Republic of China (SAC) publishes international and other standards under its own numbering system, often based on ISO standards. It has National Technical Committee 268 on Intelligent Transport Systems (SAC/TC268) to coordinate standardization efforts including voting.

The SAC/TC268 is the counterpart of the ISO/TC204 in the PRC. It is responsible for the administrative affairs of the technical standardization in the ITS sector. The main scope includes standardization of technology and equipment in the fields of (i) advanced management systems for road transport, (ii) advanced traffic message service systems, (iii) advanced public transport systems, (iv) electronic toll collection, (v) truck and fleet management systems, (vi) control system for intelligent highway and advanced vehicles, (vii) two-way and multimodal traffic short-range communications and information exchange, and (viii) management information systems for transport infrastructure (National Center of ITS Engineering and Technology, China, 2014). Appendix F discusses in detail the status of ITS standardization in the PRC.

3.3 Communication Channels

Cooperative systems require a means of data communications, either between vehicles (V2V), or between vehicles and infrastructure (V2I). The actual communications protocols, frequencies, and modulation methods can vary widely, but are mostly in two categories:

- Long-range, low-speed cellular networks, normally called wide area networks (WANs) or cellular networks. We will use the term cellular networks in this paper. These are only suitable for V2I communications.
- Short-range, high-speed non-cellular networks, normally called wireless local area networks (WLANs). Typical examples include DSRC, 802.11p WAVE, Wi-Fi, etc. In this paper we will refer to this as short-range communications, which can be used for both V2V and V2I communications.

In addition, a number of existing unidirectional channels may carry data relevant to cooperative applications. These include:

- Broadcast radio channels carrying traffic data. These are data channels overlaid onto broadcast radio which can carry data on prevailing traffic conditions. Originally designed to broadcast voice messages while drivers are listening to the radio, they can also be used to carry non-voice data. Examples include RDS (radio data system), traffic message channel (TMC), and DAT (digital audio transmission).

[6] Society of Automotive Engineers of Japan, Inc. 2013. *ITS Standardization Activities in Japan.* Tokyo. https://www.jsae.or.jp/01info/its/2013_bro_e.pdf

- Global Navigation Satellite System (GNSS) and related data, which are used for geolocation services. Most cooperative applications require that the vehicle knows its location, and this is commonly determined using GNSS, sometimes simultaneously with augmentation (to improve accuracy and reliability) and assistance (to improve start-up times) services. There are expected to be at least four GNSS services with global coverage by 2020, namely the Global Positioning System (US), GLONASS (Russian Federation), COMPASS/BEIDOU (PRC), and Galileo (Europe). The first two are fully operational. It is expected that eventually all four will be interoperable, allowing the use of a single receiver to decode all four systems with a consequent benefit of potentially improved accuracy.

As the unidirectional channels are well defined and understood, the next section will only look at cellular and short-range networks.

3.4 Communications Technologies

This section describes the communications networks involved in C-ITS. Of particular relevance is V2I and V2V.

Two types of communications are principally considered, namely cellular for long-range V2I (section 3.4.1), and WLAN like short-range networks for roadside V2I and V2V (section 3.4.2). Fixed line communications are considered briefly in section 3.4.3. Frequency allocation for wireless communications in the PRC is discussed in section 5.4.4.

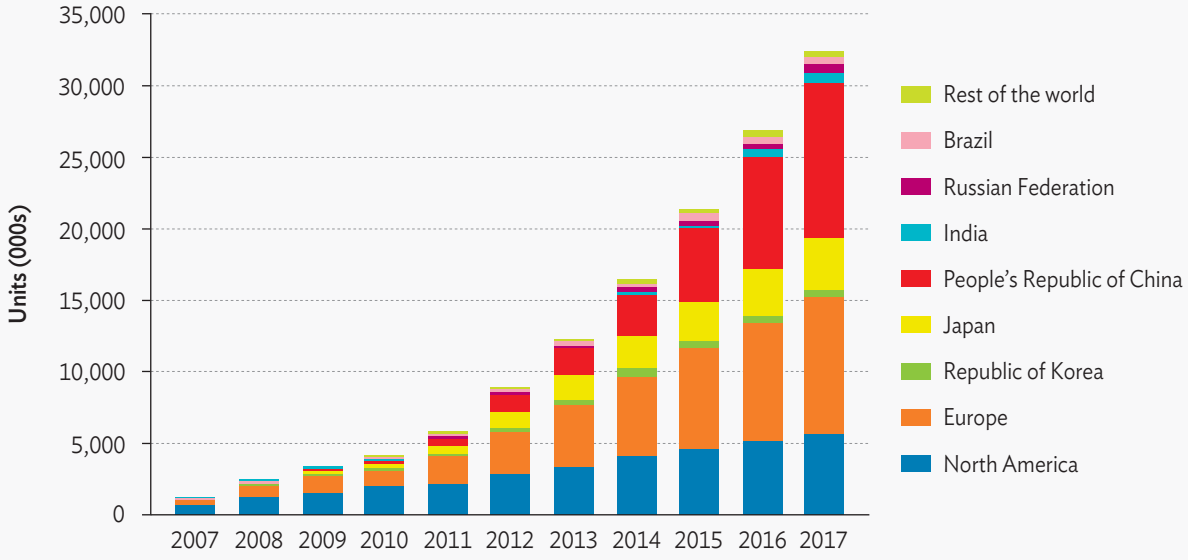
3.4.1 Cellular Networks

Cellular networks are characterized by having a wide area coverage (typically national, but with small areas of limited or no coverage), relatively low data speeds of tens to hundreds of kilobits per second, latencies of hundreds of milliseconds or more, and slow channel setup times. The services are provided by mobile network operators. Neither ad hoc networks, nor V2V services are supported.

The in-vehicle installation of cellular communications units in the PRC, which permit floating vehicle and other cooperative applications to be used, have grown considerably over the past few years. Figure 16 shows that such growth in the PRC is particularly strong compared to other parts of the world, providing an excellent opportunity to introduce cooperative vehicle applications.

Cellular networks have evolved through several generations of capability. The first packet data networks called the general packet radio service (GPRS) were deployed on the second generation of cellular networks for mobile phone communications (2G) global system for mobile communications (GSM) cellular networks supporting data speeds of tens of kilobits per second. GPRS has been upgraded to enhanced data rates for GSM evolution (EDGE), supporting speeds of hundreds of kilobits per second. With the introduction of 3G, data speeds increased to a few megabits per second, and high-speed downlink packet access (HSDPA) providing tens of megabits per second. Fourth generation cellular networks (4G) using long-term evolution (LTE) technology are starting to be offered in a number of countries. All aspects of performance will be improved. LTE will provide

Figure 16: Smartphone Connectivity Electronic Control Unit: Regional Shipments



Source: R. Lanctot. 2012. *"The Starting Point: Apps to Define the in-Car User Experience"* Strategic Analytics–Content & Apps for Automotive 2012, 18–19 April 2012, Kempinski Hotel, Munich, Germany.

data rates which are similar to short-range networks. Latency is also expected to improve but will not reach the measure demanded by many V2V services. There are also questions about geographic coverage which may not reach that of 2G. Overall, 4G will be able to enhance cooperative services but may not unite the services provided through V2V and V2I links.

Currently all generations of packet switched wireless cellular networks are in widespread use, with data terminals able to switch seamlessly between the various generations of connectivity. While this ability to switch between data channels maximizes coverage, it means the capacity of channels can vary widely as a vehicle travels through the coverage area. No cellular network is able to guarantee data packet delivery due to the non-deterministic nature of wireless communications, particularly over a wide coverage area, hence, these networks are not considered suitable for safety-critical applications.

Other technologies are also becoming available, for example Worldwide Interoperability for Microwave Access (WiMAX). Originally designed as a competitor for LTE in 4G, this is becoming popular in point-to-point "last mile" applications. There is a mobile version designed specifically for cellular-like applications, but at this stage it is not widely used and appears likely to lose out to LTE.

3.4.2 Short-Range Networks

Short-range networks, more correctly called wireless local area networks (WLANs), are short-range, high-speed networks. Examples are Wi-Fi (802.11a, b, g, and n), dedicated short-range communications (DSRC) operating at various frequencies and using a number of different protocols, and wireless access in vehicular environments (WAVE, also called 802.11p). Nearly all WLANs use one of three frequency bands, namely 2.4 GHz (an open band shared with many other users and technologies), 5 GHz (actually 4.9 GHz–5.7 GHz depending on the location), and 5.8 GHz–5.9 GHz, part of which is dedicated to ITS use and this is where WAVE is located.

These networks are characterized by high data speeds of tens to hundreds of megabits per second, low latencies (WAVE), and in some cases rapid channel setup times. Ad hoc networks are supported, and both V2I and V2V communications are possible.

Due to their short-range, WLANs can only be expected to provide limited network coverage. However, where the coverage exists, it is likely to be more predictable in quality and capacity than cellular networks.

In the transport domain, it is necessary to differentiate between the use of WLANs designed for general use (802.11a/b/g/n) and those designed specifically for transport use (802.11p WAVE and DSRC). WLANs designed for general use has many advantages in terms of ubiquity, low-cost, and widespread availability, but as it is designed for fixed usage, may be too compromised for use in transport, particularly in the higher speeds found on extra-urban road networks. DSRC/WAVE, being designed specifically for use in transport, will more easily cope with the higher relative speed of terminal equipment, and rapid channel setup times allows meaningful communications in the very short times (possibly less than a second) when the two terminals may be in range. Table 4 summarizes the technical characteristics of the above communications channels.

Table 4: Characteristics of Cellular Networks and Short-Range Networks

	Cellular Networks				Short-Range Networks	
	2G GPRS/EDGE	3G/HSDPA	4G/LTE	Mobile WiMAX	DSRC/WAVE	Wi-Fi
Data rate	< 250 kbps	< 20 Mbps	<300 Mbps	1–32 Mbps	3–27 Mbps	6–150 Mbps
Latency	Seconds	Seconds	100 ms, 10 ms small packets	50 ms	< 50 ms	Seconds
Range	< 10 km	< 10 km	<30 km	< 15 km	< 1 km	< 250 m
Mobility	> 100 kph	> 100 kph	>100 kph	> 100 kph	> 100 kph	< 10 kph
Nominal Bandwidth	< 3 MHz	< 3 MHz	1.4–20 MHz	< 10 MHz	10 MHz	20/40 MHz
Operating Band	800 MHz, 1.9 GHz	1.9 GHz, 2.1 GHz	Numerous	2.5 GHz	5.86–5.92 GHz (ITS-RS)	2.4 GHz, 5 GHz (ISM)
IEEE standard	N/A	N/A	N/A	802.16e	802.11p	802.11 a/b/g/n

DSRC = dedicated short-range communications; EDGE = enhanced data rates for mobile communications evolution; GHz = gigahertz; GPRS = general packet radio service; HSDPA = high-speed downlink packet access; IEEE = Institute of Electrical and Electronics Engineers; ISM band = industrial, scientific, and medical band; ITS-RS= intelligent transportation systems – radio, service; kbps = kilobits per second; km = kilometer; kph = kilometer per hour; LTE = long-term evolution; m = meter; Mbps = megabits per second; MHz = megahertz; ms = millisecond; N/A = not applicable; WiFi = wireless fidelity; WiMAX = Worldwide Interoperability for Microwave Access.

Source: Transport Research Laboratory, United Kingdom.

Further technologies are available for niche requirements, for example Bluetooth[7] (low-cost, short-range, medium speed) and ZigBee[8] (ultra low-cost, short-range, low-speed). While there have been applications which use these technologies (e.g., Bluetooth for journey time analysis, ZigBee for low-cost, mesh-networked in-road sensors), no significant C-ITS applications use these channels at the time of writing, and none are expected to in the future.

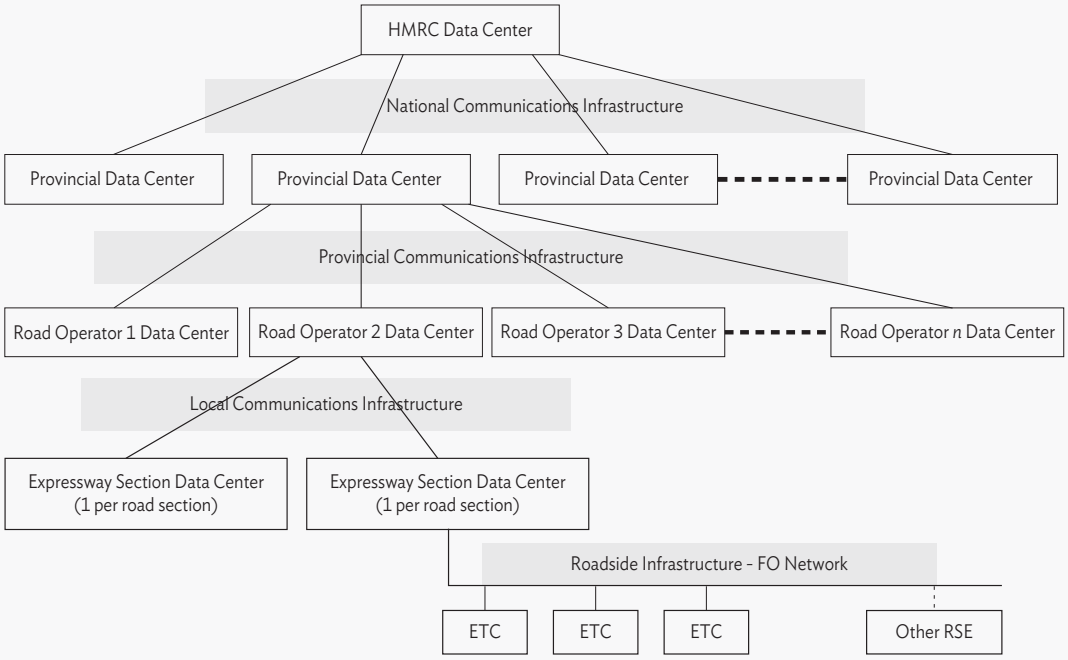
3.4.3 Fixed Line Communications

Fixed line communications are required:

- Between the cellular service provider and any infrastructure-based intelligence required for C-ITS. This is well established and need not be considered further.
- Between roadside beacons used in short-range V2I and infrastructure-based intelligence. This requires communications infrastructure to be installed on the road network.

The NTHS has a well-developed fixed communications infrastructure up to the provincial level. This is currently being upgraded to national level. The basic infrastructure is shown in Figure 17.

Figure 17: National Transport Communications Infrastructure



ETC = electronic toll collection, FO = fiber optic, HMRC = Highways Monitoring and Response Center, RSE = roadside equipment.
Sources: Transport Research Laboratory, United Kingdom and Research Institute of Highways, the People's Republic of China.

[7] A wireless technology standard for exchanging data over short distances from fixed and mobile devices, and building personal area networks.
[8] A specification for a suite of high-level communication protocols used to create personal area networks built from small, low-power digital radios.

Each expressway has a fiber-optic communications network laid along the road. The fiber-optic network is owned by the road operator, and this is used to provide high-speed data communications from the expressway data center to the roadside. Currently, it is being used to connect Electronic Toll System tolling infrastructure, but it has sufficient capacity to fulfill an extensively enhanced role, such as connecting other roadside equipment for incident detection, traffic management, etc. All roadside communications infrastructure are brought together in an expressway data center.

Other roadside equipment may include Manual Toll Collection systems, closed-circuit cameras, emergency telephones (every 500 meters on either side of expressways), etc.

For road operators who manage more than one expressway section (note that as national expressways can be very long and pass through multiple provinces, a single expressway may be divided into several sections, each managed by different operators), the various expressway data centers are connected to a single road operator data center, allowing them to manage all roads under their authority from a single location.

All road operators in a province are (or will in the future be) connected to a provincial data center (often called a transport telecommunications and information center, but names may vary), which is an administrative organization affiliated with the Provincial Department of Transport (the provincial-level transport administration under the Ministry of Transport). This allows the control center to monitor all NTHS roads in the province from a single location. Currently, less than 10 provinces have data centers, and the other provinces are just starting with construction. In the future, it is expected that every province in the PRC will have a data center, which includes not only expressway information but also other transport information (roads, waterways, railways, etc.).

There is an ongoing project to connect all provincial control centers to the national Highways Monitoring and Response Center. At the time of writing, 4 of the 31 existing and planned provincial control centers have been connected, with a fifth due to be completed this year. The ultimate aim of this project is to allow real-time monitoring of the entire NTHS from the Highway Monitoring and Response Center.

[4]

COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS STAKEHOLDERS FOR SERVICES IN THE PEOPLE'S REPUBLIC OF CHINA

4.1 Relevant Stakeholders in the People's Republic of China

In 2000, the People's Republic of China (PRC) started to realize the potential of Cooperative Intelligent Transport Systems (C-ITS), when the electronic toll collection (ETC), the first C-ITS, was being implemented widely. Like in other countries, the implementation of C-ITS in the PRC involves various stakeholders, each having special needs.

Digital mapping service providers want to use C-ITS for improved data collection (i.e., more wide-ranging data for all travel-related information) to provide complete travel-related information (both static and dynamic) to their customers.

Government transport agencies want to make use of good quality data in making decisions on traffic management and control, and emergency responses, as well as for future services such as planning new roads based on information from quality data.

C-ITS equipment suppliers or integrators claim that the information dissemination on expressways in the PRC is mainly based on traditional means such as signage, variable message sign, etc., and this remains to be the trend in the short term as there is still plenty of scope for safety and traffic improvement using more traditional means prior to C-ITS. In the longer term, they suggest that roadside and in-vehicle equipment should work together, but this is currently still at the research stage. Although there may only be a limited market for C-ITS, some major suppliers/integrators suggest the following services as potentially useful in the near future:

- Route guidance and hazard warning systems
- Driver/passenger safety information, including advanced warnings and weather information (vehicle-to-infrastructure communications [V2I])
- "Concierge" services such as nearest fuel station, etc.
- Automatic Crash Notification (ACN), which can be very useful in the PRC, particularly in more rural locations where accident sometimes go unreported.

Some Tier 1 suppliers to automotive manufacturers believe that car manufacturers will only be interested in what happens to the vehicle, and what promotes the end user experience. They feel that end users would be interested in some applications, like blind-spot detection and advanced driver assistance, but not the others.

They consider the ACN application interesting. Access control or area control for congestion mitigation would also be of particular interest. However, they believe that there are as yet no actual mature products available as vehicle-to-vehicle communications (V2V) services. Some suppliers propose that government should lead the promotion of safety-related C-ITS. They suggest that applications should be standardized but note that car manufacturers are currently developing bespoke applications with no standardization.

Logistics companies, which are one of the typical road users, show interest in real-time monitoring of the conditions of their drivers and vehicles such as fatigue, behavior, fuel consumption, etc. They also think that hazard warnings (e.g., accidents, congestion) and route guidance for drivers, in addition to full communication between drivers and their back office are useful. Logistics companies are willing to pay for such services providing they can find an acceptable balance between costs and reliability.

4.2 Collaborative Organizations

To help collaboration among different stakeholders in developing ITS, a number of organizations have been established in the PRC. Although few are dedicated to C-ITS, it is one of the topics under the broader concept of ITS for most organizations. Typical organizations are:

- ITS China, established by the Ministry of Science and Technology (MOST), Ministry of Public Security (MPS), Ministry of Housing and Urban–Rural Development (MOHURD), Ministry of Transport (MOT), Ministry of Railways (MOR), and Civil Aviation Administration of China (CAAC) in 2008. The government is one of many members, and plays a significant role (ITS China 2013).
- China ITS Industry Alliance, which is less official and has more than 100 members from institutes, universities, companies, etc. (China ITS Industry Alliance 2014).
- Telematics Industry Application Alliance, which was initiated by Chinese Electronics Standardization Association under the guidance of the Ministry of Industry and Information Technology (MIIT), MOT, Ministry of Health (MOH), and Standardization Administration of the People's Republic of China (SAC) in 2010; this is dedicated to promoting technical innovation and service applications in telematics and interconnecting vehicles (Telematics Industry Application Alliance 2014).

Nevertheless, of all the stakeholders, it is generally believed that government and the automobile industry play substantial roles in realizing C-ITS in the PRC.

Details concerning the key suppliers of C-ITS components are explored in the following sections.

4.3 Automotive Industry

The PRC is the largest automobile market in the world, accounting for just under a quarter of global sales in 2013—about 18 million passenger vehicles sold of a global total of 83 million in 2013. Sales are expected to grow to about 30 million vehicles by 2018.

The Chinese market has a large number of indigenous manufacturers, but sales are dominated by joint ventures between local and foreign companies. The top six passenger carmakers in 2013 were all joint ventures. These joint ventures can be quite complex with one manufacturer entering into joint ventures with multiple manufacturers—for example, Volkswagen Group has a joint venture with FAW (FAW Volkswagen) producing a number of Audi (A3, A4, A6, Q3, and Q5) and Volkswagen (Golf, Bora, and Sagitar) models, as well as a joint venture with Shanghai Automotive (Shanghai Volkswagen) producing a range of Volkswagen (Polo and Passat) and Skoda (Fabia, Octavia, Superb, and Yeti) models.

It is reasonable to expect that locally designed and produced vehicles will play an increasingly important role as the market expands and the local manufacturers' expertise and confidence improves.

After many years of slow growth of in-vehicle ITS, vehicle manufacturers are beginning to respond to consumer expectations for connected in-car services. According to Secured by Design, an automotive technology consultancy, there will be 28 original equipment manufacturers (OEM) offering services by the end of 2014.[9]

One of the challenges is having a fragmented market, with many suppliers in the value chain and few similarities in how services are implemented. Automotive manufacturers use different suppliers, service providers, and service architectures. Currently, companies are involved in multiple joint ventures, while at the same time producing indigenously designed and manufactured vehicles. This situation means that achieving standardization of interfaces within a company's various offerings is difficult, if not impossible.

If we look for example at SAIC Motor, they produce their own Maxus, Roewe, and MG vehicles, while at the same time being part of joint ventures with VAG, GM, and Iveco. SAIC has its own proprietary in-vehicle ITS systems (InkaNet and Ovoka), but these are only available in SAIC-branded vehicles. The ITS systems available in joint venture vehicles will, in many cases, be those of the foreign partner.

A further potential issue with achieving standardization of ITS interfaces for safety applications is that the market for ITS currently concentrates on infotainment applications. Some OEMs feel that there is little perceived market advantage to safety-related ITS applications; other market surveys suggest this is increasingly important to consumers.[10] Nevertheless, some "push" from government could help increase focus on safety-related applications, particularly where there is no consumer awareness.

With regard to support for communications technologies, the automobile industry is largely technology agnostic on the issue of cellular vs. short-range dedicated short-range communications (DSRC). However, the fact that cellular coverage is largely ubiquitous means that there is a perceived advantage in using cellular on the basis that it already exists.

On the subject of V2V, the industry seems to be taking a "wait-and-see" approach, which means that there may be a window of opportunity to influence the industry towards common goals and standards.

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9 SBD. 2016. Telematics Update China presentation. Prezi. http://prezi.com/j2qgvuomywcq/telematics-update-china-presentation/ (accessed 11 August 2015).

10 *eMarketer.* 2014. Connected Cars Grab Auto Shoppers' Attention. http://www.emarketer.com/Article/Connected-Cars-Grab-Auto-Shoppers-Attention/1010880

4.4 Digital Mapping

All geo-information used to be owned by the government. In 1998, a license system was introduced by the government's National Administration of Surveying, Mapping and Geo-information to stimulate the market. Companies need to have a license to develop digital mapping data and these are free, issued on proof of technical capability. Data can then be owned by the licensee. There are three license classes: A, B, and C. Twelve enterprises hold class A licenses.

Local authorities are required to report the construction of new roads, although this is not entirely reliable. These reports are then used by mapping companies to add new roads to geodatabases. In addition, mapping companies use their own techniques (dedicated data gathering teams, customer-derived floating vehicle data, etc.).

The PRC's technical committee TC/204 is responsible for the coordination of standards. For mapping there are only general specifications which are not very specific, each company chooses its own standard. Typically, companies will provide maps in formats as required by their customers, for example, International Organization for Standardization (ISO) geographic data files or navigation data standard.

4.5 Cellular Services

There are three major telecom service providers in the PRC: China Telecom, China Unicom, and China Mobile. China Mobile has been constructing the largest 4G network based on time-division long-term evolution (TD-LTE) since the beginning of 2013. By the end of 2013, this network had coverage for 100 major cities, over a million terminals, and 200,000 base stations. China Mobile requires the future 4G chipset to support five modes and 10 bands. This is to ensure devices with such chips can roam among different networks and countries.

China Unicom prefers to use only frequency division duplex (FDD)-LTE in the future, and currently is still focusing on promoting its 3G network. In the future, its 4G network will be upgraded from its legacy 3G network.

China Telecom maintains a neutral position as the upgrade to 4G using either mode is difficult for them. If they are issued with an FDD-LTE license in the future, they will be more willing to use FDD-LTE. If not, they will consider collaboration with China Mobile or other service providers using TD-LTE to construct their 4G network.

Although there is a lack of accurate data, it is generally believed that data rate and coverage are not uniform but fairly good in urban areas; and that the coverage on the National Trunk Highway System (NTHS) is good. Data rate performance can be affected by user speed. Coverage on the NTHS is mainly 2G, whereas 3G coverage on the NTHS is not so good.

It can be noted that data is increasing in proportion to communications traffic. Although all three providers have their own fairly static user base (there is a low "churn" rate—low percentage of subscribers that discontinue subscription to cellular services—in the industry), all are interested in increasing market share and channel usage. They all offer a range of packages for their services, including both voice and data.

4.6 Road Infrastructure and Procurement

As for road infrastructure for implementing C-ITS in the PRC, there is currently only some traffic data collected using inductive loops in the road. However, this is not widely implemented due to high costs. It was suggested by several stakeholders that a business model based on loops does not work, and that new business models are needed.

At present, there is no clear consensus on which communications technology will eventually be used for V2I. No DSRC protocols are specified, and no spectrum is specifically allocated for ITS (although 5.8 gigahertz [GHz] is used for ETC). The specification of DSRC protocols and spectrum allocation are more likely to be driven by industry. However, it is generally believed (by the industry and other stakeholders consulted for this project) that the government is likely to favor the use of existing cellular systems rather than build new infrastructure such as beacons, considering a balance between cost and other factors. Some stakeholders expressed preference for cellular over DSRC, and floating vehicles over loops, which can both significantly lower costs without losing too much usability.

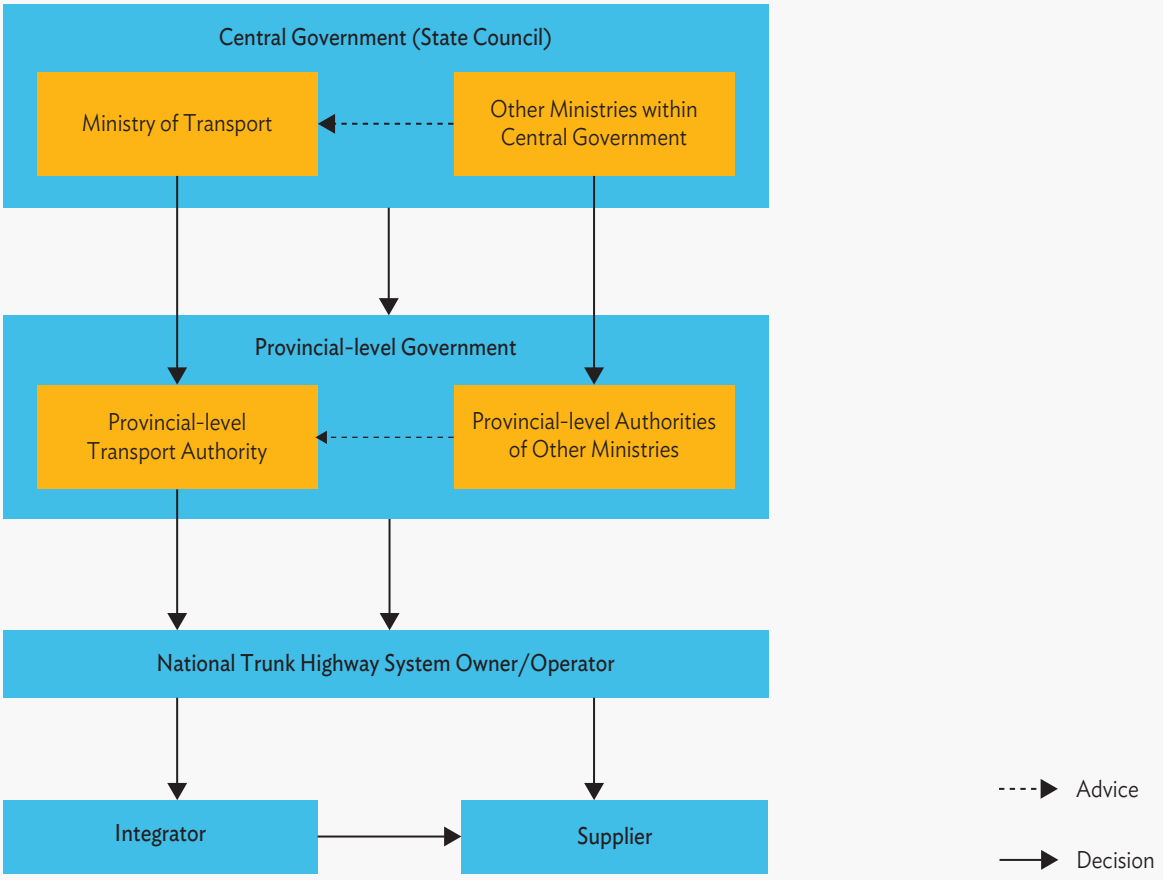
The process for the procurement of new equipment and control systems on the NTHS is summarized in Figure 18.

In each phase of the NTHS, the parties who make decisions on ITS equipment procurement are different. As for the construction phase, the owner makes this decision while in the operation phase the operator does. The owner and the operator can be two different parties.

- From the owner or operator downward, an appropriate integrator is selected, which in turn selects the supplier(s), or they directly select certain suppliers for the procurement, usually through bidding.
- From the owner or operator upwards, as most owners or operators of the NTHS are state owned or affiliated, when necessary, they must report to the related authorities above them to get approval for the procurement.
- If the owner or operator is owned or affiliated by a provincial-level transport authority, this provincial-level transport authority approves the proposal, if necessary, and the provincial-level government in the same province (or municipalities directly under the central government such as Chongqing, Beijing, Tianjin, and Shanghai; or autonomous regions such as Inner Mongolia, etc.) acts in an advisory role.
- If the owner or operator is owned directly by a provincial-level government, this provincial-level government approves the proposal, if necessary, and the provincial-level transport authority in the same province acts as an advisory role.
- A request for approval depends on how important a project is. The request can go up to the central government (i.e., the state council), if necessary.
- Other ministries such as the MPS, Ministry of Industry and Information Technology, within the central government as well as their provincial-level counterparts act in advisory roles in accordance with administrative levels, if necessary.

In summary, most of the owners or operators of a section of the NTHS in the PRC are either owned or affiliated with the government, and hence the government has a very strong influence on procurement decisions.

Figure 18: Decision Process for Procurement on the National Trunk Highway System in the People's Republic of China



Source: Research Institute of Highways, the People's Republic of China.

Industry stakeholders are ready to develop additional ITS services, if suitable business models could be found. The strong influence of the government in procurement decisions for ITS is an opportunity for stimulating the demand for development and use of C-ITS services. Market solutions should be encouraged for C-ITS services, and the government should take the lead in helping establish and stimulate the market. To increase market demand, the government can promote the benefits of using new systems and services. Developing suitable C-ITS standards with industry stakeholders' participation is also important. Government incentives are also important to encourage the development and use of C-ITS services. C-ITS market development should be supported by identifying evidence on impacts, surveys, marketing, business case development, partnering, and financing.

[5]

COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS OPERATIONS

5.1 Introduction

This chapter discusses important operational issues that need to be considered in more detail during Cooperative Intelligent Transport Systems (C-ITS) deployment. For the short-listed applications identified in this report, their operational requirements are outlined in terms of system security and integrity, reliability, and other aspects of performance.

Also included in this chapter is an initial exploration of data control and data management issues, identifying some important legal issues that would need more attention during actual deployment of C-ITS.

5.2 System Security and Integrity

The People's Republic of China (PRC) has been increasingly strengthening its information security since 1994, when the Computer Information Systems Security Protection Regulations in the PRC, the first national act relating to information security, took effect (Fan 2008). After that, a series of acts, regulations, guidelines, and standards have been devised to respond to the fast-growing information technologies and increasing dependencies on information systems. In 2012, the state council released sweeping new information security guidelines (The Central People's Government of the People's Republic of China 2012) designed to enable public and private bodies to protect themselves more effectively against new cyber threats. The state council's long list of recommendations cover almost every conceivable aspect of information security.

In February 2014, the Central Network Security and Information Technology Leadership Team (CNSITLT), a national level information security management administration, was established. The CNSITLT is directly led by President Xi Jinping and is in charge of overall information security in the PRC. The CNSITLT called for more independent innovation in core technology and the construction of infrastructure, and enhanced abilities to collect, process, spread, utilize, and secure information to better benefit the livelihood of the general public. There is a trend that the PRC is more likely to procure core infrastructure from local suppliers.

Information security in the transport sector is one of the core themes of the national information security strategy and is principally managed by the Ministry of Transport (MOT), in collaboration with the Ministry of Public Safety (MPS), and the Ministry of Industry and Information Technology. The Research Institute of Highways has been working closely with the MOT to develop a strategic plan for information security management in the transport industry.

The MOT's goal of information security management is "to achieve full and dynamic security for all elements and all phases in a life cycle of every important information system" (MOT 2013). The MOT published the strategic plan for information security management in 2013, which defined the extent of important information systems, and provided guidelines for major activities of local governments, information systems designers, developers, and suppliers, etc.

The MOT has been working on developing detailed information security management regulations under the national information management framework. At the same time, when there is a lack of regulations in the transport industry, the MOT directs information systems participants to refer to existing national guidelines and regulations when conducting activities. Activities related to information systems and security, such as design, development, and procurement of information systems, must meet a series of national standards, which are developed and maintained by the National Technical Committee 260 on Information Security of the Standardization Administration of the People's Republic of China (SAC/TC260). Details of the working groups and the architecture of the information security standards in the PRC are summarized in Appendix F.5.

Table 5 provides an indication of the importance of data security to those C-ITS services which are believed to be relevant to the National Trunk Highway System (NTHS) in the PRC.

Table 5: The Importance of Security to the Chosen Cooperative Intelligent Transport Systems Services

Service	Level of Importance of Security
Hazard Warning	Medium to low: In the short term people are not so dependent on such systems; but people may rely on such systems in the long term and any malfunction or false indication resulting from security failure could result in false anticipation or inappropriate driving behavior, which may result in accidents.
Enhanced Driver Awareness: IVS/ISA	Low: The importance of security increases when such systems are more intervening or mandatory, as in such cases drivers are likely to be dependent on systems.
Automatic Crash Notification	Medium to high: This is a safety of life application but other means could be available when such systems fail.
Floating Vehicle Data	Medium: There are individual privacy issues. Data fusion from other sources of data could mitigate some bias when FVD fails.
Dynamic Route Guidance	Low for individuals High for service providers because it could affect large numbers of vehicles, and therefore traffic efficiency.
Dynamic Traffic Management (DTM)	High: DTM could be relied on to control critical arteries or large areas; a security breach could result in a severe threat to traffic efficiency.

ISA = intelligent speed adaptation, IVS = in-vehicle signage.

Source: Transport Research Laboratory and Research Institute of Highways, the People's Republic of China.

5.3 Reliability and Performance

Table 6 provides an indication of the importance of reliability and performance to those C-ITS services which are believed to be relevant to the NTHS in the PRC.

Table 6: Cooperative Intelligent Transport Systems Services and Level of Importance of Performance Indicators

Service	Level of Importance of Reliability	Level of Importance of Other Aspects of Performance
Hazard Warning	Medium (advice only, but it is a safety application). Unreliable systems cannot attract drivers or may mislead them to have false anticipation or driving behavior, resulting in potential risk.	Medium location accuracy Latency is very critical, especially when vehicles are travelling at high speeds.
Enhanced Driver Awareness: IVS/ISA	Medium: Advisory or supportive systems only act as supplementary methods for drivers to make decisions; intervening or mandatory systems should have higher reliability.	High Location Accuracy Latency is very critical, especially when vehicles are travelling at high speeds.
Automatic Crash Notification	Medium to high: It is a safety of life application but other means could be available when such systems fail.	High: Location accuracy and latency are both crucial as emergency responses rely on accurate information.
Floating Vehicle Data (FVD)	Medium to low: Statistics of large numbers means that individual failures will not greatly affect the outcome. Data fusion from other source of data could mitigate some bias when FVD fails.	Medium: Fidelity (outliers can be pruned). Penetration is crucial, or at least an accurate knowledge of what proportion of vehicles are reporting their presence, when roads are more congested.
Dynamic Route Guidance	Medium at an individual level: Unreliable services cannot attract drivers. High for service providers: because it could affect large numbers of drivers.	Medium location accuracy
Dynamic Traffic Management	High: as it is a safety of life and traffic application. Such systems could be used to control critical infrastructure.	Latency should be kept to minimal (a few seconds).

ISA = intelligent speed adaptation, IVS = in-vehicle signage.

Source: Transport Research Laboratory, and Research Institute of Highways, the People's Republic of China.

5.4 Legal and Regulatory Issues

5.4.1 Road Safety

In the PRC, the legislation usually falls behind the fast-growing transport industry. While the fatality rate had been high for a long time, the first road traffic law in the PRC came into effect in October 2003. There are some other regulations on road transport safety such as Regulations on the Implementation of the Road Traffic Safety Law of the People's Republic of China (State Council Mandate 405), Regulations on Road Transport, and Regulations on the Management of Dangerous Goods Transport. However, most of these laws and regulations are not well enforced. A large portion of accidents recorded were the results of violation of laws and regulations.

5.4.2 Information Systems and Security

In the field of computers, communications, control, electronics and mechanical engineering, and security, the PRC has complied with most international standards. In the PRC, there are special regulations for the design, implementation, and procurement of information systems in sensitive civil industries such as transport, electrical power, telecommunications, etc. SAC/TC260 is responsible for the development and revision of the information security standards in the PRC. For most civil information systems such as C-ITS, a mechanism called "information security classified protection," which includes a number of standards and regulations have to be followed. In keeping with this mechanism, information systems are evaluated and classified into five different levels according to importance and potential risk once their security properties are damaged. Systems are then required to reach at least the baseline of their security levels. Dynamic and persistent improvements in system security, according to their ever changing environment, are also frequently required. Along with a number of national and regional supporting teams, the MPS is responsible for the enforcement of such mechanisms nationwide.

5.4.3 Data Control and Data Management

Data are typically generated from roadside infrastructure such as electronic toll collection (ETC), cameras or other sensors on the NTHS. Usually, these data are transmitted through a continuously developing fixed communications infrastructure, as discussed in section 3.4.3, to the expressway section data center, road operator data center, provincial data center and then finally to the Highways Monitoring and Response Center (HMRC) data center. Each data center level can store its own data to some extent, and then all data are compiled in the HMRC data center. Such data are mainly controlled by different levels of transport administrations or expressway operators which are owned or affiliated to those administrations. The government has been increasingly paying attention to the importance of such data. Although there is increasing encouragement to open these data to the public, they are currently used primarily within the government agencies.

In addition, on some sections of the NTHS near cities, floating vehicle data (FVD) are also collected, mainly by taxi companies or commercial fleet operators, who have strong relationships to local government and therefore share data with government.

5.4.4 Frequency Allocation in the People's Republic of China

Frequency allocation in the PRC is governed by the Radio Management Committee of the Ministry of Industry and Information Technology. SAC/TC268 has raised suggestions to the Radio Management Committee to allocate the 5.8 gigahertz (GHz) frequency for ITS, based on three considerations: (i) the standard architecture and spectrum allocation patterns of the radio communications in the PRC are similar to the ones in Europe (both sides use 900 megahertz [MHz] for mobile communication, 2.45 GHz for medical equipment and home appliances and 5.8 GHz for satellite communications, industry, military, research, and spread spectrum communications); (ii) the background noise of the 5.8 GHz is low and it is easier to solve its interference problems than those of 915 MHz and 2.45 GHz; (iii) there are more equipment suppliers for 5.8 GHz.

The latest regulations, which have been effective since July 2002, are that the 5.725 GHz–5.850 GHz band are shared by high speed wireless local area network (LAN), broadband wireless access systems, Bluetooth equipment, and vehicle wireless identification related applications such as the ETC. If a provincial department of transport wants to use 5.8 GHz for ITS applications, it must report to the corresponding provincial radio management agency for approval and pay the spectrum occupation fee.

In summary, there is currently no spectrum dedicated to ITS, but 30 MHz at 5.8 GHz is widely used for ETC. ITS-specific spectrum is currently being discussed, but without a timetable. This will be industry driven, rather than government driven.

5.4.5 International Conventions in the People's Republic of China

To date, the PRC is not a signatory country to the following conventions:

- Vienna Convention on Road Traffic
- Geneva Convention on Road Traffic
- Vienna Convention on Road Signs and Signals
- Convention on International Transport of Goods Under Cover of TIR (Transports Internationaux Routiers [International Road Transport]) Carnets.

[6]

CONCLUSIONS AND RECOMMENDATIONS

This chapter provides an overview and brief commentary with conclusions on the most important findings arising from desk analysis, technical visits, and stakeholder discussions.

Recommendations arising from these conclusions are also presented, based on the status overview and discussion, identifying the most relevant ministries, and proposing methods by which the recommendations could be implemented by first suggesting a list of possible next steps.

6.1 Improving Safety on the National Trunk Highway System

Cooperative Intelligent Transport Systems (C-ITS) certainly has a role in improving safety on the National Trunk Highway System (NTHS), but it cannot be expected to provide an efficient and effective means of addressing all identified safety issues. Through suitable planning and coordination, it should be possible to pursue selected C-ITS developments parallel with conventional safety measures and other ITS developments.

Based on the analysis of combined accident data on expressways and the NTHS, some key factors which could be addressed by C-ITS aimed at improving safety on the NTHS are identified. These are driver behavior, weather, road surface conditions, and highway network conditions. C-ITS applications identified and relevant for the NTHS are grouped into the following applications:

- Cooperative Hazard Warnings
- Enhanced Driver Awareness and Control
- Automatic Crash Notification (ACN)
- Controlling congestion and maximizing efficient use of the road network
- Tracking and tracing of dangerous/valuable goods
- Floating Vehicle Data (FVD)

Nevertheless, accident data collection, storage, and analysis could be improved to support current and future evidence based policy making. It is recommended that the People's Republic of China (PRC) develop a national electronic collection storage and analysis system for road accident data.

Conventional traffic safety engineering should also be undertaken on the NTHS in parallel with C-ITS development. Conventional traffic safety engineering measures expected to be beneficial include:

- separation of pedestrians from motorized traffic on the NTHS
- better control of overladen vehicles
- measures to promote compliance with speed limits
- measures to reduce driver distraction caused by in-vehicle devices (particularly handheld phones).

6.2 Existing National Trunk Highway System Infrastructure

Electronic Toll Collection (ETC) is one C-ITS service already widely deployed on the NTHS. The wireless communication path for ETC requires strong authentication and security because of the financial transactions involved, and this can be achieved with short-range dedicated communication links. Sharing of these links by other C-ITS services is not considered feasible because of:

- Possible compromises to ETC transaction security
- Limited message size capability
- Communication only at very specific ETC charge points

Therefore, ETC does not provide a suitable basis for more general C-ITS but will continue to exist as a stand-alone service. However, the NTHS is equipped with a fiber-optic backbone and virtually complete cellular network coverage. The national communications architecture links toll stations to data centers (typically one per NTHS road operator) and from data centers to the provincial traffic center. These existing communications architecture are necessary for further development and deployment of other C-ITS services in the NTHS.

6.3 Pioneer Cooperative Intelligent Transport Systems Services and Communications Options

It should be noted that there are already a number of services which can be called C-ITS in the PRC. These are truck tracking, ETC, and FVD collection in urban areas.

A structured process has been adopted which has identified the C-ITS services likely to be most readily deployable and which will provide safety benefits on the NTHS. With suitable leadership and initial support, it should be possible to develop sustainable business models to provide the following C-ITS services:

- Dynamic Route Guidance
- In-vehicle signage including speed limits
- Hazard Warning Ahead
- More floating data vehicles—supporting many other ITS services

FVD is expected to improve information about real-time traffic flows on the NTHS and therefore has potential to improve traffic management. Aside from advising drivers of upcoming hazards by in-vehicle displays and on variable message signs (VMS), real-time information can also be used to drive dynamic traffic management strategies such as reducing speed limits during high traffic demands to help smoothen traffic flow. Road operators may need to be encouraged to make best use of these new information sources.

ACN is also expected to provide substantial safety benefits both for passenger cars and heavy trucks. There are also various possible deployment scenarios including mandatory fitment like those in Europe. Given the expected benefits of ACN, the complexities of deployment, a pilot trial would be a good way to explore options and decide on the most suitable deployment route.

The communications network is critical in the development of C-ITS services. Cooperative systems require data communications between vehicles (V2V) or between vehicles and infrastructure (V2I). The actual communications protocol falls into the cellular networks, which are suitable for V2I communications, and the wireless local area networks, which can be used for V2I and V2V communications. There are time-critical services (such as collision warning or mitigation) where the latency of cellular communications would be insufficient, and roadside beacon density would be insufficient. For such services there are two options, (i) the use of V2V communications between the vehicles involved in the maneuver, and (ii) the use of on-board sensors.

The use of on-board sensors can be a robust solution in a situation where other vehicles are not equipped with V2V services. Thus, the case for V2V is weakened by the "rollout" issue: autonomous sensing provides immediate and progressively increasing benefits as vehicles are equipped, whereas V2V does not provide benefits until most vehicles are equipped. Although eventually it might be a cheaper solution, the case for deployment of on-board sensors is difficult to make.

Discussions with industry representatives reveal that they need to see a business case before investing in any new NTHS installations or new services. It can be concluded that car manufacturers will not build a beacon-based short-range network on the NTHS for economic reasons. Independently, they are interested in V2V services, but this is not an area where there is any need for infrastructure interaction.

6.4 Stakeholders and Business Models

Based on stakeholder discussions, it appears that the government and the automobile industry, can be identified as the key stakeholders to realize deployment of C-ITS. The government should spearhead the update and dissemination of state-of-the-art national ITS architecture and deployment plan for all stakeholders to accelerate the deployment of C-ITS.

Industry stakeholders are ready to develop more ITS services if suitable business models could be found. Business models require customers who want the services, and a value chain capable of delivering those services (such that the chain supports all the participants) and in a way that provides affordable services. Similarly, there is increasing interest in integrating smartphones within the vehicle ecosystem although, again, there are many approaches and options. The automotive industry is not able to finance the installation of beacons providing a dedicated communication channel to vehicles. Consequently, they are pragmatically basing V2I services on cellular communications. The PRC's three main cellular communications providers are ready to support the automobile industry and their customers with cellular communications services.

Industry stakeholders have indicated that they are looking at government to take the lead in establishing a market for V2I and V2V services. They are not anticipating direct or continued government funding for C-ITS, but see the government role as stimulating market demand with a need to identify solutions that can become self-funded and sustainable in the longer term.

Several approaches to stimulate C-ITS deployment are available to the government. Typically, the government sponsors research, trials, pilot projects, and similarly undertakes work on standards and specific "Grand Challenges" such as autonomous vehicles. The insurance industry could also have a role in deployment, as technology can reduce accident risk and/or monitor higher risk drivers. All existing routes appear to be suitable for stimulating deployment of C-ITS. Market solutions should be encouraged for C-ITS such as FVD collection, Dynamic Route Guidance, In-Vehicle Signage, and Hazard Warning Ahead.

6.5 Skills and Experience for Cooperative Intelligent Transport Systems Deployment

The PRC has suitable arrangements for higher education and university academic teaching, including postdoctoral research. Technical visits and discussions with various stakeholders have also provided evidence for high-level skills and capabilities within the industry. Nevertheless, ITS is a rapidly developing area which calls for continuous professional development (CPD) and it appears that professional registration, such as through engineering institutions, is not as developed as in Europe and the United States. For instance, professional registration and ongoing formal skills development do not seem to be sufficiently financially supported by industry. Therefore, without any deficiency in educational or skill capacity, which would be an impediment to deployment of C-ITS, additional attention on professional registration and CPD would support future growth.

An international literature review has shown that several countries and regions are currently advancing rapidly in terms of readiness for, and deployment of, C-ITS and other ITS building blocks. For instance, the US is preparing legislation to mandate connected cars, the European Union (EU) is introducing eCall, and Japan has a national beacon-based infrastructure for C-ITS. There are also many international research studies, pilot trials, and international standards being developed. The EU/US/JP Task Force on connected vehicles is a forum for exchange of information and experience.

The international review also shows that there is currently no single deployment model, this presents an opportunity to learn from the different international approaches and be able to contribute. The PRC should consider joining the EU/US/JP Cooperative Systems International Task Force for collaboration and exchange of information.

6.6 Longer-Term Cooperative Intelligent Transport Systems Developments

Given the rapid technology development within the ITS area and the field of consumer electronics, there are challenges in predicting future capabilities and the timetable for deployment of different services. While the pioneer services have already been identified, other services may become much more attractive in a shorter period than initially thought, and it would seem prudent to continue research and monitoring of development in all prospective C-ITS areas.

APPENDIXES

A APPLICATIONS

B COSTS AND BENEFITS OF COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS REPORTED IN THE LITERATURE

C SUPPORTING ROAD SAFETY IMPROVEMENTS WITH ACCIDENT DATA

D APPLICATION EVALUATION

E OVERVIEW OF CURRENT INTELLIGENT TRANSPORT SYSTEMS ARCHITECTURE IN THE PEOPLE'S REPUBLIC OF CHINA

F COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS STANDARDIZATION

APPENDIX A
APPLICATIONS

The list of applications considered for this project were drawn from a number of sources, including the experience of the project team.

The principal "lists" of applications are the European Telecommunications Standards Institute (ETSI) "Basic Set of Applications" and the Connected Vehicle Reference Implementation Architecture (CVRIA), led by the United States Intelligent Transport Systems Joint Program Office and currently hosted on the ITERIS website.[1]

A.1 European Telecommunications Standards Institute

The ETSI has identified a "Basic Set of Applications" (ETSI 2009) which require the use of communications for both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I). These are listed in Table A1.

Table A1: European Telecommunications Standards Institute Basic Set of Applications

Applications Class	Application Group	Use Case (Application)
Active road safety	Driving assistance–Cooperative awareness	Emergency vehicle warning
		Slow vehicle indication
		Intersection collision warning
		Motorcycle approaching indication
	Driving assistance–Road Hazard Warning	Emergency electronic brake lights
		Wrong way driving warning
		Stationary vehicle–accident
		Stationary vehicle–vehicle problem
		Traffic condition warning
		Signal violation warning
		Roadwork warning
		Collision risk warning
		Decentralized floating car data–Hazardous location
		Decentralized floating car data–Precipitations
		Decentralized floating car data–Road adhesion
		Decentralized floating car data–Visibility
		Decentralized floating car data–Wind

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[1] Connected Vehicle Reference Implementation Architecture. http://www.iteris.com/cvria/ (accessed 12 May 2014).

Table A1: ***continued***

Applications Class	Application Group	Use Case (Application)
Cooperative traffic efficiency	Speed management	Regulatory or contextual speed limits notification
		Traffic light optimal speed advisory
	Cooperative navigation	Traffic information and recommended itinerary
		Enhanced route guidance and navigation
		Limited access warning and detour notification
		In-vehicle signage
Cooperative local services	Location based services	Point of Interest notification
		Automatic access control and parking management
		ITS local electronic commerce
		Media downloading
Global internet services	Communities services	Insurance and financial services
		Fleet management
		Loading zone management
	ITS station life cycle management	Vehicle software or data provisioning and update
		Vehicle and RSU data calibration

ITS = intelligent transport systems, RSU = road side unit.

Source: European Telecommunications Standards Institute. 2009. *ETSI TR 102 638 V1.1.1: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Definitions.*

The first application class "Active road safety" is of most interest to this project, although the second "Cooperative traffic efficiency" can also contribute to improved road safety.

A.2 Connected Vehicle Reference Implementation Architecture

The CVRIA describes a reference architecture for connected vehicles. Part of the initiative has been to identify applications which require the vehicle to be connected. The complete list is shown in Table A2.

Table A2: Connected Vehicle Reference Implementation Architecture Applications

Type	Group	Application Name
Environmental	AERIS[a] or Sustainable Travel	Connected Eco-Driving
		Dynamic Eco-Routing
		Eco-Approach and Departure at Signalized Intersections
		Eco-Cooperative Adaptive Cruise Control
		Eco-Integrated Corridor Management Decision Support System
		Eco-Lanes Management
		Eco-Multimodal Real-Time Traveller Information
		Eco-Ramp Metering
		Eco-Smart Parking

continued next page

Table A2: ***continued***

Type	Group	Application Name
Environmental	AERIS[a] or Sustainable Travel	Eco-Speed Harmonization
		Eco-Traffic Signal Timing
		Eco-Transit Signal Priority
		Electric Charging Stations Management
		Low Emissions Zone Management
		Roadside Lighting
Environmental	Road Weather	Enhanced Maintenance Decision Support System
		Road Weather Advisories and Warnings for Motorists
		Road Weather Information and Routing Support for Emergency Responders
		Road Weather Information for Freight Carriers
		Road Weather Information for Maintenance and Fleet Management System
		Variable Speed Limits for Weather-Responsive Traffic Management
Mobility	Border	Border Management Systems
	Commercial Vehicle Fleet Operations	Container Security
		Container or Chassis Operating Data
	Commercial Vehicle Roadside Operations	Smart Roadside Initiative
	Freight Advanced Traveller Information Systems	Freight Drayage Optimization
		Freight-Specific Dynamic Travel Planning
	Miscellaneous	Ad Hoc Messages
	Planning and Performance Monitoring	Performance Monitoring and Planning
	Public Safety	Advanced Automatic Crash Notification Relay
		Emergency Communications and Evacuation
		Incident Scene Pre-Arrival Staging Guidance for Emergency Responders
		Incident Scene Work Zone Alerts for Drivers and Workers
	Traffic Network	Cooperative Adaptive Cruise Control
		Queue Warning
		Speed Harmonization
		Vehicle Data for Traffic Operations
	Traffic Signals	Emergency Vehicle Priority
		Freight Signal Priority
		Intelligent Traffic Signal System
		Pedestrian Mobility
		Transit Signal Priority
Mobility	Transit	Dynamic Ridesharing
		Dynamic Transit Operations
		Integrated Multi-Modal Electronic Payment
		Intermittent Bus Lanes
		Route Identification for the Visually Impaired
		Smart Park and Ride System
		Transit Connection Protection
		Transit Stop Request

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Table A2: ***continued***

Type	Group	Application Name
Mobility	Traveller Information	Advanced Traveller Information Systems
		Receive Parking Space Availability and Service Information
		Traveller Information–Smart Parking
Safety	Transit Safety	Transit Pedestrian Indication
		Transit Vehicle at Station or Stop Warnings
		Vehicle Turning Right in Front of a Transit Vehicle
	V2I Safety	Curve Speed Warning
		Oversize Vehicle Warning
		Pedestrian in Signalized Crosswalk Warning
		Railroad Crossing Warning
		Red Light Violation Warning
		Reduced Speed Zone Warning
		Restricted Lane Warnings
		Spot Weather Impact Warning
		Stop Sign Gap Assist
		Stop Sign Violation Warning
		Warnings about Hazards in a Work Zone
		Warnings about Upcoming Work Zone
	V2V Safety	Blind Spot Warning + Lane Change Warning
		Control Loss Warning
		Do Not Pass Warning
		Emergency Electronic Brake Light
		Emergency Vehicle Alert
		Forward Collision Warning
		Intersection Movement Assist
		Pre-accident Actions
		Situational Awareness
		Tailgating Advisory
		Vehicle Emergency Response
Support	Communications	Communications Support
	Core Services	Core Authorization
		Data Distribution
		Infrastructure Management
	Security	Security and Credentials Management
	Signal Phase and Timing	Signal Phase and Timing

[a] AERIS refers to "Connected Vehicle Applications for the Environment: Real-Time Information Synthesis" — See more at: http://www.pcb.its.dot.gov/AERIS/intro.asp#sthash.q1HCfZp9.dpuf

Source: CVRIA 2014.

The applications of most interest for this project are those in the "Safety" type, but applications in other groups need to be considered as some also have safety benefits even if this is not their primary objective, e.g., "Queue Warning." In addition, some of the applications in the "Support" group are required for the realization of any cooperative applications, e.g., "Communications Support."

A.3 EasyWay

The EasyWay project has identified cooperative applications (Kulmala et al. 2012), and prioritized these to identify which are most appropriate for the European road environment. The initial identification of applications yielded those in Table A3.

Table A3: EasyWay Applications

Safety Applications	
Emergency vehicle warning	Warns drivers to yield right of way to an approaching emergency vehicle.
Overtaking vehicle warning	An overtaking (passing) vehicle signals its action to the vehicle being overtaken to secure the situation.
Lane change assistant	Provides information about cars on neighboring lanes when the driver intends to make a lane change.
Cooperative merging assistance	Vehicles negotiate the merging process with each other and give advice to the driver.
Cooperative glare reduction	Enables automatic switching of headlights (high-beam to low-beam) of the vehicle when it approaches an oncoming vehicle
Intersection collision warning	Crossing vehicle collision warning Informs or warns driver in case of potential collision with crossing vehicles. Left (right) turn collision warning Informs or warns driver in case of potential collision with oncoming vehicles.
Signal or Sign violation warning	Red traffic light violation warning Warns drivers when they are going to violate a red traffic light signal Stop sign violation warning Warns drivers when they are going to violate a stop sign rule Speed limit violation warning Warns drivers when they are going to violate a speed limit indication
Emergency electronic brake light	Warns drivers before driving into a (suddenly) hard braking vehicle.
Wrong way driving warning	Detects wrong way driving vehicles and warn affected, endangered drivers.
Pre-accident sensing	Prepares for imminent and unavoidable collisions by exchanging vehicle attributes after a non-avoidable accident is detected.
Cooperative flexible lane change	Considers the flexible allocation of a dedicated lane (e.g., reserved to public transport) to some vehicles, which get a permanent or temporary access right.
Cooperative forward collision warning	Warns drivers when collisions (rear-end collisions, etc.) might happen.
Hazardous location notification	Warns drivers against upcoming bad weather road conditions (slippery road, fog, rain, etc.)
Car breakdown warning	Warns drivers when approaching a breakdown car either by the stranded car itself or by a following car that detects a disabled vehicle (e.g., detecting zero velocity).
Traffic jam ahead warning	Warns drivers when approaching the tail end of a traffic jam.
Slow vehicle warning	Warns drivers to prevent rear-end collisions to slow moving vehicles.
Road works warning	Informs drivers of ongoing road works and associated obstruction of road traffic in the vicinity.
Post-accident warning	Warns drivers when approaching a crashed car either by the crashed car itself or by a following car that detects a crashed vehicle warning ahead.
Curve speed warning	Based on received curve information the safe speed is calculated for the vehicle entering the curve and the driver will be warned if current speed is higher than safe speed.
Obstacle on driving surface warning	Warns drivers to prevent collisions with stationary or moving obstacles in the carriageway
Vulnerable road user warning	Provides warning to driver of the presence of vulnerable road users, e.g., motorcycles in case of dangerous situations.

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Table A3: ***continued***

Traffic Efficiency Applications	
Decentralized floating car data	Informs the driver with advice about the conditions along his further route.
Green light optimal speed advisory	Drivers receive a recommendation in order to hit the next traffic lights in green phase and to avoid waste acceleration.
Traffic information and recommended itinerary	Recommends a route for the vehicle navigation system to direct the driver around congested locations and to distribute the traffic load on alternative routes. A special use case is the guidance to a parking place, which helps to avoid unnecessary drives searching for a free slot.
Enhanced route guidance	Exploits traffic information provided by a public traffic monitoring authority to empower a better navigation.
Traffic light optimization	The intersection controller optimizes the traffic light phases based on the information from the vehicles at the intersection in order to reduce the overall waiting time for the vehicles
Limited access warning	Controls the entrance to an area or road segment where some or most vehicles have limited access. An ITS Roadside Station at the entrance announces its presence and approaching vehicles may validate themselves to seek access.
In-vehicle signage	Informs the driver about effective speed limits along the road including special or contextual variations. Speed recommendations are also included.
Cooperative flexible lane allocation	Considers the flexible allocation of a dedicated lane (e.g., reserved to public transport) to some vehicles, which get a permanent or temporary access right.
Adaptive power train management	Infrastructure informs about road structure ahead (such as slope, curve) and possible dynamic road traffic information (for example, queue warning). The vehicle uses the information to prepare and optimize the power train performance (shift, throttle, brakes...).
Cooperative adaptive cruise control and cooperative vehicle highway automation system	Automated positional and velocity control of vehicles to operate as a platoon on a highway.
Value-Added Services	
Point of interest notification	Drivers receive notifications informing about local peculiarities.
Automatic access control/parking management including ITP	Grants access to restricted areas automatically. This also includes Intelligent Truck Parking related service.
Local commerce	Vehicle drivers get in touch with local business and consume offered services.
Car rental or sharing assignment or reporting	A roadside unit, which has the capability to manage the booking of non-assigned vehicles and the release of returned vehicles.
Electronic toll collect	A vehicle pays the road toll electronically and fully automatic by means of communication without stopping.
High speed Internet access	Media download Download of multimedia content (audio, video) for entertainment. Map download and update Download of map updates from map servers Ecological drive Techniques focusing on safe, environment-friendly, and economic driving style and behavior. Instant messaging Vehicle-to-vehicle instant messaging service (also known as chat system). Personal data synchronization Exchange of personal data for synchronization between devices of the vehicle driver or owner and components in the home infrastructure, e.g., a personal computer.
Stolen vehicle alert	Information about a stolen vehicle is provided to relevant authorities.
Remote diagnosis and just in time notification	A vehicle exchanges information with a vehicle service center for a remote functional diagnosis.

continued next page

Table A3: ***continued***

Value-Added Services	
Fleet management	Communication and data processing for assisted management of vehicle fleets, including vehicle maintenance and vehicle tracking; driver management and transport logistics.
Vehicle software provisioning and update	A vehicle service station provides new software or software updates for vehicles.
SOS service	Automated transmission of emergency messages to a service center in case of life-threatening emergency (in-vehicle detection).
Vehicle relationship management	This connects vehicles to an IP-based backbone infrastructure. The general objective is to establish a bi-directional information exchange in order to support commercial and business opportunities.
Design re-use and change management	Management of product design reuse and change in the automotive industry economical system
Business intelligence for high-volume service parts management	Optimization of service parts management in the automotive industry economical system
Insurance and financial services	On-demand and real time interaction with financial and insurance coverage service providers
Pay/Earn as you drive (congestion)	This rewards or punishes drivers when not driving (or when driving) in traffic-peak regions during traffic peak hours. A system in the car controls the time and route of the driver and communicates with a central system.

IP = internet protocol, ITP = internet telephone providers, ITS = Intelligent Transport Systems.

Source: Kulmala et al. 2012.

EasyWay selected their first priority applications from this list according to a number of criteria, which includes safety, congestion, environmental benefit, relevance, achievability, etc. This led to the identification of the following as their first priority applications:

- Hazardous location notification
- Traffic jam ahead warning
- Road works warning
- Decentralized floating car data
- Traffic information and recommended itinerary
- In-vehicle signage (including speed management)
- Automatic access control/parking management (including Intelligent Truck Parking)

A.4 Other Sources

In addition to the sources listed, applications were identified in a range of research projects, including:

- Cooperative Vehicle Infrastructure Systems (CVIS), (Gelencser et al. 2010)
- New Services Enabled by the Connected Car (SMART2010/65, 2011) (Passchier et al. 2011)
- Defining the required infrastructure supporting Cooperative systems (Malone et al. 2011)
- Cooperative Benefits for Road Authorities (COBRA) (Ball et al. 2013)
- CVHS Advice for the UK Highways Agency (2012) (Hopkin et al. 2012)

APPENDIX B

COSTS AND BENEFITS OF COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS REPORTED IN THE LITERATURE

B.1 Co-Operative Systems Deployment Impact Assessment (2008)

Co-Operative Systems Deployment Impact Assessment (CODIA) (Kulmala et al. 2008) was a project for the European Commission. It aimed to provide an independent assessment of direct and indirect impacts, costs and benefits of five cooperative systems:

- Speed adaptation due to weather conditions, obstacles or congestion (vehicle-to-infrastructure [V2I] and infrastructure-to-vehicle [I2V] communication)
- Local danger or hazard warning (vehicle-to-vehicle [V2V] communications)
- Cooperative intersection collision warning (V2V and V2I)
- Reversible lanes due to traffic flow (V2I and I2V)
- Postaccident warning (V2V)

Concerning safety impacts, speed adaptation systems were assessed as contributing a 7.2% fatality reduction, and a 4.2% reduction in local danger warning.

Cooperative intersection collision warning had the highest potential (–7%) to reduce injuries.

With regard to benefit to cost ratios, speed adaptation and local danger warning indicate socioeconomic profitability. Cooperative postaccident warning is not socioeconomically profitable due to its modest safety impacts, and reversible lane control is also not profitable due to its restricted potential use.

The CODIA estimates should be considered as indicative rather than robust for a number of reasons:

- Some of the data on benefits are now dated.
- Several assumptions have had to be made about future scenarios.
- As time goes by, other technology will also contribute to safety (and other) improvements.
- The function is not widely implemented and drivers' behavior has to be surmised.
- The in-vehicle implementation and human–machine interface (HMI) will affect driver reaction.

B.2 SAFESPOT (2009)

SAFESPOT was a European Union project.[1] V2I functions and potential safety benefits are reported in terms of fatality reductions:

- Speed alert 7%
- Hazard and incident warning 2%
- Cooperative intersection 3% (an urban service, not relevant here)

V2V functions and potential safety benefits in terms of fatality reductions:

- Longitudinal collision reduction 7%
- Lateral collision reduction <1%
- Road departure <1%
- Combined package ~8.3%

Although these latter functions could be implemented with V2V technology, autonomous operation is also possible and is becoming commercially available. Therefore, the incremental benefit offered by Cooperative Intelligent Transport Systems (C-ITS) is low. See also the section on iMobility Effects, below.

The SAFESPOT estimates should be considered as indicative rather than robust for the same reasons as given for CODIA.

B.3 SMART 63/64/65 (2010)

These three projects were carried out for the European Commission (DG Information Society and Media) during 2011.

SMART 63 (Malone et al. 2011) looked at what the future infrastructure for supporting cooperative systems will look like. In order to identify infrastructure requirements, the project selected and ranked cooperative systems. Applications were grouped according to their requirements for communications and roadside infrastructure. The project also looked at socio-economic impact assessments and road maps for deployment.

SMART 64 (van Schijndel-de Nooij et al. 2011) was concerned with what is needed to achieve wide scale deployment of automated driving by 2025. It examined technical issues, policy and other issues, and carried interviews with key players. The conclusions covered three main areas where action is needed for deployment to become a reality: the drivers, the technology, and the business models.

SMART 65—European Services Enabled by the Connected Car (Passchier et al. 2011)—identified the needs of both public and private sectors for the services enabled by cars being connected to the internet by 2025. It identified the technologies and services facilitated by the concept of a European Wide Service Platform. The project consulted a range of stakeholders across Europe with different roles in providing and using connected vehicle services on future requirements, priorities, and issues. Scenarios and road maps for Future Mobility services enabled by the Future Internet were examined in order to identify future research requirements.

[1] SAFESPOT Integrated Project. http://www.safespot-eu.org/ (accessed 15 August 2015).

The most quantitative and relevant here is SMART 63. The impacts table (based on research from previous studies) is provided in Table B1.

Table B1: Impacts Estimated in the SMART 63 Project

No.	Name of Service	Safety (Fatality)	Efficiency	CO_2 reduction
1	In-vehicle signage	<+1%	−2% to −4%	<−2%
2	Road works warning	<−1%	±0%	<−1%
3	Wrong way driving warning	<−1%	<−1%	<−1%
4	Decentralized floating car data	+2%	−2% to −3%	<−1%
5	Automatic access control/parking management including Integrated Truck Parking	<−1%	<−1%	<−1%
6	Automatic Crash Notification	−4% for fatalities −6% for injuries	−3% to −17%	
7	Vulnerable road user warning	<−1%	<−1%	<−1%
8	Traffic information and recommended itinerary	<+1%	−2% to −4%	<−2%
9	Hazardous location notification	−4%	−3%	<−1%
10	Traffic jam ahead warning	−4%	−3%	<−1%
11	Postaccident warning	−1%	−1% to +3%	<−1%
12	Enhanced route guidance	<+1%	−2% to −4%	<−2%
13	Car breakdown warning	<−1%	−1% to +3%	<−1%
14	Obstacle on driving surface warning	<−1%	<−1%	<−1%
15	Insurance and financial services	**	<−1%	0.8%–2.8%

** = not applicable, CO_2 = carbon dioxide.

Source: Malone et al. 2011.

As SMART 63 was a desk study of previous work, the caveats from CODIA and SAFESPOT on the robustness of these findings also apply here.

B.4 Cooperative Benefits for Road Authorities (2013)

Cooperative Benefits for Road Authorities (COBRA) (Ball et al. 2013) was a European Research Area Network project funded by a group of road authorities and the European Commission. It developed a methodology for assessing the impact of a bundle of C-ITS services and calculated some expected impacts of cooperative services in terms of optimized vehicle flow, traffic safety, and emission reduction, compared to existing intelligent transport systems. It also undertook a cost–benefit analysis of cooperative systems, based on the impact assessment and given investments and maintenance costs.[2]

[2] Conference of European Director of Roads. ERA-NET ROAD. http://www.cedr.fr/home/index.php?id=251&dlpath=2011_Call_Mobility-Design-Energy%2F01_ENR%20Call%202011%20-%20Mobility%2FCOBRA&cHash=7a4b114b4c603a2a0b41cd020911caef

Bundles investigated in the COBRA project were:

- Local Dynamic Event Warnings: Hazardous location notification, road works warning, traffic jam ahead warning, and postaccident warning (eCall)
- In-Vehicle Speed and Signage: In-vehicle signage, dynamic speed limits, and Intelligent Speed Adaptation
- Travel Information and Dynamic Route Guidance: Traffic information and recommended itinerary, multimodal travel information and truck parking information and guidance

COBRA largely used previous findings and calculated the effects of the bundles on fatality reductions of 7% (Local Dynamic Event Warnings), 7% (In-Vehicle Speed and Signage) and 4% (Travel Information and Dynamic Route Guidance, etc.).

B.5 DRIVE C2X

DRIVE C2X laid the foundation for rolling out cooperative systems in Europe, leading to safer, more economical and more ecological driving. It was successfully completed in July 2014.[3]

The project website states that "*there are no doubts about the potential benefits of C2X communication technology but so far those benefits cannot be quantified because there are no field trials with cooperative systems technology ongoing yet that can provide the data needed for a serious assessment of the benefits.*"

B.6 iMobility Effects (2014)

The iMobility Effects database summarizes results from a number of recent published studies on the effects of different ITS applications and services.[4]

See:

The functions and services that can be implemented using V2I communications (relevant to hazards and speed limits) are reported as having the following safety benefits in terms of fatality reductions:

- Local danger warnings (using VMS) 1%–5%
- Real-time traffic information—no reliable estimates but certainly <10% (but substantial traffic flow benefits)
- Speed alert—could be up to 30% for mandatory; less for warnings

Emergency braking, blind spot, and lane-keeping applications also offer considerable safety benefits (overall a 7% fatality reduction). Although these could be implemented with V2V technology, autonomous operation is also possible and commercially available. See also SAFESPOT.

[3] DRIVE C2X. Accelerate Cooperative Mobility. http://www.drive-c2x.eu/project
[4] iMobility Effects Database. http://www.imobility-effects-database.org/applications.html

The literature is taken mostly from Europe but with some US studies. Some of it goes back more than 15 years. No examination of the original sources has been undertaken at the time of writing (it would be quite a significant undertaking). Overall, the results probably present a "best estimate or consensus" but cannot be considered completely firm.

B.7 European Field Operational Test on Safe, Intelligent and Sustainable Road Operation (2014)

European Field Operational Test on Safe, Intelligent and Sustainable Road Operation (FOTSIS)[5] is a member of Field Operational Test Networking and Data Sharing Support (FOT-NET), a project coordinating and summarizing field operational testing. The following information is based on a review of FOTSIS Deliverable D4.2 M29 (Safety impact assessment—Preliminary Report version number: 0.6).

The services being considered are:

- S1. Emergency Management (eCall)
- S2. Safety Incident Management
- S3. Intelligent Congestion Control
- S4. Dynamic Route Planning
- S5. Special Vehicle Tracking (e.g., dangerous or valuable goods)
- S6. Advanced Enforcement (on board recording and tutoring)
- S7. Infrastructure Safety Assessment ("black spot" identification from vehicle data)

S2 provides real-time warnings to drivers using I2V of congestion, incidents, speed, and weather.

S3 attempts route load balancing using real-time information and predictive algorithms, and attempts to affect traffic using VMS.

S4 provides route recommendations to individual drivers (I2V) based on the view of the network from S3.

The deliverable provides a qualitative indication of the impacts expected from each service. Research questions and indicators are discussed. The difficulty of obtaining statistically significant results is presented e.g., for fatalities, and therefore the need to consider proxy measures. The proposed trials will be for 8 months (4 months without the treatment and 4 months with treatment).

The deliverable's conclusion is:

> "As of this writing no definitive conclusions with respect to safety impacts are possible. Almost all of the research methodologies require a comparison of the field test results, yet to be conducted, with baseline or reference data."

[5] FOTSIS is a current EU project carrying out trials of specific V2V and V2I technologies/services. European Field Operational Test on Safe, Intelligent and Sustainable Road Operation. Accessed 7 September 2015 from http://www.fotsis.com/

B.8 Benefits Reported in United States Literature

B.8.1 Benefits and Costs Database

The benefits and costs recorded in the United States (US) Federal Intelligent Transportation Systems (ITS) program are principally related to the ITS functionality rather than its implementation such as through V2V or V2I. Although there is reference to some European C-ITS work, there is little in the way of benefits included for C-ITS more generally.[6]

B.8.2 Research and Innovative Technology Administration (2008)

The US Department of Transportation (DOT) Research and Innovative Technology Administration (RITA) had a program called the "Vehicle–Infrastructure Integration (VII) Initiative." In 2008, a benefit–cost analysis (Version 2.3, 2008) was produced.

The report investigated a bundle of V2V and V2I applications with on-board unit equipped vehicles and a 5-year rollout of DSRC beacons. Table B2 illustrates benefits and calculates an overall BCR. However, the text says for several parts of the bundle that "*it is not yet possible to generate meaningful quantitative estimates of safety and mobility aspects.*"

Table B2: Summary of Estimated Benefits and Costs, billions in 2008 dollars

Application or Cost Element	Safety Benefits	Mobility Benefits	Costs
Signal Violation Warning	11.0	0.1	
Stop Sign Violation Warning	2.7	0.0	
Curve Speed Warning	14.6	0.1	
Electronic Brake Lights	13.6	0.2	
Ramp Metering		0.3	
Traffic Signal Timing		0.3	
Winter Maintenance		0.4	
Traveler Information		0.9	
Total Benefits	41.8	2.4	
Roadside Equipment			9.3
On-board Equipment			12.4
Network Backhaul, Operation and Maintenance			3.7
Governance and Program			1.0
Application–Specific Costs			0.8
Total Costs			27.3
NET BENEFITS: 16.9 COST–BENEFIT RATIO: 1.6			

Source: US DOT Research and Innovative Technology Administration (RITA). http://152.122.41.186/connected_vehicle/508/Library/Library-RRs-Institutional/VII%20BCA%20Report%20Ver2-3.htm

[6] The Federal Intelligent Transportation Systems (ITS) program provides an overview of the applications and contains links to various information resources. Government of the United States, Department of Transportation. Intelligent Transport Systems Joint Program Office. Accessed 15 September 2014 from http://www.its.dot.gov/

The recent National Highway Traffic Safety Administration (NHTSA) announcement in 2014 indicates that more recent work has identified sufficiently robust benefits to support mandatory fitment of this technology.

B.8.3 The United States Government (2013)

The US Government Accountability Office (GAO) report to Congressional Requesters can be summarized as "vehicle-to-vehicle technologies are expected to offer safety benefits, but a variety of deployment challenges exist."[7]

According to the US DOT National Highway Traffic Safety Administration (NHTSA), if V2V technologies are widely deployed, they have the potential to address 76% of multi-vehicle accidents involving at least one light vehicle by providing warnings to drivers. However, the potential benefits of V2V technologies are dependent upon a number of factors including their deployment levels, how drivers respond to warning messages, and the deployment of other safety technologies that can provide similar benefits.

All of the automobile manufacturers interviewed by the US GAO said that it is difficult to estimate in-vehicle V2V component costs. The costs associated with a V2V communication security system also remain unknown but could be significant.

B.8.4 National Highway Safety Administration (2014)

The NHTSA in the US announced in 2014 that it will begin taking steps to enable V2V communication technology for light vehicles.[8]

V2V communications can provide the driver and vehicle with a 360-degree situational awareness to address additional accident situations—"V2V crash avoidance technology has game-changing potential to significantly reduce the number of accidents, injuries, and deaths (fatalities) on our nation's roads." In addition to enhancing safety, future applications and technologies could help drivers conserve fuel and save time. V2V technology does not involve exchanging or recording personal information or tracking vehicle movements.

In August 2012, DOT launched the Safety Pilot "model deployment" in Ann Arbor, Michigan, where nearly 3,000 vehicles were deployed in the largest-ever road test of V2V technology. The NHTSA report on the pilot model deployment included analysis of the department's research findings in several key areas including technical feasibility, privacy and security, and preliminary estimates on costs and safety benefits. Now, NHTSA will begin working on a regulatory proposal that would require V2V devices in new vehicles in a future year, consistent with applicable legal requirements.

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7 Government Accountability Office. http://www.gao.gov/assets/660/658709.pdf

8 Government of the United States, National Highway Traffic Safety Administration. 2014. U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles. 3 February. http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles

B.9 World Road Association-PIARC (2012)

The World Road Association-PIARC's *Connected Vehicle* report[9] was developed by a joint task force of the World Road Association-PIARC and the International Federation of Automotive Engineering Societies (FISITA). The report explores the commercial and public sector perspectives and discusses a number of issues and implementation factors. They say that:

> "Research suggests that connected vehicles and cooperative systems will bring economic savings in transport.. but for most countries (Japan is an exception) the evidence is not yet sufficiently compelling to justify a government investment program."

B.10 Cooperative Intelligent Transport Systems Support for Environmental Benefits

Transportation is responsible for an increasing proportion of greenhouse gas (GHG) emissions. For example, 27% of GHG emissions of the US, and 20% of Europe's GHG emissions derive from transportation.

There is relatively not much literature on the actual measured benefits of C-ITS in addressing environmental issues. However, a few projects emerging are reporting potential benefits and/or plan to undertake field testing. Many applications are urban in nature; for example, linking vehicle speeds to traffic lights. However, some services are more relevant to the NTHS and relevant projects are noted below.

ECOSTAND[10] is a project assisting the US, the EU, and Japan to agree on ways to assess the impacts of ITS on carbon dioxide (CO_2).

eCoMove[11] investigated various integrated solutions to green mobility including V2V and vehicle-to-anything communications (V2X) services. V2X eco-driving and re-routing were found to offer environmental benefits.

The EU project Amitran[12] has ranked the likely impacts of C-ITS on CO_2 emissions in Deliverable D3.1 (available on the website). Of the C-ITS services relevant to interurban road traffic, Cooperative ACC is highly rated, and speed control is also considered worthwhile.

The US Applications for the Environment: Real-Time Information Synthesis (AERIS) program[13] is focusing on "green" transportation using connected vehicles and will implement eco-integrated corridor management including variable speed limits transmitted from the roadside to vehicles.

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9 http://www.piarc.org/en/order-library/13731-en-The%20connected%20vehicle.htm
10 ECOSTAND. http://www.ecostand-project.eu/
11 eCoMove. http://www.ecomove-project.eu/
12 Amitran. http://www.amitran.eu/
13 Government of the United States, Department of Transportation, Intelligent Transport Systems Joint Program Office. Applications for the Environment: Real-Time Information Synthesis (AERIS) Program. http://www.its.dot.gov/research_archives/aeris/index.htm

B.11 Dynamic Route Guidance

Dynamic route guidance navigates the driver around accidents and congestion hot spots, taking account of current (and to some extent predicted) travel times. The route provided is calculated as best for the individual driver. Example commercial services in Europe are TomTom HD and Google Maps Navigation.

Real-time data typically comes from the sensors installed in or above roads and from (anonymous) real time location and speed from service users of certain commercial services such as TomTom HD or Google Maps. This "crowdsourcing" approach helps to improve the overall picture of the road network.

Dynamic guidance can be implemented in at least two distinct architectural forms:

- "thick client" where the navigation system on-board the vehicle periodically receives information about travel times and delays and makes its own calculation of the route based on the vehicle's current position and destination (e.g., TomTom).
- "thin client" where the system provides current position and destination to an off-board server which periodically returns routing information based on centrally held journey times and delays (e.g., Google Maps Navigation).

B.11.1 Identification of Benefits in Literature

There are several subtle issues to be taken into account when reporting benefits:

Incremental benefits: As static and individual dynamic route guidance are commercially available, these can be taken as the "baseline" and the issue will be the identification of the incremental benefits of enhanced functionality.

Benefits for less-equipped drivers: As the proportion of users of route guidance increases, there are benefits to unequipped drivers whose experience of congestion will be less severe due to more efficient routing of other drivers. (It is probably impractical to measure such benefits; TomTom's modeling studies suggest that if 10% of drivers use dynamic routing, average journey times for all drivers is reduced by up to 5%.)

Benefits by road and congestion level: The benefits of dynamic and enhanced guidance depend on the road topology and level of congestion. There is no benefit in very light uncongested traffic. Also there is no benefit when the road system is highly congested and with no re-routing capacity. Thus benefit averages need to take account of actual use.

B.11.1.1 Individual Static and Dynamic Route Guidance

Some previous European studies of dynamic route planning have been:

- Transport Guidance and Information System for Freight Transport in the City of Berlin (TRANSLIB) 1991.

- City Laboratories Enabling Organization of Particularly Advanced Telematics Research and Assessment (CLEOPATRA) 1998.
- Enabling quick and inexpensive map updates (FEEDMAP) 2006.
- Realizing Enhanced Safety and Efficiency in European Road Transport (REACT) 2006.
- Integration of Dynamic Route Guidance and Traffic Control System (CARGOES).
- Technologies for travel planning and comprehensive information for travellers en route (I-TRAVEL) 2008.
- Real-time Traffic and Travel Information (RTTI) services (IN TIME) 2009.

Numerous sources are also listed in the US DOT benefits database.[14]

B.11.1.2 TomTom Dynamic Navigation

Analysis by TomTom of randomly selected trips shows that TomTom users with TomTom IQ routes (a form of dynamic route guidance) can save an average of 2%–4% of their journey time relative to static route guidance, depending on the availability of a good alternative route to reduce journey time.[15]

B.11.1.3 iMobility Effects

The iMobility summary of reviewed sources concerning individual dynamic route guidance states that "users reach their destination via a personally optimal route, which means that the whole transport network is being utilized more efficiently." However, no overall figures are given although a small positive effect of around 2% is recorded in terms of fuel efficiency. The summary also stated that "Dynamic navigation is also very likely to have a positive impact on traffic safety as drivers are better informed about hazardous situations such as a tail of congestion, ghost drivers, or the overall high traffic volumes."[16]

B.11.1.2 SMART 63

The SMART 63 project has a concept called "enhanced navigation" although on close reading of the project deliverable's annexes, this appears to be "only" individual dynamic route guidance. The offered benefits are shown in the table.

Table B3: Benefits of Enhanced Route Guidance

Number	Name of Service	Safety (Fatality)	Efficiency	CO_2 reduction
12	Enhanced route guidance	<+1%	−2% to −4%	<−2%

Source: SMART 63 project.

[14] Government of the United States, Department of Transportation. Intelligent Transportation Systems Joint Program Office. Benefits Database. Accessed 14 May 2013 from http://www.itsbenefits.its.dot.gov/its/benecost.nsf/BenefitTerminators/DAS+Navigation_Route+Guidance

[15] TomTom. 2010. *Traffic manifesto.* October. Accessed 14 May 2013 from http://www.tomtom.com/landing_pages/trafficmanifesto/content/pdf/Support%20Document_lid1.pdf

[16] iMobility Effects Dynamic Navigation. Accessed 14 May 2013 from http://www.imobility-effects-database.org/applications_17.html

B.11.2 Summary and Conclusions on Benefits of Dynamic Route Guidance

Route guidance provides substantial individual benefits to drivers, and secondary benefits to other users in terms of reduced congestion. *Individual* dynamic guidance makes use of real-time congestion information and provides additional benefit estimated to be 2%–4% of travel time and corresponding benefits to environmental performance. The *further* incremental benefits of enhanced guidance using "collective" (system optimal) routing, have not been practically researched or measured but are probably significantly less than 2%–4%. Note that actual benefits will also depend on the system's technical performance and the driver HMI.

B.12 Automatic Crash Notification (eCall)

Automatic Crash Notification (ACN), known in Europe as eCall, is a C-ITS service that automatically summons emergency assistance in the event of a vehicular accident.

B.12.1 Benefits Reported in Literature

The potential improvement of safety from ACN depends largely on the current road situation and rescue chain efficiency in the area of application. Benefits of up to 5% reduction in fatalities have been estimated in some studies.

In the European eCall impact assessment study (Francsics et al. 2009) cost–benefit ratios were estimated for EU-25 in 2020 and 2030, under scenarios with three different levels of policy intervention; the different levels of policy intervention being assumed to result in different penetration rates for eCall in the vehicle fleet. The cost of in-vehicle units was found to be the most critical factor in assessing the costs. Based on reduction of casualties, congestion, and emissions, the cost–benefit ratio was greater than one (1.31) by 2030 under the mandatory introduction scenario, but not in the other scenarios.

The iMobility Effects database summary states that "*The systems should lead to a higher efficiency of the rescue chain reducing the consequences of the accidents and their severity. The system is estimated to reduce the number of road fatalities by 2%–15% and the number of severely injured by 3%–15%. The congestion and environmental effects of eCall, mainly due to reduction in accident related congestion, are quite small.*"

B.12.2 Summary and Conclusions on Benefits of Automatic Crash Notification

ACN should lead to a higher efficiency of the rescue chain reducing the consequences of accidents and their severity. However, the benefits of this application depends on many factors including road and terrain characteristics, and the quality of the safety–rescue chain. Optimistic estimates suggest that a 5% fatality reduction should be possible. Data from large-scale trials are not currently available. In any case, it may be difficult to distinguish benefits arising from eCall introduction from benefits arising from other developments in the rescue chain such as better procedures, communications, mapping, or other equipment.

B.13 Extended Adaptive Cruise Control and Platooning

Some studies (e.g., reported in the iMobility Effects database) have identified a small safety benefit of adaptive cruise control (ACC) as it provides a measure of forward collision warning to drivers.

Extended ACC which provides collision warning is considerably more beneficial although it can be implemented autonomously. Another form of ACC extension allows vehicles to "platoon."

The concept of the SARTRE project[17] is to have a group of vehicles driving together with a lead vehicle, driven normally by a trained professional driver, and several following vehicles driven fully automatic by the system with small longitudinal gaps between them. Driving in a platoon brings benefits in fuel consumption, safety, and driver convenience. In addition to investigating the concept, a demonstrator system has been developed consisting of five vehicles: a lead truck, a following truck, and three following cars. An off-board system has also been developed to allow a potential SARTRE driver to find, and navigate to a suitable platoon, although this has not been fully integrated into the vehicle system.

There are several claimed benefits for following passenger vehicles:

- Increased safety, approximately 50% reduction of highway related accidents, as trained truck drivers statistically are exposed to fewer accidents than the average driver;
- Decreased fuel consumption, approximately 10% reduction; and
- Enabling drivers to perform other tasks, e.g., reading or working.

Trials are underway in Europe, the US, and Japan to refine the technology, address the legal and organizational issues, and characterize the real-world benefits and practicality of such systems operating in mixed traffic.

B.14 Summary and Conclusions on Vehicle-to-Vehicle Communications Benefits and Costs

B.14.1 Main Benefits

Nearly half of the accidents examined by the US Highway Loss Data Institute involve rear-end collisions. In theory, information-swapping between cars could virtually eliminate such accidents. However, results from field operational tests are still awaited but should become available over the next year. Some additional points are:

- The actual benefits will also depend on the systems' technical performance and either the driver HMI or the vehicle actuation of control.
- Field Operational Test (FOT) results should, as well as measuring benefits, provide information about driver acceptance issues and any behavioral changes.

[17] Safe Road Trains for the Environment. http://www.sartre-project.eu/en/Sidor/default.aspx

- The same communications and hardware could support a broad range of V2V and V2I services to and from roadside beacons.
- However, the case for V2V benefit is weak until many (most) vehicles are equipped. Whereas autonomous sensing provides immediate and progressively increasing benefits as vehicles are equipped, V2V does not provide benefits until most vehicles are equipped.

B.14.2 Anticipated Costs

B.14.2.1 Hardware Costs

All of the automobile manufacturers interviewed for the US GAO report said that it is difficult to estimate in-vehicle V2V component costs. There are probably several reasons for this:

- Bundling—which services would be supported
- Sharing—which in-vehicle components can be shared with existing hardware
- Architecture—in particular, which communication channel
- Quantity—how many units of each design are required
- Time scale—when would these need to be available
- Line-fit by original equipment manufacturer, dealer, or aftermarket—which channel to the customer
- Regulation—which aspects of the design may be regulated

B.14.2.2 Communication Costs

V2V should not have any usage cost associated with communications as the dedicated short-range communications (DSRC) frequencies and protocols are open.

The GAO report referred to the above notes that the costs associated with a V2V communication security system also remain unknown but could be significant. Security would become particularly important when the functionality of the V2V service includes control of the vehicle (e.g., to avoid another vehicle).

B.14.3 Commercial Feasibility Issues

It should be noted that the business case for wide deployment of C-ITS has not been firmly established.

As stated in SMART 63:

> "There are still a number of challenges to be sorted out by the members of the value chain in cooperative ITS. The responsible stakeholders may vary from member state to member state and even might vary from region to region. The deployment choices may also depend on the legacy systems and the roles chosen by the public and private parties."

Car manufacturers can be in control of V2V communications channels without the need to pay third party (providers) for communication costs. This causes conflicts with cellular networks.

Many V2V services can also be delivered through V2I channels and although these could use roadside beacons, many can be supported with cellular radio.

There are some time-critical services (such as collision warning/avoidance) where the latency of cellular communications would be insufficient, and where roadside beacon density would be insufficient. For such services, there are two options:

(i) the use of V2V communications between the vehicles involved in the maneuver.
(ii) the use of on-board sensors.

The use of on-board sensors is a robust solution for other vehicles not equipped with V2V services. Thus, the case for V2V is weakened by the "rollout" issue—autonomous sensing provides immediate and progressively increasing benefits as vehicles are equipped, whereas V2V does not provide benefits until most vehicles are equipped. Although ultimately it *might* be a cheaper solution, the case for deployment is difficult to make.

In the US, it must be noted that steps are being taken to make V2V mandatory. This makes commercial issues partly disappear, as all manufacturers will have to provide at least some minimum functionality.

B.15 Summary and Conclusions on Vehicle-to-Infrastructure Benefits and Costs

B.15.1 Main Benefits

The two functions which offer the greatest potential benefits are speed advice, and hazard ahead warning. From analysis of accidents and driver behavior, estimates in the literature suggest a 7% potential fatality saving from speed advice, and from 2% to 7% for hazard ahead warning. However, such estimates have been derived from desk studies rather than actual field operational tests. Information from such tests should become available over the next year. Some additional points are:

- the actual benefits will also depend on the system's technical performance and the driver HMI;
- FOT results should, as well as measuring benefits, provide information about driver acceptance issues and any behavioral changes; and
- the same communications and hardware could support additional V2I services (providing additional benefits).

B.15.2 Anticipated Costs

B.15.2.1 Hardware Costs

Automobile manufacturers interviewed for the US GAO report said that it is difficult to estimate in-vehicle V2V component costs. It can be expected that the same is true of V2I. There are probably several reasons for this:

- Bundling—which services would be supported,
- Sharing—which in-vehicle components can be shared with existing hardware,
- Architecture—in particular which communication channel,
- Quantity—how many units of each design are required,
- Timescale—when would these need to be available,
- Line-fit by original equipment manufacturer, dealer, or aftermarket—which channel to the customer, and
- Regulation—which aspects of the design may be regulated.

B.15.2.2 Communication and "Back-Office" Costs

V2I using cellular communication is relatively low-cost and feasible. The actual information transfer cost will depend on the service package that the customer has with the cellular service provider.

Communications using dedicated short-range roadside beacon is initially more expensive due to the necessary beacon deployment. Back-office hardware or software costs to support these services are one-off costs and relatively low compared with the millions of IVS required for full deployment.

COBRA has investigated costs and benefits. For Bundle 1 (local dynamic event warnings): if the services are delivered through cellular network communications to smartphone apps, such that there are no additional in-vehicle costs, and communication costs are negligible, then the cost–benefit ratio is positive and increases over time. If the service is delivered through beacons, then the costs greatly exceed the benefits, due to the investment in the roadside beacons.

Bundle 2 (In-Vehicle Speed and Signage) achieved a benefit–cost ratio slightly higher than 1 in the examples considered where it is delivered via cellular networks.

B.15.3 Commercial Feasibility Issues

It should be noted that the business case for wide deployment of V2I has not been firmly established.

As stated in SMART 63:

> "There are still a number of challenges to be sorted out by the members of the value chain in cooperative ITS. The responsible stakeholders may vary from member state to member state and even might vary from region to region. The deployment choices may also depend on the legacy systems and the roles chosen by the public and private parties."

APPENDIX C

SUPPORTING ROAD SAFETY IMPROVEMENTS WITH ACCIDENT DATA

C.1 Introduction

One of the recommendations from this project is that accident data collection, storage, and analysis could be improved to support current and future evidence-based policymaking by implementing a national-level accident data management and analysis system.

The use of data has underpinned the development of successful programs and strategies in countries which have managed to reduce their road safety problems. An understanding of the magnitude of the economic, medical, and social impacts has generally been the motivation for many countries to start investing significantly in road safety programs. Reliable information on accidents help guide counter-strategies, and ensure treatments are as targeted and effective as possible.

A previous Asian Development Bank (ADB) report on road safety in the People's Republic of China (PRC) (Ono et al. 2013) noted that the PRC is in a position to learn from the evolution of road safety thinking in countries which have a longer history of tackling road safety issues, and thus to accelerate the process which has evolved over some 50 years. It also highlighted the importance of improving accident data and analysis, with "full and accurate traffic accident reports to be collected by the police, and for the data to be shared with other professionals involved in road safety."

A number of issues have been identified with current accident reporting in the PRC:

- Underreporting—the ADB report identified research published in *The Lancet* which points towards underreporting of road accidents in the PRC (although this is likely to be less of a concern of the National Trunk Highway System [NTHS] than on other roads).
- Conflicts faced by police officers at an accident scene who are required to both deal with the incident and record the details of the circumstances and factors in a systematic way (also identified in the ADB report).
- The combination of paper records of individual accidents not made public, and published statistical tables in a set format, does not lend itself to detailed analysis for identifying countermeasures, or to monitoring the effectiveness of policies and countermeasures which are introduced.

Appendix C outlines some of the common features of electronic accident databases and the ways in which they are used. It provides examples of the ways databases are used in Australia, Japan, the United Kingdom (UK), the United States (US), and the State of Himachal Pradesh in India.

C.2 International Perspective

In almost all countries, police collect information on accidents that occur across the road network. This is generally a statutory requirement whenever accidents involving injury occur. Data collection by the police is carried out in a wide range of ways from country to country. It is important to understand that it is not done primarily to collect information which can be used by road safety stakeholders to develop countermeasure schemes and policies. It is chiefly collected for legal purposes. Such information is used in court cases as evidence where persons are fined or charged in relation to accidents. The information may also be required as part of the insurance claim procedure to allocate blame.

The extent to which data is managed within a police organization varies considerably from country to country. Some countries rely solely on the police to maintain and manage the data, and even regard it as confidential information.

In many countries, including the UK, the police attend to the scene of a collision and complete the initial accident report form. It is then passed to the local highway authority for processing and validation before being consolidated in the Department for Transport's national database. The police may have little interest in the management and analysis of the data and can regard collection, and hence accuracy, as a non-important task.

Even where roads are operated by private organizations such as toll road franchises, concessionaires, or public–private partnerships, they will usually have a responsibility (often linked to a key performance indicator) to collect and analyze information on road traffic collisions. Initial attendance at the scene is still undertaken by an enforcement agency (police or other regulatory body).

The overriding guidance is to have a single centralized database that manages national data. Crucial to management is the accuracy and description of locational information, and a consistent format for reporting.

Electronic storage is now a basic requirement as reliance on individual paper records is too variable, yet majority of data is still recorded at the scene using pen and paper. Accuracy and reliability, as the data is consolidated and transposed between different media, is an ongoing concern.

The possibility for local or regional authorities to maintain discrete subsets for local analysis is also important. This is usually achieved through the consolidation process of aggregating individual records to national statistics.

Many countries, including developed ones, need to improve the quality and availability of accident data.

C.3 Data

C.3.1 Accident Data

The content of accident databases is usually developed over time in consultation with those responsible for collecting data, road safety professionals, and policymakers who use the data. A periodic review process will ensure that new factors can be recorded, and those which are no longer relevant can be omitted.

Typically, an electronic accident database is a relational database with records of the accident, the vehicles and the casualties involved, defined in a common national standard.

Increasingly, accident and vehicle records also include an assessment of the causal factors made by the officer attending the accident scene; the coding frame for recording the factors may be developed through a research project and will normally be reviewed or tested by those responsible for collecting and using the data.

The European Union's SafetyNet initiative (with Community Road Accident Database [CARE]) has reviewed accident data collection in Europe with the aim of identifying the best report practice for accident report content. The project identified 73 variables for the Common Accident Data Set (CADAS) 2014 with 471 values. These were selected to be comprehensive, concise, and useful for accident data analysis. This can provide guidance on what variables and fields should appear in an accident report pro forma, and covers four basic categories as noted in Table C1.

Table C1: Main Variables in the European Common Accident Data Set

Crash Related	Road Related	Vehicle Related	Person Related
• Crash identifier unique reference number assigned to the crash usually by police • Crash data • Crash time • Crash municipality or place • Crash location • Crash type • Weather conditions • Light conditions • Crash severity	• Type of roadway • Road functional class • Speed limit • Road surface conditions • Intersection • Traffic control at intersection • Road curve • Road segment grade	• Vehicle number • Vehicle type • Vehicle make • Vehicle model • Vehicle model year • Engine size • Vehicle special function • Vehicle maneuver (what the vehicle was doing at the time of the crash)	• Person identification • Occupant's vehicle number • Pedestrian's linked vehicle number • Date of birth • Sex • Type of road user • Seating position • Injury severity • Safety equipment • Pedestrian maneuver • Alcohol use suspected • Alcohol test • Drug use • Driver's license issue date • Age

Source: Yannis et al. 2008.

We understand that regulations and common standards for accident data exist in the PRC, but the scope and coverage of these standards are not clear.

The World Health Organization (WHO) Data Systems Manual (2009) gives comprehensive information on accessing and improving accident data, and implementing associated systems.

While it is possible to use paper based systems to perform data analysis, undoubtedly any analysis can be done much easier when the data are contained in a database. It is understood that trials of electronic data have been undertaken in some regions. For a national database system, it is important to standardize data entry forms and procedures to maintain quality and consistency of data.

Dedicated computerized accident database systems make the task of trend and other spatial analyses much easier than manual methods. The replication of analysis is allowed so that work can be easily checked and rechecked, they permit individuals to identify sites much more quickly, and be used effectively by staff with less training and capacity compared with manual processes and systems.

Typical systems have:

- A data entry module which enables staff to enter the data from a paper report into a computer database (mobile solutions may negate the need for this step)
- Functionality for checking validity and completeness of accident records (algorithms that interrogate the consistency of information entered)
- Analysis capabilities that allow staff to identify and work with subsets of data
- Analysis capabilities to identify patterns in the data
- Geographical information system (GIS) or other modules that allow staff to plot accidents and support spatial analyses
- Modules which allow the easy production of standard and user defined reports
- Audit trail to enhance transparency.

More advanced and modern systems may have specific spatial cluster functionality. These advanced systems should have statistical capability to support monitoring and evaluation and advanced analysis to produce accident diagrams and movement pattern analysis.

Systems can vary greatly in cost and complexity, from the use of existing databases and GIS software systems, to internally developed systems, to bespoke and commercial off-the-shelf systems. The appropriate system will depend on the size of the country or jurisdiction, the number of accidents typically recorded yearly, and available budget.

Accident and casualty severities are important in quantifying the economic impact of road accident. Police accident data are broadly categorized into different severities based on the level of the worst injured casualty. Accidents are generally categorized as being:

- **Damage only**—no one is injured, but there is damage to vehicles or property.
- **Slight**—at the worst there is bruising, bleeding, and only minor medical assistance is required to treat any casualties.
- **Serious**—at least one person was hospitalized overnight, or there were life-threatening injuries sustained.
- **Fatal**—at least one person died as a result of the accident. Ideally the medical progress of seriously injured persons is followed for up to 30 days, however, in many countries only deaths (fatalities) at the scene are considered.

International best practice defines a fatality as death of a person occurring at the scene of an accident, or within 30 days after such accident.

A variety of additional sources of accident data are used to support the development and monitoring of road safety programs internationally.

C.3.2 Health Data

Data on deaths (fatalities) and injuries from road accidents may also be available from medical databases. It is considered good practice for hospitals to collect a range of information on patients, chiefly for budgeting and resource planning purposes. Ideally, information is collected from all patients who receive treatment at health facilities, and it is also recommended that the broad cause of any injury is recorded. Involvement in road accidents is generally the major cause of unintentional injuries which require treatment in most countries. It should be noted that health data uses a different scale for measuring injury severity from that used for road traffic casualties, and this can add to the complexity of comparing different data sources.

It should also be noted that hospitals will generally only retain data on seriously injured road victims, since minor injuries are more likely be treated at home or at smaller local health facilities which are less likely to record and share information systematically.

A medical or public health data source which may potentially hold information on road fatalities is a vital register. A vital register is concerned with recording births, migration, and deaths (fatalities) for planning purposes. Since population size and age and gender distributions have a fundamental effect on how government spends resources, especially medical provisions, the vital register tend to be associated with the medical sector. Cause of death should be recorded in a standard vital register, and if death resulted from injury, it should be recorded if it was due to involvement in a road accident.

Medical data are more accurate for assessment of injury severity, though it is very unlikely that any significant information on accident circumstances, vehicles involved, or detailed location information will be collected.

Although medical data may not help an engineer identify hazardous locations; it can, however, assist road safety personnel evaluate underreporting rates and the realistic distribution of injury severity (proportions of fatal, serious, and slight) as hospitals record and categorize road casualties and the severity of trauma injury differently.

C.3.3 Other Sources

Although the main type of data used in road safety engineering is accident report information, there is a range of other data that can be used to help engineers. These may be available in datasets from preexisting surveys; in some cases, collection of such data may be commissioned specifically as part of the site investigation process.

These data include traffic flow and related data (vehicles per day, traffic mix, pedestrian crossing, and road use), road condition information (friction, rutting, micro and macro texture, condition information), and speed data.

C.4 Data Entry and Processing

Police accident report information is the main source of data used for road safety engineering analyses. This is collected manually at the scene of any reported accident—usually involving injury, or damage to third party property.

In its simplest form, police accident data will include a narrative description about the accident. Principally recorded using pen and paper, there is often no clear structure for reporting accident details. It relies on the individual officer to determine what information they record or what is considered important, and how much information is provided. In such instances, subsequent detailed or comparative analysis cannot be easily undertaken.

In many countries, traffic police have agreed to collect information on accidents on a structured pro forma questionnaire. This has significant advantages since it helps the officer collect a wider range of consistent details useful for road safety purposes. A short "tick box" form is most likely to be filled in. However, much of the interpretation of how that information gets filled in can be subjective and is reliant on the police officer's expertise, whose primary concern is dealing with the incident rather than completing the collision form.

In some locations, the police use duplicating paper forms creating multiple copies as the information is collected. Typically, three copies are created, with one copy staying in the local police station, another being sent to police headquarters, and a third copy sent to the engineering department. This means that several organizations enter the same information into different databases, leading to unnecessary duplication. The quality of these multiple copies can also be difficult to read, which may cause data entry errors.

Records are subsequently entered into an electronic database, and data is checked for inconsistencies and cleaned before transmission to a central office where records are compiled into a single national database.

The widespread availability of handheld electronic data entry devices now makes it possible for data entry to be accomplished at the accident scene, and for data entry software to perform automatic checks instantly, thus improving the data quality—reducing costs and time before data are made available for analysis.

C.5 Data Enhancement

Underreporting is not just an issue in the PRC—it is a common concern. To overcome limitations resulting from underreporting, an electronic database can be linked with other electronic data such as hospital records, mortality or survey data, to enable estimation of the extent of underreported types of accidents and casualties. A recent review of accident data sources in the PRC suggested that linking police data on accidents with other sources could strengthen current road safety data and improve the basis for monitoring trends and identifying risks (Ma et al. 2012).

Linkages with other types of data such as driver licenses, vehicle registrations, asset management registers, and road databases can be used to add further detail to accident records and add accident information to other databases, enhancing and enriching data—increasing the range of analysis and other possible uses of data.

Data from insurance claims can be used to enhance the understanding of accidents, as in many countries, insurance records cover a wider range of accidents than may be available from police records, e.g., accidents involving vehicle damage but no injuries.

C.6 Storage and Access

As previously described, the majority of data collected at the scene of accident are recorded on forms by hand and then manually encoded into a database—usually electronic for ease of analysis. Every time the data is transcribed, an opportunity for error is introduced.

A useful move to improving and centralizing data and its use is to input the data from the outset into an electronic dataset. With the advent of mobile phones and tablet computers, the development of a suitable 'app' for secure data collection at the scene—including using the global positioning system (GPS)—is becoming much easier, and indeed many providers of accident databases already provide this functionality.

In the absence of GPS, accident locations can still be identified by a variety of different methods with varying degrees of sophistication and accuracy, such as:

- Chainage,
- Node–link–cell systems,
- Accident location sketches and photographs, and
- Mobile data capture.

Most modern mobile devices already have location recording using a number of built-in techniques. A data capture system specification for accident recording should provide location referencing, including the required accuracy.

It is important to ensure that engineers, other road safety practitioners, and researchers gain access to any relevant data being collected. This requires a clear agreement in place between the data collector and users who share the data. Typically, this could be in the form of a memorandum of understanding which sets the basis on what is to be shared, how frequently, and through what mechanism.

Traditionally, users would either request specific analysis designed from their requirements from a database administrator, or be issued a copy of the database which would enable them to analyze the data in a more interactive manner. Recently, web technology has provided new opportunities for storing and sharing accident databases within and among organizations.

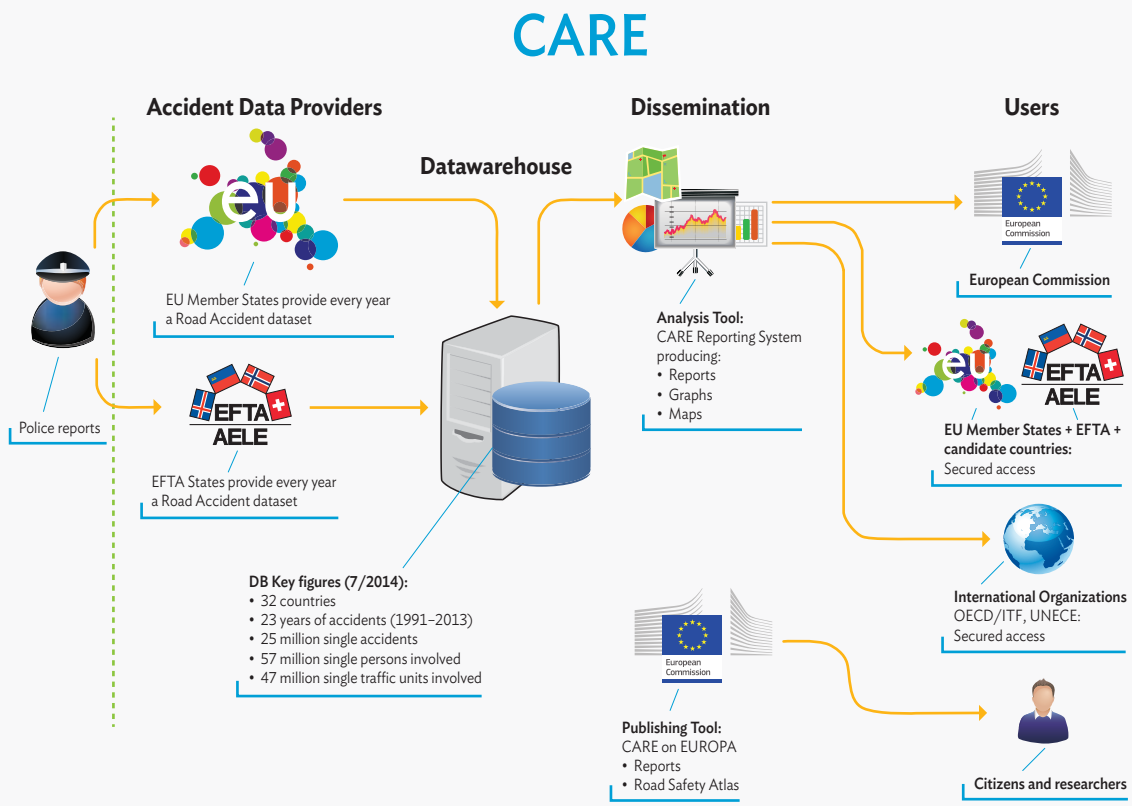
If the data are stored in an electronic database, then the information can be shared relatively easily. Web-based data systems are particularly useful in ensuring consistency of information, and can allow very simple data sharing. Different stakeholders can access the same data set using different log-in credentials that permit them to view different data fields and use different data analysis tools. This deals with concerns about the sharing of sensitive information as fields containing such information (e.g., vehicle registration number, names and addresses, etc.) are simply not accessible to those who do not need them. There are available software products that can be used for managing, analyzing, and reporting road accident data in tabular, graphical, and map form.

If accident databases are implemented in individual provinces, consideration should be given to legislate for a minimum set of data to be recorded, and methods of remotely accessing the data in a consistent and reliable manner. The CADaS data set is a good example of a minimum data set.

C.7 Roles and Responsibilities

Implementing and operating a national accident database is a complex enterprise, involving many roles and levels of responsibility. Figure C1 shows the various roles as identified in the European CARE project. While specifically designed for the European context, this provides a good oversight of the system complexity.[1]

Figure C1: Database Roles Identified in European Community Road Accident Database Project



AELE = L'Association européenne de libre-échange, CARE = Community Road Accident Database, EFTA = European Free Trade Association, EU = European Union, OECD = Organisation for Co-operation and Development, UNECE = United Nations Economic Commission for Europe.

Source: Community Road Accident Database (CARE) Project. http://ec.europa.eu/transport/road_safety/specialist/images/about-care-flowchart.jpg

Any database is only as good as the source data going in. As potentially the prime collector of accident data, the police need a statutory duty to collect-and share-the data, ideally through an electronic process from the outset. The police need to be trained and informed of its use and analysis. Without police buy-in to the project, it will be nearly impossible to implement a successful accident database. The only alternative to using the police as the prime data collectors is to assign a separate agency with the task of data collection. This could, however, be very expensive as many data collectors would need to be employed to attend every serious accident site.

[1] Community Road Accident Database (CARE). http://ec.europa.eu/idabc/en/document/2281/5926.html

In large countries like the PRC, accident databases are often hierarchically organized, local–regional–national, with accident data aggregated as it moves up the hierarchy. The amount of data aggregated at each level may vary, but there needs to be a clear process for its management, consistency, and access.

It is very important to have a clear understanding of who ought to manage the data. The prime reason for implementing a comprehensive accident database is to use such data to improve road safety. Management of data consequently needs to be carried out by those who will use it for improving the road safety situation. Accident data management should be handled by independent bodies which will not be held responsible for poor accident performance.

A well-organized road accident database also allows for a consistent system of analysis and research to be established so that common data sets can be probed and cross tabulated.

To ensure that the database is nationally useful and consistently implemented, best practice suggests that the national government needs to not only setup and manage data collection, storage and analysis, but also share such data with research organizations, local, and national road bodies to manage, analyze, and use the data.

Regular liaison needs to be established between the various authorities and levels of organization, and be aware of the needs of all parties.

C.8 Sources of Funding for the Database

A core decision needing to be resolved is how the database shall be funded. There are two top-level options; it could be funded directly by government from general tax revenue, or it could be funded by a levy borne mainly by road users.

Direct government funding is simple and easy to implement, but it can make the system vulnerable to political interference and conflicting spending priorities.

Funding by a levy on road users removes the funding a step away from political control and could potentially provide a reliable funding source if properly organized. As it is, drivers who are the main cause of accidents, and their use of the road network could be a basis for raising revenue to manage their infractions. Two potential sources are a levy on fines imposed for traffic/safety offenses, or a road fund levy from vehicle licensing or fuel duties.

C.9 From Accident Database to Observatory

An accident database is the core and the starting point to take action to improve road safety. Built around the database can be a range of supportive information to help promote on-the-ground activity. The approach of bringing information together creates an “observatory” for road safety which has been used in Europe, and is recommended for the PRC. This section briefly introduces the European Road Safety Observatory (ERSO) and then describes the elements, in addition to the actual accident database, that support improvements in road safety.

C.9.1 European Road Safety Observatory

To support the ambitious goals of the European Road Safety Action Plan (2003) a requirement emerged for ERSO to become the primary focus for road safety data and knowledge.

SafetyNet was an Integrated Project funded by the Directorate General for Mobility and Transport (DG-TREN) of the European Commission, that provided the framework for the ERSO. It involved 22 institutes from 17 countries working for 4.5 years and completed in 2008. SafetyNet made proposals for common approaches in several areas including exposure data and Safety Performance Indicators. It extended the existing (CARE) database to incorporate the new EU member states and developed new fatal and in-depth accident causation databases. It also developed new statistical methods that can be used to analyze combined macroscopic and other data.

ERSO now supports all aspects of road and vehicle safety policy development at the European and national levels, and has been incorporated within the European Commission website.

C.9.2 Elements of an Observatory

Road safety policy and legislation—This section should contain national policies and legislation including responsibilities at different levels and geographic regions for collection and processing of data. It can also, include related issues such as enforcement legislation and responsibilities.

Reports based on accident data—This section contains processed "views" of the core accident data. Examples include an overview of basic statistics, maps of accident "hot spots," charts of processed figures, analysis by topic (such as type of accident, type of vehicle, etc.).

Projects and case studies—This section is for summaries of ongoing road safety projects and for case studies where safety has been addressed in specific ways.

Road safety knowledge products—This section is for scientifically sound advice on specific road safety topics such as speed, alcohol, driver licensing, mobile phones, roadwork signage, vulnerable road users.

External references—This is for other reference information such as manuals and best practice guides from different international organizations.

Queries and suggestions—This facility allows road safety practitioners such as road operators or local road administrators to issue requests to the central statistical service, such as tables of data for their region, or to make suggestions for new data sets and outputs.

C.10 Uses

An accident database on its own does not provide a safety benefit, but it supports development of evidence-based policymaking. Therefore, it is important to consider the uses for the data.

Examples of the ways in which national accident databases are used include:

- Compiling and publishing national statistics in a timely manner. These provide evidence for policy decisions and the data for monitoring the effectiveness of those decisions; progress against targets for safety improvements is also monitored both nationally and locally.
- Monitoring long-term trends to support research and policy development.
- Research to develop safety improvements and guidance for implementing them in the areas of road user behavior, vehicle and road design, traffic management and so on.
- Establishing priorities for local improvements such as engineering measures at specific sites, education programs and enforcement campaigns, and then designing the most effective measures to implement in the prioritized schemes.
- Measuring the safety of individual roads and monitoring the effectiveness of improvements as they are implemented, as in the International Road Assessment Program (iRAP) which is currently being developed for the PRC.[2]
- Planning the deployment of enforcement officers and other operational resources concerned with accident prevention and incident management.

C.11 Examples

C.11.1 United Kingdom

This section provides an example of a national accident database. This is from the accident database for Great Britain in the United Kingdom. The form used to collect the data is available from their website.[3]

Examples of how the database can be used are available on the Department for Transport's website.[4]

Using the website, road safety professionals can access and download the accident profile for local administrative areas, or make comparisons between areas.

It is possible to view an accident map of a local authority area as in Figure C2 using Crash Map.

The website also provides data showing trends in casualties and how casualty numbers relate to traffic flows and spending on road safety.

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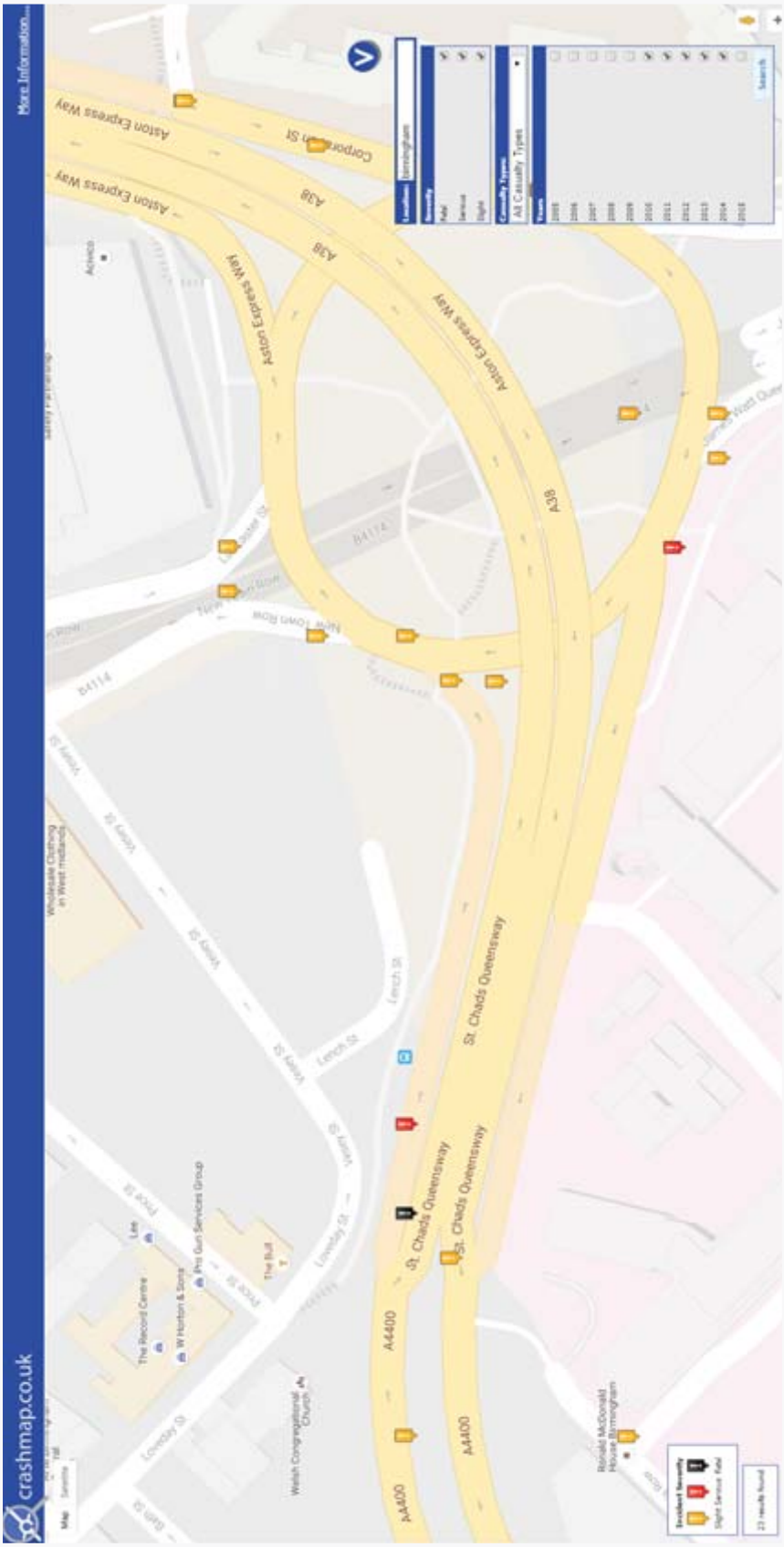
2 iRAP. http://www.irap.net/en/
3 Department for Transport. Road Safety Data. UK. https://data.gov.uk/dataset/road-accidents-safety-data/
4 http://www.crashmap.co.uk/Search

Figure C2: Example of Database Output for Local Area



Source: Crash Map. http://www.crashmap.co.uk/ (accessed July 2016).

C.11.2 United States

There are several searchable safety databases in the US.

The National Highway Traffic Safety Administration (NHTSA) operates the Fatality Analysis Reporting System. The site is maintained by NHTSA's Center for Statistics and Analysis. It contains data on all US vehicle accidents that occur on a public roadway and involve a fatality in the accident. The website[5] provides instant access to the Fatality Analysis Reporting System data via a Query Engine, Wizard, and Reports Library.

C.11.3 Japan

The Japan Traffic Accidents General Database (J-TAD) (macro) is maintained by the Institute for Traffic Accident Research and Data Analysis (ITARDA) from data collected by the government. Traffic accidents data and drivers' licenses data are provided by the National Police Agency. Vehicle registrations data and road traffic census data are provided by the Ministry of Land, Infrastructure, Transport and Tourism.

Japan police investigate all traffic accident cases, including fatalities and injuries, and records these cases without exception. Police investigations always include on-the-scene examinations, and are actually a prerequisite for insurance payment.

In addition to having comprehensive information on traffic accidents, the J-TAD (macro) database combines these with drivers' license data, vehicle registrations data, and other data.

ITARDA also maintains a database of selected accidents called Japan Traffic Accidents In-Depth Database (J-TAD) (micro) for which in-depth investigations have taken place.

With the Japan Traffic Accidents Databases, ITARDA conducts studies and analysis on traffic accidents to contribute to developing effective and efficient traffic safety measures in various fields.

ITARDA publishes books and booklets, and also provides lectures and seminars, in order to disseminate results of the research and analysis and to provide knowledge and ideas related to road safety. "Daily Fatalities," is an example of the publicly available statistics. It shows the number of fatalities for each day by region and prefecture. For example, there were 11 fatalities on 27 August 2014 of which one was in Tokyo.

ITARDA is a member of the Organisation for Co-operation and Development's International Road Traffic and Accident Database, and provides data for it.

[5] http://www.nhtsa.gov/FARS

C.11.4 Australia

The Australian Road Deaths (fatalities) database provides basic details of fatalities on the roads. Data from the individual states are combined together into a national database which is updated every month with the latest records. Published data includes the circumstances such as date, time, and type of accident, the speed limit of the road, and some information about the fatality: type of road user, age, and gender. The data are published by the Bureau of Infrastructure, Transport, and Regional Economics of the Australian government.[6]

The Australian Bureau of Statistics uses data to report trends over time at a national level, and comparisons between states in the fatalities per head of population, and per registered motor vehicle.[7]

Individual states also publish their own reports and analysis. The state of New South Wales describes the processing of accident data involving the New South Wales Police, a private organization which supplies coding and data entry services, and Transport for New South Wales, whose Centre for Road Safety is responsible for collating and disseminating road accident data (Transport for New South Wales 2011). A paperless system is used to record details, supplemented with a scanned copy of the site diagram—a sketch made at scene. Data collected at the scene are verified and supplemented with accurate location details. Data are held in the Centre for Road Safety's Traffic Accident Database System (TADS). The data are enhanced with the results of blood alcohol analysis from the Forensic and Analytical Science Service. The New South Wales Centre for Road Safety's accident reporting database, known as CrashLink, is used within Transport for New South Wales for monitoring and research, strategic planning, and producing reports and analyses. The database is also used by other government departments, the police, local authorities, motoring associations, and the general public.

C.11.5 Off-the-Shelf Accident Database Software

In more than 40 countries, the Microcomputer Accident Analysis Package (MAAP) accident data software is used to record and analyze accident data. iMAAP,[8] the latest version of this software, includes additional capability and has been developed for web access so that it can be implemented on servers within an organization or accessed from a cloud platform. A mobile version, iMAAP Mobile is also available. iMAAP has been implemented in several localities in the UK and has also been supplied to the National Road Safety

6 Australian Road Deaths Database. http://www.bitre.gov.au/statistics/safety/fatal_road_crash_database.aspx (accessed 3 July 2012).

7 Australian Bureau of Statistics. 2012. http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Accidents,%20injuries%20and%20fatalities~189

8 A software product available from TRL. http://trl.co.uk/solutions/safety/imaap/

Council in Ghana. In Abu Dhabi, Dubai, and Oman, iMAAP has been extended and customized to meet individual requirements. The iMAAP example illustrates how commercial off-the-shelf database software designed specifically for collecting, analyzing, and mapping accident data can help road safety professionals monitor trends, identify problems, establish safety targets, plan programs of countermeasures, and evaluate their effectiveness. Some of these benefits can be seen from examples of iMAAP implementations.

C.11.5.1 Himachal Pradesh

Himachal Pradesh has some unique road safety challenges resulting from its terrain and extreme weather conditions. Both iMAAP and iMAAP Mobile enable police officers to use tablet computers and mobile phones to collect real-time road accident data at the scene. Road safety specialists can use the analytical tools of the software to identify accident trends and clusters, enabling them to develop and deploy effective safety interventions. This project was supported by the World Bank.[9]

C.12 Summary of Recommended Requirements

The main requirements for accident data collection, storage, and analysis system can be summarized as follows:

- Relational database with records for accident, vehicles, and casualties defined in a common national standard.
- A national system for recording accident details at the scene, ideally recording details into the database using handheld electronic data entry devices with built-in checks on data quality (if electronic data entry is not feasible, paper records require stringent cleaning and checking process).
- Linking the accident database with hospital records to identify and reduce underreporting of casualties.
- Linking the accident database with database on drivers and roads to enhance accident data with contextual information.
- Integrating the accident database using software for managing, analyzing, and reporting data in tabular, graphical, and map form.
- Providing a national web-based service enabling organizations to access the database (anonymized where appropriate) and analyze data to meet their own requirements, whether these are for understanding road safety issues, designing improvements, or monitoring effectiveness.
- To ensure that the integrity and quality of stored data is maintained, database should be stored and managed by an independent body e.g., a statistical office whose main interest is maintaining data quality.

[9] TRL. 2014. iMAAP, TRL's world leading road traffic safety management system is commissioned by the Indian State of Himachal Pradesh.

C.13 Next Steps

The WHO provides an excellent step-by-step guide for the implementation of road safety data systems.[10]

C.13.1 Overview of the World Health Organization Data Systems Manual

The WHO road safety manual provides practical guidance for establishing data systems to improve measurement of a country's road traffic injury problem, facilitate selection of evidence-based interventions, and allow for better evaluation of progress.

This manual presents a conceptual framework for data-led road safety management, and presents steps for assessing the availability and quality of existing road safety data. It offers guidance both for making improvements to existing road accident data systems, and for the design and implementation of a new road accident data system.

Stressing the importance of comprehensive data systems that cover not only deaths (fatalities) and injuries from road traffic accidents, but also exposure measures, intermediate outcomes, and social costs, the manual acknowledges that most countries are struggling to establish quality data systems to document deaths (fatalities) and injuries. This practical guidance, related to improving data quality and improving effectiveness of data systems, focuses mainly on data related to deaths (fatalities) and injuries—and more specifically, on the implementation of an accident database derived from police records.

The manual also contains numerous case studies.

Module 1 explains why road safety data systems are needed. It presents a conceptual framework for data-led road safety management, and describes what data are needed by various sectors involved in road safety.

Module 2 provides an overview of how to assess the current status of road safety data collection. Four major components of the situational assessment are:

- Step 1: Identify people and agencies involved in the collection, management, and use of road safety data. Describe their roles, responsibilities, and relationships. Begin a dialogue with key stakeholders.
- Step 2: Identify existing data sources and systems. Describe their characteristics, and assess data quality with a focus on definitions, accuracy, completeness, and underreporting.
- Step 3: Describe the needs and expectations of end-users of road safety data.
- Step 4: Identify factors in the political environment that will facilitate or hinder proposals for improvements to road safety data systems.

[10] WHO. 2009. *Data systems: a road safety manual for decision-makers and practitioners.* http://whqlibdoc.who.int/publications/2010/9789241598965_eng.pdf?ua=1

Module 3 is concerned with design improvement and implementation of data systems. The key points noted are:

- Establish a working group of key stakeholders with technical responsibility for implementation. The working group should develop a long-term road safety data strategy as well as a short-term action plan. The group should define primary goals and technical requirements for the system, and use the situational assessment to determine the best course of action.
- Police are key stakeholders. Efforts to improve final outcome data will not succeed without them. Involve the police in all stages of project planning, and ensure police participation in decisions that will affect their workload and methods of working.
- The specification of minimum data elements allows a common dataset for describing road traffic accidents, their characteristics, and resulting injuries. The common dataset provides the information necessary for national analysis and road safety planning. This module proposes a set of minimum data elements and specifies uniform definitions and data values.
- Implement a 30-day definition for road traffic fatality. If it is not possible to apply this definition for data collection purposes, identify the appropriate correction factors and apply it to fatality data during data processing.
- Data quality can be improved by implementing minimum data elements, refining definitions, legal requirements to report injury accidents, improving data collection tools and procedures, improving methods used to identify and record accident location, training, and implementing quality assurance measures.
- Road accident data system performance can be strengthened by improving the flow of data through the system (from accident scene to final output), inclusion of useful features in the database system, and implementing a data management plan.
- Linkage to other databases can improve data quality if the other source is accurate, up-to-date, stable, and has accessible format. However, this is often not feasible because of issues such as incompatibility of databases or privacy concerns. The methods to assess underreporting described in Module 2 can be applied periodically as an alternative. In situations where other key databases (e.g., road inventory, vehicle registration, injury surveillance) are also in development, it may be easier to link databases or integrate data from other sources into the main accident database.
- Selection of consultants and suppliers requires research and careful consideration.
- "Off-the-shelf" software platforms can be an effective solution for new systems and can often be rapidly implemented. Products should be widely pre-tested and proven, and come with appropriate levels of support for database installation and support beyond the initial implementation period.
- The quality of non-fatal road traffic injury data can be improved by using appropriate definitions of severity for police reporting, organizing a follow-up mechanism between police and hospitals, periodic assessments of the accuracy of police-reported severity, periodic assessments of police underreporting of non-fatal injuries (allowing estimation of conversion factors), implementing a hospital-based injury surveillance system, linking databases (where feasible), and conducting population-based surveys.

C.13.2 Specific Steps for the People's Republic of China

The WHO document is generic, and in addition to the steps described in modules 2 and 3, several technical steps are also required to provide a systematic approach to the implementation of a national accident database taking into account the specific needs of the PRC. There is a need for policy review to ensure that implementation of any accident database aligns with current policy.

(i) *Review regional approaches:* To gain understanding of the existing regional accident recording systems operating in PRC today, in particular the standards, formats, quality requirements and processes, including ownership and arrangements for sharing.

(ii) *Review of previous trials and research:* It is understood that pilot trials of database systems have taken place. These should be reviewed to ensure that knowledge is gained and not lost, and knowledge gaps are identified.

(iii) *Identify options for harmonization and network coverage:* Investigate the creation of a single national accident database, incorporating inputs from regional systems where appropriate.

(iv) *Further research to support future implementation:* Issues identified in the previous steps are likely to identify knowledge gaps which will require additional research before implementation. These may include:

- Moving from paper to electronic record-taking,
- Integration between regional and national databases,
- Arrangements for access by road safety professionals and other stakeholders, and
- Running pilot trials: A project of this complexity and scale will benefit from a pilot trial where the specification and implementation can be validated and fine-tuned. Pilot trials should be administered in at least two distinctly different areas of the country e.g., a large city and a rural area.

APPENDIX D
APPLICATION EVALUATION

In this appendix, we evaluate the identified Cooperative Intelligent Transport Systems (C-ITS) applications to select which are most relevant to the National Trunk Highway System (NTHS) in the PRC. This selection has been done on the basis of expert judgement by the project team.

For all the identified applications, the following were evaluated:

- Does the application require, or benefit from, vehicle-to-vehicle (V2V) communications?
- Does the application require, or benefit from, short-range vehicle-to-infrastructure (V2I) communications?
- Does the application require, or benefit from, cellular V2I communications?
- Does the application require, or benefit from, intelligent central infrastructure (e.g., databases)?
- Does the application require, or benefit from, in-vehicle sensors?
- Can the application be retrofitted?
- Is the technology sufficiently mature to implement this?
- Are there already products on the market?
- Will there be products in 5 years?
- Will there be products in 10 years?
- Does the application provide real safety benefit?
- Does the application address an existing issue in the People's Republic of China (PRC) (as identified by the safety analysis)?
- What level of penetration is required? This is highly relevant as some applications provide a real benefit as soon as vehicles become equipped, while others only start providing a significant benefit with very high levels of penetration.

All the evaluation criteria other than the level of penetration required were evaluated as Y (required), N (not required), or Y/N where the criterion is optional depending on the exact implementation. For the level of penetration, the criterion is L (<10% penetration provides a real benefit), M (10%–90% penetration required) and H (>90% penetration required).

For this early analysis, it was decided that the most important issues which need to be addressed are:

- Will solutions be available on the market in the short- (5 years) or medium-term (10 years)? Note that this is more than just a technology issue, and it includes addressing liability, security, privacy, and economic issues. Further research will be needed to determine if this evaluation needs updating.
- Does the application provide a real safety benefit?
- Does the application address an issue in the PRC?

The two columns "Relevant in 5 years" and "Relevant in 10 years" were created by giving the evaluation criteria values of 1 for Y, 0.5 for Y/N, and 0 for N, and scored as follows:

- "Relevant in 5 years" = "Ready in 5 years?" * "Safety benefit?" * "Issue in the PRC?"
- "Relevant in 10 years" = "Ready in 10 years?" * "Safety benefit?" * "Issue in the PRC?"

The analysis is shown in Table D1.

Table D1: Application Evaluation

Application Analysis	V2V	V2I (DSRC)	V2I (Cellular)	Infrastructure	I-V sensors	Retro-fit?	Technology Ready?	Market ready?	Ready in 5 years?	Ready in 10 years?	Safety benefit?	Issue in the PRC?	Penetration required?	Relevant in 5 years	Relevant in 10 years
Hazard Warning															
Accident warning	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	L	1	1
Road condition	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	M	0	0
Vehicle breakdown	N	Y	Y	Y	N	Y	Y	N	Y/N	Y	Y	N	H	0	0
Pre-accident sense	Y	N	N	N	Y	N	N	N	N	Y	Y	Y	H	0	1
Ice and weather warnings	Y/N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	L	1	1
Hazardous location	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	L	1	1
Vulnerable user	Y/N	Y	N	Y	N	Y	N	N	N	N	Y	Y	L	0	0
Road works	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y/N	L	0.5	0.5
Traffic jam	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y/N	M	0.5	0.5
Low bridge	N	Y	Y	N	N	Y	Y	N	Y	Y	Y	N	L	0	0
Curve speed	N	Y	Y	Y	Y/N	Y	Y	N	Y	Y	Y	Y	L	1	1
Wrong-way driver	Y/N	Y	Y	Y	Y	N	N	N	N	N	Y	Y/N	H	0	0
Enhanced Driver Awareness															
IVS	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	L	1	1
ISA1–advisory	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	L	1	1
ISA2–supportive	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	L	0	1
ISA3–mandatory	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	L	0	1
Lane change, etc.	Y	N	N	N	Y	N	N	N	N	Y	Y	N	H	0	0
Automatic Crash Notification															
ACN including HGV	N	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	L	1	1
Efficiency															
Traffic info/route guidance	N	Y	Y	Y	N	Y	Y/N	Y/N	Y	Y	Y	N	H	0	0
Dynamic traffic management	N	Y	Y	Y	N	Y	Y/N	Y/N	Y	Y	Y	Y	H	1	1
C-ACC	Y	Y	Y	Y	Y	N	Y	Y/N	N	Y	Y	Y	H	1	1
Platooning	Y	Y/N	Y/N	Y/N	Y	N	Y/N	N	N	Y	Y	Y	L	0	1
Eco-driving support	N	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	L	0	0
Tracking and Tracing (TNT)															
TNT dangerous goods	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	L	0	0
Data Gathering															
Floating Vehicle Data	N	Y	Y	Y	Y	N	Y	Y/N	Y	Y	Y	Y	LMH	1	1

C-ACC = cooperative adaptive cruise control, DSRC = dedicated short range communications, H = >90% penetration required, HGV = heavy goods vehicle, I-V = infrastructure to vehicle, ISA = intelligent speed adaptation, IVS = in-vehicle signage, L = level of penetration <10% provides real benefit, M = 10%–90% penetration required, N = not required, PRC = People's Republic of China, V2I = vehicle-to-infrastructure communications, V2V = vehicle-to-vehicle communications, Y = required.

A score of 1 means that the application is relevant for the PRC in the relevant timescale, while a score of 0.5 means that it is partially relevant, i.e., it partially addresses a known issue. This shows that the applications listed in Table D2 are most relevant for the PRC.

As detailed from the analysis of accidents and driver behavior, estimates suggest between 2% and 7% potential fatality saving for hazard warning, and 7% from enhanced driver awareness due to speed advice. These are the first two groups of applications in Table D2.

The safety benefits of Automatic Crash Notification (ACN) have been sufficiently recognized in Europe that the eCall system is to be mandated. Particularly, if trucks are included in deployment, ACN is also expected to offer safety benefits in the PRC. This is the third main application in Table D2.

The case for V2V benefit is weak until most vehicles are equipped. While autonomous sensing provides immediate and progressively increasing benefits as vehicles are equipped, V2V does not provide benefits until most vehicles are equipped. Since this project focuses on Cooperative Intelligent Transport Systems, the noncooperative vehicle safety application (such as collision warning and mitigation) are not featured in Table D2. However, in the efficiency area, Cooperative Adaptive Cruise Control and Platooning are included. These are functions that can only be implemented using V2V technology; i.e., there is no noncooperative version.

Table D2: Relevant Cooperative Intelligent Transport Systems Applications

Application	Relevance
Hazard Warning	
Accident warning	Relevant in 5 years
Pre-accident sense	Relevant in 10 years
Ice and weather warnings	Relevant in 5 years
Hazardous location	Relevant in 5 years
Road works	Partially relevant in 5 years
Traffic jam	Partially relevant in 5 years
Curve speed	Relevant in 5 years
Enhanced Driver Awareness	
IVS	Relevant in 5 years
Advisory ISA (ISA 1)	Relevant in 5 years
Supportive or Warning ISA (ISA 2)	Relevant in 10 years
Intervening or Mandatory ISA (ISA 3)	Relevant in 10 years
Automatic Crash Notification	
ACN including HGV	Relevant in 5 years
Efficiency	
Dynamic traffic management	Relevant in 5 years
C-ACC	Relevant in 10 years
Platooning	Relevant in 10 years
Data Gathering	
Floating vehicle data (FVD)	Relevant in 5 years

C-ACC = cooperative adaptive cruise control, HGV = heavy goods vehicle, ISA = intelligent speed adaptation, IVS = in-vehicle signage.

Floating Vehicle Data is not a stand-alone application but is a building block for other C-ITS services including Dynamic Traffic Management and Hazard Warning; for this reason, it is included in Table D2.

APPENDIX E

OVERVIEW OF CURRENT INTELLIGENT TRANSPORT SYSTEMS ARCHITECTURE IN THE PEOPLE'S REPUBLIC OF CHINA

The second edition of the People's Republic of China's National Intelligent Transport Systems (ITS) Plan, developed from 2001 to 2005, sets out an ITS Architecture for the PRC. The high-level architecture is summarized below.

User services: Three hierarchical levels including 9 service domains, 47 services, and 179 subservices. The nine service domains at the top level are listed as follows:

No.	Name
US1	Traffic Management
US2	Electronic Payment
US3	Transportation Information Service
US4	Intelligent Highway and Assistance for Safe Driving
US5	Transportation Security
US6	Transportation Operation Management
US7	Multimodal Transportation
US8	Transportation Infrastructure Management
US9	ITS Data Management

ITS = intelligent transport systems, US = user service.

Source: ADB consultants.

Logical framework: Four hierarchical levels including 10 functional domains, 57 functions, 101 subfunctions, and 406 processes. The 10 functional domains at the top level are listed as follows:

No.	Name
LF1	Traffic Management
LF2	Electronic Payment
LF3	Transportation Information Service
LF4	Emergency Management
LF5	Passenger Transit Management
LF6	Freight Management
LF7	Urban Public Transportation Management
LF8	Intelligent Highway and Assistance for Safe Driving
LF9	Transportation Infrastructure Management
LF10	ITS Data Management

ITS = intelligent transport systems, LF = logical framework.

Source: ADB consultants.

Physical systems: This part includes three hierarchical levels including 10 systems, 38 subsystems, and 150 system modules. The 10 systems at the top level are listed as follows:

No.	Name
PS1	Traffic Management System
PS2	Electronic Payment System
PS3	Transportation Information Service System
PS4	Security and Emergency Management System
PS5	Passenger Transit Management System
PS6	Freight Management System
PS7	Urban Public Transportation Management System
PS8	Intelligent Highway and Assistance for Safe Driving System
PS9	Transportation Infrastructure Management System
PS10	ITS Data Management System

ITS = intelligent transport systems, PS = physical system.

Source: ADB consultants.

Applications: This part includes two hierarchical levels including 10 application domains and 58 applications, which are shown as follows:

Application Domains	Applications
Traffic Management	122 call center
	CCTV surveillance
	GIS
	Information dissemination
	Police patrol vehicles GPS positioning system
Electronic Payment	Electronic payment for parked vehicles
	Electronic payment for urban congestion charging
	Electronic payment for urban buses
	ETC
	Electronic payment for value added traffic information services
Transportation Information Service	In-vehicle navigation system
	In-vehicle traffic information service system
	Travel planning system
	Customized information service system
	Car-pooling information system
	Call center traffic information system
	PDA-based traffic information system
	Traffic yellow page information system
	Traffic information inquiry system
	Traffic information service website
	Traffic information broadcasting system
	Traffic information customer service
	Traffic information digital broadcasting system
	VMS
	Traffic Information booth
	Information center based navigation system

continued next page

Application Domains	Applications
Passenger Transit Management	Policy enforcement management system (passenger transport)
	Coach stations inter-operational ticketing system
	Passenger transport hub information system
	Passenger transport company operations and management system
Freight Transport Management	Policy enforcement management system (freight transport)
	Freight transport company operations and management system
	Vehicle overloading management system
	Safety monitoring system for important vehicles
	Logistics hub information system
Traffic Management	Real-time and dynamic collection, processing, analysis and dissemination of traffic flow information
	Traffic accident management system
	Automatic traffic police system
	Traffic signal control system
	Traffic enforcement integrated information system
Urban Public Transport Management	Urban public transport security insurance system
	Urban public transport stations management system
	Urban public transport rescue and dispatch system
	Urban public transport passenger information service system
	Urban public transport electronic payment system
	Urban public transport planning system
	Urban public transport operation and dispatch management system
	Light rail transport operation and dispatch management system
	High-capacity BRT management system
	Public transport electronic board display system
Intelligent Highway and Assistance for Safe Driving System	In-vehicle assistance for safe driving system
	Roadside assistance for safe driving system
	Intelligent vehicle system
	Intelligent highway system
Transport Infrastructure Management	Integrated information management system for high-class highways
	Expressways surveillance and dispatch system
	Expressways operation and management system
	Policy enforcement management system
	Work zone management system
	Transport infrastructure maintenance and management system
	Road weather information system
Safety and Emergency Rescue	Transport safety management system
	Transport safety information website
	Emergency incident rescue system
ITS Data Management System	Transport integrated information platform
	Floating vehicle data collection system
	Traffic management information platform
	Passenger transport management information platform
	Freight transport management information platform
	Urban public transport management information platform
	Transport infrastructure management information platform

BRT = bus rapid transit, CCTV = closed circuit television, ETC = electronic toll collection, GIS = geographical information systems, ITS = intelligent transport systems, PDA = personal digital assistant, VMS = variable message sign.

Source: ADB consultants.

APPENDIX F

COOPERATIVE INTELLIGENT TRANSPORT SYSTEMS STANDARDIZATION

F.1 Cooperative Intelligent Transport Systems Standards Groups

Cooperative Intelligent Transport Systems (C-ITS) standardization in International Organization for Standardization (ISO) takes place through the ISO Technical Committee (TC) 204 Working Group (WG) 18 with convenor Hans-Joachim Schade. There is also a relevant joint working group under the responsibility of committee ISO/TC 22/Subcommittee (SC) 3 on vehicle station gateway (VSG).

WG18 has the following structure:

- Two active sub-working groups (SWG1 and SWG2)
- Nine active drafting teams (DT2, DT8) with standardization projects
- Liaisons: European Telecommunications Standards Institute technical committee on intelligent transportation systems (ETSI TC ITS), Society of Automotive Engineers (SAE), Trade in Services Agreement (TISA)
- External interfaces: ITS Coordination Group, EU–US task force and WGs, FOT, Amsterdam Group.[1]

Joint WG16/WG18	SWG1	C-ITS standards harmonization	K. Evensen (Norway)
	SWG2	Gap/Overlay analysis	S. Ueda (Japan)
	DT2	Applications management	H.-J. Fischer (Germany)
	DT3	LDM	A. Schalk (Austria)
	DT4	Architecture (R&R)	T. Herb (Germany)
	DT5	Applications (In-vehicle signage)	L. Blaive (France)
	DT6	Message handling	T. Ernst (France)
	DT7	Applications (Contextual speeds)	P. Mieybégué (France)
	DT8.1	Message Sets (SPaT, MAP, SRM, SSM)	B. Christie (United States)
	DT8.2	Message Sets (PVD, PDM)	P. Spaanderman (The Netherlands)
	DT8.3	Message Sets (IVI)	J. Tiijink (Austria)
	Liasons	ETSI, SAE, TISA	H.-J. Schade (Germany)
	Interfaces	ITS–CG, EU–US TF and WGs, FOT, Amsterdam Group	H.-J. Schade (Germany)

CG = Coordination Group, C-ITS = cooperative intelligent transportation systems, DT = drafting team, ETSI = European Telecommunications Standards Institute, EU = European Union, IVI = in-vehicle information, ITS = intelligent transportation systems, LDM = local dynamic map, MAP = map data, PDM = probe data management, PVD = probe vehicle data, R&R = Roles and Responsibilities, SAE = Society of Automotive Engineers, SPaT = signal phase and timing, SRM = signal request message, SSM = signal status message, SWG = special working group, TF = task force, TISA = Trade in Services Agreement.

Source: ADB consultants.

[1] The European group comprising representatives of four organizations for road authorities, toll road operators, urban road authorities, vehicle manufacturers, and communications.

SWG1 C-ITS contributes to the standards harmonization activities by the EU–US–Japan cooperation (according to clause 10 of the EU–US Joint Declaration on Cooperative Systems for ITS). Work has included security and CAN (controller area network) messages.

As C-ITS is relatively new, a fully structured approach to standardization is currently missing. However, there is some European Commission funding provided and the situation is improving but would benefit from more participation.

F.2 Status Overview

Table F1 provides information of the status with the various standards texts.

Table F1: Status of Cooperative Intelligent Transport Systems Standards Being Developed

Reference	Title	Status
TS 17419	Cooperative Systems—Classification and management of ITS applications in a global context	DTS ballot submission to CEN/TC278 and ISO/TC204 ends on August 2013. The document was published in April 2014.
TS 17423	Cooperative Systems—ITS application requirements for selection of communication profiles	DTS ballot submission to CEN/TC278 and ISO/TC204 closing on 25 January 2014. The document was published in April 2014.
TR 17424	Cooperative Systems—State of the art of Local Dynamic Maps concepts	DTR ballot submission to CEN/TC278 and ISO/TC204 closing on 20 December 2013. The document was published in May 2015.
TS 18750	Cooperative Systems—Definition of a global concept for Local Dynamic Maps	Circulated for comment/vote closed on 20 December 2013. Two rather adverse comment forms received from France and Austria. Subsequent joint NP–CD comment only ballot approved with comments. The document was published in May 2015.
TS 17427	Cooperative Systems—Roles and responsibilities in the context of cooperative ITS based on architecture(s) for cooperative systems	DTS ballot submission to CEN/TC278 and ISO/TC204 closed on 24 January 2014. The document was published in July 2014.
TS 17425	Cooperative Systems—Data exchange specification for in-vehicle presentation of external road and traffic related data	The document was published in May 2016.
TS 17429	Cooperative Systems—Profiles for processing and transfer of information between ITS stations for applications related to transport infrastructure management, control and guidance	Still under development.
TS 17426	Cooperative Systems—Contextual speeds	The document was published in March 2016.
TS 19091	Cooperative ITS—Using V2I and I2V Communications for Applications Related to Signalized Intersections	NWIP/NP ballot submitted to CEN/TC278 and ISO/TC204 Closed on 29 August 2013. Approved as NWI. Still under development.
TS 19321	Cooperative ITS—Dictionary of In-vehicle Information (IVI) data structures	ISO/TS 19321:2015 document was published in April 2015.

CEN = Comité européen de normalisation, DTS = draft technical specifications, I2V = infrastructure-to-vehicle, ITS = intelligent transport systems, ISO = International Organization for Standardization, NP-CD = new proposal – committee draft, NWI = new work item, NWIP = new work item proposal, TC = technical committee, TS = technical standard, V2I = vehicle-to-infrastructure.

Source: ADB consultants.

F.3 International Organization for Standardization Topics

- **TS 17419** "Cooperative Systems—Classification and management of ITS applications in a global context"

TS 17419 specifies nontechnical and technical elements and procedures needed for registration and management of ITS application objects for C-ITS based on the specification of the globally unique "ITS application object identifier" (ITS-AID) and related technical elements for classification, registration and management of ITS application objects provided in ETSI TS 102860. The major focus is on international applicability for C-ITS based on the ITS communications architecture and the concept of operation in an ITS station as specified in ISO 21217. Starting with an architectural description of classification and registration, the two major clauses of the deliverable provide details of the organizational framework and the technical framework.

- **TS 17423** "Cooperative Systems—ITS application requirements for selection of communication profiles"

TS 17423 specifies requirements in technical terms to be used for automatic selection of communication profiles in an ITS station, (i.e., mapping of application flows to paths). Specification of procedures for the static and dynamic selection processes considers also the special needs of cooperative road safety and traffic efficiency applications. Major focus is on international applicability for C-ITS based on the ITS communications architecture and the concept of operation in an IT station as specified in ISO 21217, with consideration of technical elements specified in ETSI TS 102 860. Starting with an architectural description of the abstraction of ITS-S applications from ITS-S networking and access technologies, the two major clauses of the deliverable will provide the details of the ITS-S application requirements and the related ITS-S procedures for communication profile selection (initial flow-to-path mapping, and dynamic settings-handover).

- **TR 17424** "Cooperative Systems—State of the art of Local Dynamic Maps concepts"

TR 17424 delivers information about the current status of the Local Dynamic Map (LDM) concepts as they have been developed in the different research and development (R&D) projects in Europe, Japan, and the US. It presents different architectures, implementations, LDM functional blocks and the related standardization activities. TR 17424 proposes actions for future standardization activities and harmonization needs.

- **TS 18750** "Cooperative Systems—Definition of a global concept for Local Dynamic Maps"

This technical specification describes the functionality of a LDM in the context of the "Bounded Secured Managed Domain" (BSMD) and specifies the interfaces in an ITS station used to access an LDM.

- **TS 17427** "Intelligent Transport Systems—Cooperative Systems—Roles and responsibilities in the context of cooperative ITS based on architectures for cooperative systems"

TS 17427 provides a description of high-level architectural viewpoint on C-ITS. It can be used as a blueprint when implementing C-ITS and the corresponding organizational structures. The characteristics of C-ITS entail a huge number of data/information exchanges—therefore the implementation of the organizational architecture

stringently needs to respect privacy and data, which is defined in ISO 12859 (CEN TR WI 278314), and in national laws and regulations. Privacy and data protection affects all roles defined in this technical specification; due to these characteristics, all actors occupying roles in C-ITS need to respect the corresponding standards and regulations.

TS 17427 provides a methodology for the identification of service specific roles and their corresponding responsibilities based on a process oriented approach. Additionally, the defined methodology is used to identify the roles and responsibilities for C-ITS in general. The methodology, roles, and responsibilities for C-ITS are deduced from the reference model of "Open Distributed Processing." Open distributed processing offers five viewpoints of which the enterprise viewpoint corresponds with the organizational architecture—and the roles and responsibilities.

▶ **TS 17425** "Intelligent transport systems—Cooperative Systems—Data exchange specification for in-vehicle presentation of external road and traffic related data"

TS 17425 specifies the application that delivers information to ITS stations (vehicle or nomadic device) on road and traffic conditions qualified by road authorities/operators, in a consistent way with road authorities'/operators' requirements, in the manner that is coherent with the information that would be displayed on a road sign, or variable message sign (VMS/DMS). It complies with the ITS station reference architecture. This application is colloquially called "in-vehicle signage." The targeted draft includes the on-board information management, to be contextually coherent (e.g., vehicle characteristics, message priority, etc.). The production of information supporting this application, its qualification, and its relevance that are the responsibility of road authorities/operators (traffic control center or transportation management center in general) are not considered. It does not specify the design of in-vehicle human-machine interface but it does specify requirements that such interfaces shall be capable of supporting in order to permit the correct deployment and use of the "in-vehicle signage" end-user service.

▶ **TS 17429** "Intelligent transport systems—Cooperative Systems—Profiles for processing and transfer of information between ITS stations for applications related to transport infrastructure management, control and guidance"

The purpose of TS 17429 is to specify the profiles for processing the collected information at the receiving ITS station, and transferring the processed data to other ITS stations for applications related to transport infrastructure management, control, and guidance.

This TS specifies a set of communication requirements and objectives (profiles) using the methods defined in ISO 17423 to select the level of performance (i.e., best effort or real-time, etc.), confidence and security (i.e., authentication, encryption, etc.) for information exchange between ITS stations such as data provision, event notification, roadside configuration, and map update.

▶ **TS 17426** "Intelligent transport systems—Cooperative Systems—Contextual speeds"

In a C-ITS environment, contextual speeds are context-dependent (e.g., weather conditions), as well as time-specific and road section-specific authorized speeds. Subject to local regulations, they may be regulatory speed limits and/or recommended advisory ones.

TS 17426 will define and characterize "contextual speeds" in detail, with use cases. It will also specify the general service requirements for the support of this feature and provide recommendations for the definition of application profiles.

▶ **TS 19091** "Intelligent transport systems—Cooperative ITS—Using V2I and I2V Communications for Applications Related to Signalized Intersections"

The scope of this TS 19091 is to define messages and related data structures and data elements for the following exchanges between roadside equipment and vehicles:

- Definition of the signal phase and timing (SPaT) message transmitted from a traffic controller that describes the state of the signals and signal timing as necessary to support the applications identified herein. This will typically include such information as the passage time, permitted movements, future movements permitted, etc. The SPaT message is dependent upon the map data (MAP) message.
- Definition of the MAP message (which include the definition of motorized lane, vehicles, buses, trams, bicycle, pedestrian crosswalks, etc.).
- Definition of the messages to be exchanged between an intersection traffic controller and approaching vehicles (signal request message, signal status message) to support priority treatment as might be expected for special vehicles, such as emergency vehicles, freight transport, and public transport vehicles to improve safety, and operational and environmental efficiency.

The need for standardized communications to support interoperability in applications related to eco-driving, safety, and prioritization. A number of countries are using SPaT as part of their timing information and also prioritization. The only international standard that deals with some of these applications is the SAE J2735-2009. However, modifications need to be made to accommodate different national needs and to support new applications. The messages are intended for real time, short-range communications, but are not restricted to this environment.

▶ **TS 19321** "Intelligent transport systems—Cooperative ITS—Dictionary of In-vehicle Information (IVI) data structures"

This TS specifies the IVI data structures that are required by different ITS services (e.g., In-vehicle Signage such as Contextual Speed, Road Works Warning, vehicle restrictions, lane restrictions, Road Hazard Warning, Re-routing) to transmit information between ITS stations (I2V). The information will be specified in terms of content/data elements, and data structures. A general data structure that is future proof and extensible will be specified. A split into substructures will be done. The data structures are to be specified as communications agnostic. The TS needs to identify groups of potential communication services (e.g., broadcast) such as existing delivery mechanisms used by Transport Protocol Experts Group (TPEG), Data Exchange Interfaces generation II (DATEX II).

This technical specification will not provide the communication protocols. It is intended to address a combination of mobility applications to improve air quality, travel time efficiency and reliability, and safety. The messages that are required by different ITS services to transmit information from the central/roadside ITS station to other ITS stations will be specified. A set of operational situations will be evaluated as use cases and be used to describing the message, its message structure, and the dialogues required to support these. The TS will leverage from the existing field operational tests and deployments around the world and utilize existing standards such as SAE J2735.

F.4 Intelligent Transport Systems Standardization in the People's Republic of China

In order to promote ITS standardization and to make good use of experts from the areas in research, design, production, application, management, education, surveillance, and testing, the Ministry of Transport (MOT) had been promoting the establishment of the ITS standardization technical committee under the approval of the Standardization Administration of the People's Republic of China (SAC). In September 2003, the National Technical Committee 268 on ITS of the Standardization Administration of the PRC (SAC/TC268) was approved with a secretariat set up at the RIOH (National Center of ITS Engineering and Technology, China 2014).

The SAC/TC268 is the PRC's counterpart of the ISO/TC204. It is responsible for the administrative affairs of the technical standardization in the ITS sector. The main scope includes standardization of technology and equipment in the fields of advanced management systems for road transport, advanced traffic message service systems, advanced public transport systems, electronic toll collection, truck and fleet management systems, control system for intelligent highway and advanced vehicles, two-way and multimodal traffic short-range communications and information exchange, and management information systems for transport infrastructure (National Center of ITS Engineering and Technology, 2014).

The National Center of ITS Engineering and Technology, China website[2] records that specific responsibilities of the SAC/TC268 are:

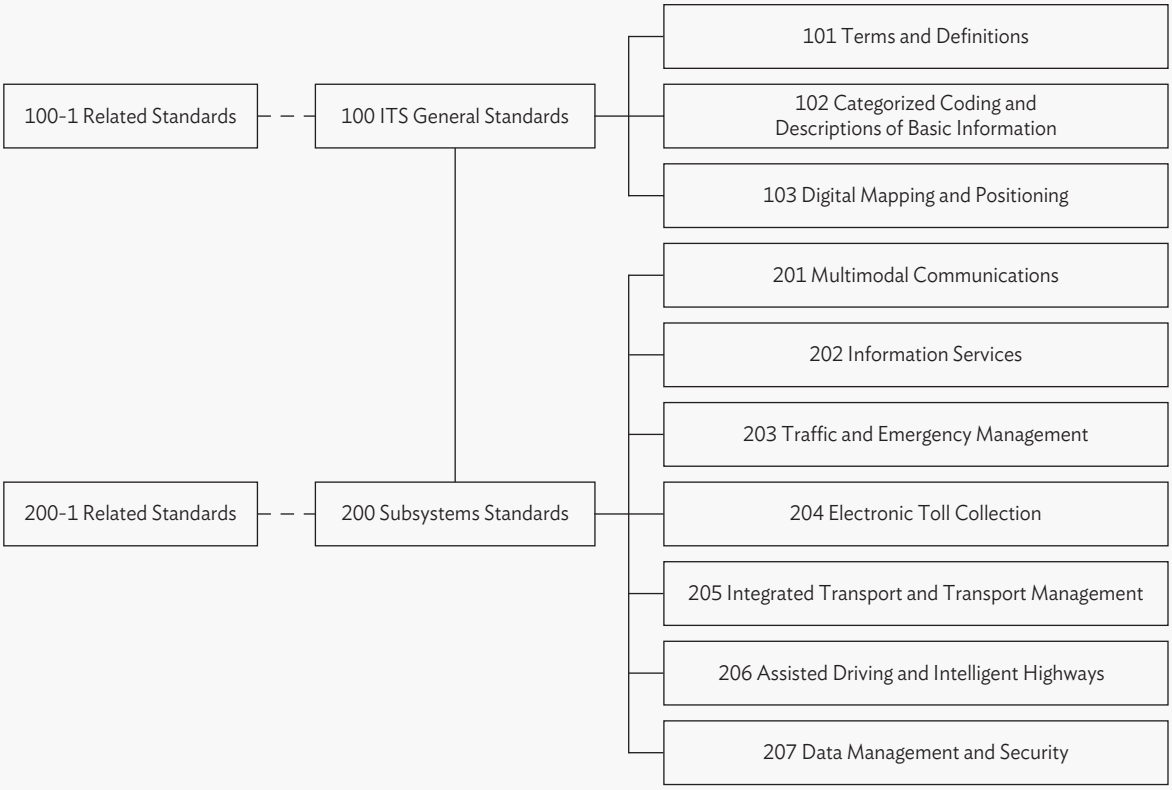
(i) To put forward policies and technical measures for ITS standardization to the SAC and other related administrations;
(ii) To put forward the annual developing and revising programs of ITS national and sector standards;
(iii) To assist in organizing the development, revision, and review of ITS national and sector standards;
(iv) To organize the examination of drafts for approval or revision of the ITS national and sector standards;
(v) To explain and promote ITS national standards;
(vi) To conduct investigation of the situation for the implementation of standards;
(vii) To undertake ITS standardization tasks relevant to the ISO and the International Electrotechnical Commission;
(viii) To undertake the evaluation of products' level of quality within ITS standardization range;
(ix) To examine standardization requirements in programs for ITS deployment;

[2] National Center of ITS Engineering and Technology, China. Standardization of ITS in China (in Chinese). Accessed 28 April 2014 from http://www.itsc.com.cn/article.php?id=10587

(x) To provide technical services such as formulation, examination, explanation, and consultation for ITS local standards and enterprise standards; and
(xi) To enhance the connection with the relevant commission of ISO such as knowledge exchange, and tracking international development.

The latest version of the architecture of ITS standards in PRC edited by SAC/TC268 is shown in Figure F1.

Figure F1: The Architecture of Intelligent Transport Systems Standards in the People's Republic of China



ITS = Intelligent Transport Systems.

Source: National Technical Committee 268 on Intelligent Transport Systems of the Standardization Administration of the People's Republic of China (SAC/TC268).

The planned architecture of ITS standards in PRC consists of more than 300 standards, of which approximately 10% have been published as of May 2012, indicating that there is still a long way to go. Table F2 illustrates the latest progress of ITS standardization in the PRC (SAC/TC268, 2013).

In addition, the SAC/TC268 is also actively participating in international activities. One of their major responsibilities is to vote on ISO draft standards. From June 2012 to May 2013, the secretariat of SAC/TC268 had voted on 60 ISO draft standards, including 1 preliminary work item, 1 new work item proposal, 19 committee drafts, 11 international standard drafts, 3 final international standard drafts, 16 technical specification drafts, 5 technical report drafts, and 4 committee internal ballots (SAC/TC268, 2013).

Table F2: The Progress of Intelligent Transport Systems Standardization in the People's Republic of China as of May 2012

	Published	Submitted for approval	Submitted for review	Submitted for discussion	Draft	Subtotal
100 ITS General Standards	7	2	0	0	2	11
201 Multi Modal Communications	5	0	0	0	0	5
202 Information Services	4	15	2	0	0	21
203 Traffic and Emergency Management	12	6	1	4	0	23
204 Electronic Toll Collection	6	5	0	0	5	16
205 Integrated Transport and Transport Management	5	2	7	0	1	15
206 Assisted Driving and Intelligent Highways	3	0	0	4	0	7
207 Data Management and Security	0	0	0	0	0	0
Total	**42**	**30**	**10**	**8**	**8**	**98**

ITS = Intelligent Transport Systems.

Source: ADB consultants.

F.5 Security Standards in the People's Republic of China

Security standards are dealt with in SAC/TC260. There are seven working groups (WG) within the SAC/TC260, including:

- WG1: Information Security Standard Architecture and Coordination;
- WG2: Information Security Standards for Secret-involved Information Systems;
- WG3: Password Technologies;
- WG4: Authentication and Authorization;
- WG5: Information Security Evaluation;
- WG6: Communication Security Standards; and
- WG7: Information Security Management.

The architecture of information security standards in the PRC can be summarized as follows (Fan 2008):

Tier 1: For systems involving secret information such as classified national secrets, special rules must be followed. However, most normal civil information systems such as ITS do not belong to this tier.

Tier 2: For information systems such as ITS which do not involve secret information, there is a set of standards called "information security classified protection," which consists of six levels of standards:

- Level 1: Fundamental standards, which provide guidance on how to divide the information security into different levels. Typical standards are:
  - Information security technology—Classification guide for classified protection of information system (GB/T 22240-2008)

- Level 2: Design standards, which provide guidance on the design of information security protection. Typical standards are:
  - Information security technology—Architecture framework of security classification protection for information system (GA/T 708-2007)
  - Information security technology—Fundamental model of security classification protection for information system (GA/T 709-2007)
  - Information security technology—Fundamental configure of security classification protection for information system (GA/T 710-2007)
- Level 3: Technology and management standards, which provide specific guidance for information security technologies and management. Typical standards are:
  - Information security technology—Implementation guide for classified protection of information system (under development)
  - Information security technology—Baseline for classified protection of information system (GB/T 22239-2008)
  - Information security technology—Common techniques requirement for information system security (GB/T 20271-2006)
  - Information security technology—Information system security management requirements (GB/T 20269-2006)
  - Information security technology—Information system security engineering management requirements (GB/T 20282-2006)
  - Information security technology—Security techniques requirement for operating system (GB/T 20272-2006)
  - Information security technology—Operating systems security evaluation criteria (GB/T 20008-2005)
  - Information security technology—Security techniques requirement for database management system (GB/T 20273-2006)
  - Information security technology—Database management systems security evaluation criteria (GB/T 20009-2005)
  - Information security technology—Basis security techniques requirement for network (GB/T 20270-2006)
  - Information security technology—Common security technique requirement for application software system (GB/T 28452-2012)
  - Information security technology—Information system security management assessment requirements (GB/T 28453-2012)
  - Information security technology—Physical security technical requirement for information system (GB/T 21052-2007)
  - Information security technology—Risk assessment specification for information security (GB/T 20984-2007)
- Level 4: Standards for information security products. Typical standards are:
  - Information security technology—Technical requirements of virtual private network security (GA/T 686-2007)
  - Information security techniques—Public key infrastructure—Technology requirement for security classification protection of PKI system (GB/T 21053-2007)
  - Information security techniques—Public key infrastructure—Evaluation criteria for security classification protection of PKI system (GB/T 21054-2007)

- Information security technology—Technical requirements for router security (GB/T 18018-2007)
- Information security technology—Routers security evaluation criteria (GB/T 20011-2005)
- Information security technology—Technique requirements and testing and evaluation approaches for firewall products (GB/T 20281-2006)
- Information security techniques—Security requirements for network switch (EAL 3) (GB/T 21050-2007)
- Information security technology—Evaluation criteria for switch security (GA/T 685-2007)
- Information security technology—Technical requirements of gateway (GA/T 681-2007)
- Information security technology—Technique requirement for network vulnerability scanners (GB/T 20278-2006)
- Information security technology—Technique requirements and testing and evaluation approaches for firewall products (GB/T 20281-2006)
- Information security technology—Packet filtering firewalls evaluation criteria (GB/T 20010-2005)
- Information security technology—Technique requirements and testing, and evaluation approaches for intrusion detection system (GB/T 20275-2006)
- Information security technology—Testing and evaluation approaches for network vulnerability scanners (GB/T 20280-2006)
- Information security technology—Security techniques requirements of separation components of network and terminal equipment (GB/T 20279-2006)
- Information security technology—Testing and evaluation techniques of separation components of network and terminal equipment (GB/T 20277-2006)
- Information security technology—Technical requirements, testing and evaluation approaches for information system security audit products (GB/T 20945-2007)
- Information security technology—Security techniques requirement for server (GB/T 21028-2007)
- Information security technology—Testing and evaluation requirement for server security (under development)
- Information security technology—Technology requirement for terminal computer system of security classified protection (GA/T 671-2006)
- Information security technology—General security technique requirements and testing and evaluation method for terminal computer (GB/T 29240-2012)

☐ Level 5: Standards for information security inspection and management. Typical standards are:

- Requirements for the management of technical services for information security classified protection (under development)
- Requirements for the operation of inspection and examination for information security classified protection (under development)

☐ Level 6: Design standards for information security regulations and plans in different industries. Typical standards are:

- Highway and waterborne transport industry classification guide for classified protection of information system (under development).

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Safety and Intelligent Transport Systems Development in the People's Republic of China

This report identifies factors which contribute to collisions that can be addressed by intelligent transport systems technologies in the People's Republic of China. It examines opportunities for establishing a policy framework for the development and implementation of mobile-communication-based cooperative intelligent transport systems (C-ITS) using connected vehicle-to-vehicle and vehicle-to-road-infrastructure technologies. Some C-ITS applications identified and relevant to the People's Republic of China are cooperative hazard warning systems and enhanced driver awareness and control. Government and industry—particularly the automobile industry—are the key stakeholders to realizing the deployment of C-ITS.

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