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Fostering a better life
through sustainable mobility

> AN OVERVIEW REPORT
ON THE CURRENT STATUS
AND IMPLICATIONS OF:

ROAD SAFETY
AND CONNECTED
MOBILITY

INTERNATIONAL ROAD SAFETY & CONNECTED MOBILITY TASK FORCE - MICHELIN CHALLENGE BIBENDUM 2014

AN OVERVIEW REPORT ON THE CURRENT STATUS AND IMPLICATIONS OF ROAD SAFETY AND CONNECTED MOBILITY

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› ABBREVIATIONS TABLE

ADAS	Advanced Driver Assistance Systems
AEBS	Advanced Emergency Braking System
AEVW	Approaching emergency vehicle warning
BRT	Bus Rapid Transit
CBW	Car breakdown warning
DSRC	Dedicated Short Range Communications
ESC	Electronic Stability Control
EBA	Emergency Brake Assist
EEBL	Emergency electronic brake light
GLOSA	Green-light optimal speed advisory
GPS	Global Positioning System
GIS	Geographic information system
HMI	Human Machine Interaction
ISA	Intelligent Speed Adaptation
ICT	Information and Communication Technologies
IEA	International Energy Agency
ITS	Intelligent Transportation Systems
IVS	In-vehicle signage & regulatory and contextual speed limit
NHTSA	National Highway Traffic Safety Administration
OECD	The Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
PCW	Post crash warning
RWW	Road works warning
TJAW	Traffic jam ahead warning
UMTRI	The University of Michigan Transportation Research Institute
V2V	Vehicle to Vehicle communication
V2I	Vehicle to Infrastructure communication
V2X	Vehicle to Other communication
V2P	Vehicle to Pedestrian
WW	Weather warning
WHO	World Health Organization
3G	Third generation of mobile telecommunications technology
4G	Fourth generation of mobile telecommunications technology

› AN OVERVIEW REPORT ON THE CURRENT STATUS AND IMPLICATIONS OF ROAD SAFETY AND CONNECTED MOBILITY

CHAPTER 1: STATE OF THE ART: ROAD SAFETY CONNECTED TECHNOLOGIES

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› EXECUTIVE SUMMARY

Over the course of its 11 prior editions, the Michelin Challenge Bibendum has provided a platform for the Michelin Group and its partners to prepare and acknowledge the substantial shift in mobility patterns.

The 2014 Michelin Challenge Bibendum central theme is: *Innovation in mobility at the heart of growth and urban well-being*.

For 2014, a Road Safety International task force, comprising leading international experts in road safety and connected mobility, has focused on the relation between interconnected mobility and road safety. The goal of this task force was to identify innovative and concrete solutions to be implemented by decision makers in high- and middle-income countries.

The present report introduces different connected technologies and applications. It also deals with the difficulties they may present. It has a broad approach of what connected mobility is and how it may solve road safety issues. As such, connected vehicles are only part of the equation. The report takes interest in intermodal transportation and nomadic connected devices such as smartphones and tablets.

The first chapter of the report makes a state of the art of connected technologies and applications while the second chapter makes some provisional[1] conclusions and addresses some guidelines on the implementation of connected devices. The goal of this second chapter is to have a realistic and ground related approach based on evidence and not on presumptions. These conclusions and guidelines are addressed to policy makers and private companies that are willing to use innovative solutions to decrease road-related fatalities and injuries amidst populations. Both chapters take into account the potential users of connected technologies: individual drivers, commercial drivers, pedestrians, cyclists and motorcyclists.

The task force decided to study first the potential of connected technologies in high- and middle-income countries. Indeed middle-income countries represent 72% of the World population, 80% of road traffic deaths and 47% of registered motorized vehicles, while high income countries are leaders in development of connected vehicles.

During their work the experts kept in mind the five Pillars of the Decade that helped them to build solutions that take into account all aspects that are necessary to reduce road traffic fatalities and injuries. These pillars were designed in support of the Decade of Action implemented by the United Nations. The goal of the Decade of Action is to reverse the number of fatalities on the roads. It could save, if implemented, 5 million lives, prevent 50 million injuries, and save US$ 3 trillion. The five directions that were designed for this purpose are:

›› Road Safety Management;
›› Safer Roads and Safer Roads Transportation Systems;
›› Safer Vehicles;
›› Safer Road Users;
›› Improved Post-Crash Care.

All of the five pillars aren't addressed in the same way within the report, the experts being aware that connected technologies can't solve all road-related issues. However a systematic approach is taken by the experts, taking into account the value of multidisciplinary and holistic analyses.

Having defined their methodological approach, the experts first study the road safety potential of Intelligent Transportation Systems (ITS) and other well-known technologies that are part of connected vehicles.

The massive spread all over the world of nomadic devices connected to the internet, such as smartphones couldn't be ignored either. Indeed some developers of smartphone applications underline the road safety potential of such technologies. The present report doesn't deny that some uses of smartphones while driving or even crossing a road, such as texting or web surfing are highly risky and should be discouraged. These activities involve hand use that makes them even more distracting. Having said this, the experts highlight the potential safety benefits of the use of some smartphone applications, which may be very similar to embedded connected technologies. For example, drivers can receive some alerts on traffic on their smartphones or tablets connected to their cars or even some suggestions to change their movement pattern.

However these connected technologies and applications are only a part of the notion of connected mobility: connected solutions are global; they are not related only to the vehicle user or infrastructure. One needs to think less in terms of the existing systems of vehicles and roadways, and more in terms of the emerging technologies and infrastructures for a «new mobility». This means thinking not just about how to avoid accidents on roads today, but how to intervene in road design, transport policy and urban planning so that: roads are made safer for pedestrians, cyclists, and others; new forms of connectivity emerge that may reduce demand for the use of roads and private vehicles.

The approach consists in thinking more about the next generation of moving people, moving goods, and moving less, in ways that are connected, cleaner, greener, safer, healthier, fairer, more inclusive, innovative, technology-enabled, etc. This is called a «whole system» approach. This involves how we use information technology across the board (big data, open data, mobile tech, interoperable systems, GIS and mapping, etc.). It also involves thinking about the implications of fractional use systems

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[1] Conclusions are provisional, because the task force highlighted the lack of studies on the impacts of connected technologies and applications on the road safety.

of shared/collaborative consumption; mobility management, aggregation and integration; mobile locative social networking and crowd sourcing; new strategic alliances such as public-private partnerships and city-to-city policy transfer; innovative financing mechanisms; and more.

Indeed connected technology is offering several benefits in improving mobility options, particularly in cities. New technologies are enabling people to take trips through either improved systems or entirely new applications and technology companies are taking innovative approaches to vehicle use in a shared economy. These trends have the prospect of improving safety for all road users by reducing the need to drive, thus lowering overall exposure to traffic crashes, and providing safer mobility for all road users, from car drivers to pedestrians. Some of these trends are being implemented quite rapidly in growing markets (car, bicycle sharing, mass transit technology improvements, etc).

It would therefore seem obvious that connected technologies and applications may bring more safety on highways, on rural roads and in cities. Despite this potential, some technical, legal and financial challenges need to be overcome in order to reach it completely.

The standardization of connected technologies is quite a fundamental issue for their implementation since it has huge impacts on economy of scale and more generally, on road safety. It is also quite a sensitive concern, since vehicle manufacturers are willing to produce unique products that would be competitive and original.

The legal framework will have to be adapted to all of the changes that connected technologies will produce in the society (connected vehicles will have an impact on how cities and highways will be built, how goods will travel from one point to another). Legal barriers for the implementation of connected vehicles may be even more important because of the definition of the responsibility in case of crash. The notion of driver and constructor responsibilities in case of a crash will have to be clearly defined to make possible the implementation of connected technologies.

Connected technologies and applications will produce a huge amount of Data. It is obvious that this information will be very valuable and a great amount of actors will be willing to take advantage of it at a lower cost. This Data will be possibly used to improve infrastructures, for traffic management, for road safety alerts but also for commercial purposes, i.e. some insurance companies may use collected Data for risk evaluation. This means that Data ownership will have to be defined. Also this Data will raise the key issue of privacy and of the danger of being hacked.

Mass deployment of connected technologies may be also a challenge. While the equipment of the major part of the fleet is a condition for the efficiency of connected technologies, the investment of public authorities and private companies as well as users' willingness to pay may be problematic in the current economic climate.

Despite these barriers, the experts address to public and private decision-makers a few conclusions and guidelines on the implementation of connected technologies from the economic, legal and societal points of view.

The experts underlined interests that public and private decision makers may find in the implementation of connected technologies.

Indeed ITS and other connected applications have several functions; Road Safety is only one of them. The development of ITS may represent high social benefits since it can also address the following issues:

›› reduce congestion
›› reduce energy consumption and traffic emissions
›› improve quality of life in city centres
›› increase market share of clean vehicles in private and public fleets
›› increase efficiency of the transport system
›› increase attractiveness of public transport/ encourage modal shift
›› facilitate freight delivery and servicing

Furthermore the benefits of the implementation of such technologies may have positive impacts on economic growth (research, infrastructure building, more efficient freight transport…).

Having pointed out road safety potential and implementation challenges of connected technologies and applications, the experts clarify that the present report doesn't aim at saying that connected technologies and applications are THE solution to road crashes. The experts realize that in order to be road safety-efficient, some connected technologies need to be supported by basic passive safety devices and some ADAS[2].

Connectivity should be embedded in a human factors approach (systematic vision), distraction problems should be prevented and road users need to be able to react if systems/devices fail to work. These are important conditions for the road safety efficiency of connected technologies.

The task force makes an attempt to assess road safety efficiency of some well-known connected applications through analyse of existing studies and literature. Even though some technologies seem quite promising, the experts encourage developers to further their studies on road safety impacts of connected vehicles, infrastructures and applications.

The attention of public authorities and private companies is also driven to the fact that each region or country may require its own connected mobility solutions. Indeed, connected solutions that may be useful in some areas of the world could be harmful in others. Several factors determine success: culture, economy, politics, legal system, infrastructure development. They need to be seriously studied before decision- makers decide to develop one of the connected technologies to solve road safety issues in a given county or region.

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[2] Advanced Driver Assistance Systems.

STATE OF THE ART: ROAD SAFETY CONNECTED TECHNOLOGIES
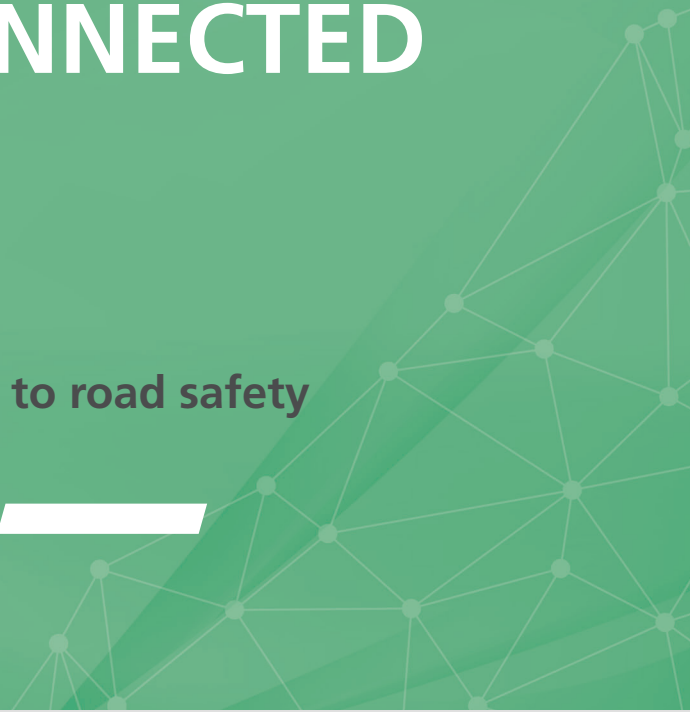
›INTRODUCTION

Mobility is growing in countries with the largest populations and it will keep growing for the years to come. Transport activity growth will be particularly high in developing countries according to a World Business Council for Sustainable Development report[3]. In 2011 the International Energy Agency (IEA) estimated that by 2035 1.7 billion cars will be on the roads[4].

The world is becoming «**fully-connected**»[5] thanks to the rise and sophistication of communication systems that allow people to connect instantaneously and transfer a great amount of data in almost real-time around the world. Access to the Internet through mobile phones or other devices has strengthened this e-connection. In 2013 there were 6.8 billion mobile phone subscribers, a number fast approaching the global population level. CISCO believes there will be 50 billion connected devices in 2020: 7 connected devices per individual. The 2013 World Economic forum report uses the notion of «**hyperconnectivity**» to describe the «interconnectedness of everyone with everything»[6].

There is an **increasing trend** of **road crashes at a Global level** (in low- and middle-income countries the trend is increasing, while in high-income countries it is stable or decreasing). Every year, approximately 1.24 million people die on the world's roads, and another 20 to 50 million are victims of nonfatal injuries as a result of road traffic crashes, according to the 2013 WHO's Global Report on Road Safety. The WHO estimates road traffic injuries to be the eighth leading cause of death in the world. Furthermore, road traffic crashes are tending to increase, particularly in low- and middle-income countries. This is partly due to the population growth and the boom of motorisation. While road traffic crashes rates are decreasing in some high-income countries, the fast proliferation of road traffic crashes in low- and middle-income countries has led to an overall global increase in deaths and injuries. According to the current trends, the WHO estimates that road traffic injuries can become the 5th leading cause of death by 2030.

Since the topic of the present report is the correlation between Road Safety and connected applications, it was decided to study first the potential of these technologies in high- and middle-income countries. Indeed middle-income countries represent 72% of the World population, 80% of road traffic deaths and 47% of registered motorized vehicles. This means that the level of fatalities is highly disproportionate to the level of motorization. In middle income countries road traffic death rates per 100,000 inhabitants is the highest at 20.1. At the same time technology innovation is very rapid in these countries and the time for implementation of connected technologies may be even shorter than in high income countries. Nevertheless it remains important to keep studying the impact of connected technologies on road safety even in high income countries, since, for the moment, most innovation in this field comes from these countries.

> **Since different factors need to be taken into account to build connected solutions, one has to introduce first some typologies of risk factors and a definition of connectivity in order to see clearly to what issues connected applications may respond.**

[3] The sustainable mobility project 2004 http://www.oecd.org/sd-roundtable/papersandpublications/39360485.pdf
[4] World Energy Outlook 2011 http://www.worldenergyoutlook.org/media/weowebsite/2011/executive_summary.pdf
[5] However, it is true, that in some communities problems of underconnectivity and inaccessibility are quiet real.
[6] Connected World Transforming Travel, Transportation and Supply Chains 2014 http://www3.weforum.org/docs/WEF_MO_ConnectedWorld_Report_2013.pdf

RISK FACTORS WITH DIFFERENT DEGREES OF IMPORTANCE

Traffic is a notion that presents a combination between all road users and risk factors they are under. Traffic is enforced by law (The traffic laws). Each user is then supposed to influence its driving to match (Page et Hermitte, 2008):

›› The general rules allegedly known since the user has passed a Driving license,

›› The assessed situation (Type of road used, reason for travel, vehicle driven …)

›› Other user presence at the same time at the same place.

Traffic system components show easily that the user is not responsible for everything. He/she does not construct roads and vehicles, has no control over weather or traffic conditions, traffic density, road works, missing signs… On the other hand, the user has to make decisions depending on trip conditions. Vehicles sold or road networks, even traffic control, should improve user safety and help improve their decisions.

The crash is a combination of various factors which create an emergency situation followed by an impact. One can refer to crash factors in relation to **user failure** (driving operator or pedestrian), **vehicle design or maintenance failure, road infrastructure failure** and a **deteriorated environment** (Weather or traffic conditions). Of course all of the factors presented in the paper don't have the same impact and rarely is one sole risk factor responsible for a road crash.

A healthy sober driver, in a powerful vehicle riding during daylight at 250 kph on an airport runway is less likely to have a crash than a drunken operator driving at 100 kph on a secondary road by night. In the second part of the introduction this systematic approach will be further developed. However, to start this presentation one can assume it is possible to separate factors in order to facilitate the analysis of their interactions.

Firstly one needs to highlight that all the risk factors presented below don't have the same level of impact.

Risk factors linked to individuals

A crash is not necessarily a consequence of reckless driving (or violation). A driver can make mistakes. An individual can take risks or perceive and wrongly interpret hazards or simply be in a situation he/she cannot deal with. Clinical, experimental or epidemiological studies show that the main major risk factors are associated with driver **status**, driver **experience** and **task difficulty**. For example:

›› Fatigue and drowsiness

›› Hypo vigilance

›› Health concerns

›› Inattention

›› Distraction

›› Nervousness, stress, aggressive behaviour

›› Alcohol or drug consumption

›› Lack of driving skills

›› Low experience of current situation

›› Time constraints

›› Excessive or inappropriate speed with respect to current traffic conditions

›› Reckless driving or dangerous manoeuvres

›› Safety distances alterations

›› Reactions not adapted to an emergency situation

›› Driving mistakes…

These factors are either associated to psychological, physiological or social characteristics of the individual (over-reaction, sleep apnea, chronic alcohol consumption for example) or to transient characteristics (driving after a family gathering, being late, speeding, low driving skills, …). These factors actually produce functional failures that are of 5 kinds: wrong, late or absent **perception, diagnosis, prognosis, decision**, and **action (Van Elslande et al., 1997)**. A driver might not perceive a danger, might see something but not identify it as a danger, might wrongly anticipate the evolution of a driving situation, or might perceive and diagnose correctly without being able to take the adequate decision (steering for example) or take the correct course of action (insufficient braking for example).

Of course, each failure of a road user does not necessarily result in a crash; likewise smokers do not necessarily develop lung cancer. Failures increase crash risks without making them certain. In some well-known cases the presence of a risk factor greatly increases the risk. For example, a driver under the influence of 2g of alcohol per litre of blood is 80 times more likely to be involved in a crash than a sober driver. And a driver under the influence of cannabis is 1.8 times more likely to be responsible for a fatal crash than a driver without drug impairment (Laumon et al., 2005). This number is a statistical average since there is a relation between the dose (quantity of cannabis consumed) and the effect (crash risk).

Road Infrastructure risk factors

It is widely known that some road zones or sections are considered as «black spots» (French definition: 850m area or junction which have shown during 5 years at least 10 crashes and 10 severe victims). Generally these locations are part of a deficient road adequacy to the traffic or design which is not in concordance to the **7 safety rules** (Setras et Cetur, 1992):

›› Visibility

›› Readability

›› Adequacy to vehicle dynamics constraints

›› Swerving and recovery manoeuver

›› Impact severity mitigation
›› Consistency between all environment and carriage way items
›› Traffic Flow management in accordance with the safety coun-
    termeasures.

The basic principle of road infrastructure is that it should create
an environment which is easy for the road user to read and
understand and that it should be forgiving when road users
make mistakes. The road safety toolkit at toolkit.irap.org details
around 40 infrastructure features that enhance safety and des-
cribes how they are used and where they are effective. But to
try to summarize it in a few sentences:
›› Segregation of the road space into lanes and carriageways,
    the design of junctions, and the creation of special lanes for
    different types of road user all serve to reduce the conflicts
    that can happen in road space
›› Lines, signs, and traffic lights influence road user behaviour
    by providing information and they create the basis for traffic
    law enforcement
›› Barriers, shoulders, and clear run-off space provide recovery
    potential in the event of driver mistakes
›› Pedestrian crossings, footpaths, and cycle paths provide pro-
    tection for vulnerable road users
›› Lighting, road alignment, skid resistant surfacing facilitating
    driver control of the vehicle.

Each of these features has an impact on crash likelihood and
severity but their impacts vary by road user type and affect dif-
ferent crash types differently. The toolkit has the details and
these factors are all built into the iRAP model which gives a
broad assessment of safety impact. However the devil is in the
details. For example, some types of barrier construction are
more effective than others and some can be positively dange-
rous in certain situations. A detailed road safety audit is needed
to ensure that the design of road infrastructure features and
their method of construction are optimal for safety.

Evidence of the effectiveness of these sorts of measures comes
from comparing the relative fatality rates on motorways (which
are high speed and congested but have high quality infrastruc-
ture safety measures) with rural roads (which have very little
traffic and much lower speeds but low quality infrastructure sa-
fety features). The rural roads have five times as many fatalities
per vehicle km as the motorways, demonstrating that safety
features on motorways have made the higher speed traffic of
motorways much safer.

We also know that the road site risk level is more associated
with the combination of a few crash prone factors rather than
with the over representation of one of them. For example on
rural roads the trees positioned at less than 4 meters from the
road, the turn radii less than 250m combined with irregular
bend and/or poor road surface friction, non-stabilised road
sides, no road markings, ambiguous or no pre-signs, are factors
that reduce or prevent swerving manoeuvres.

Vehicle risk factors

Vehicle manufacturers and their partners have demonstrated
huge improvements in their vehicle design, perceptibly in the
continuous addition of embedded safety components. Progress
is noticeable in passive safety - features which limit the severity
in case of impact: safety belt, pretensioners, load limiters, air-
bags, intrusion mitigation countermeasures, energy absorbing
materials, vehicle components quality- and comfort.

Over the past 15 years, OEMs and their suppliers have been
developing active safety features which aim at avoiding crashes
(ABS, obstacle detection systems, on board electronics, lane
departure warning systems, brake assists, night vision, anti-
colliding radars, autonomous cruise control, speed monitoring
systems, ESC…). For newer vehicles, there are less and less risk
factors associated with the vehicle itself (Page et al., 2008).

For new cars risk factors are more connected to vehicle main-
tenance: mainly tyre or brake wear and light malfunction. We
know full well that vehicles on the roads are not all in good
conditions. For example, the French company UTAC publishes
annually statistics on the technical inspection results for vehicles
aged 4 years and older. These studies show that, in 2007, 20
millions of controls were performed, out of which 17.2 million
initial visits. 16.7 % of passenger cars did not demonstrate any
of the failures notified (511 elementary failures, out of which
214 need an additional check). 20% of the controlled vehicles
did not comply with the criteria, i.e. additional checks were
required for them.

Environmental risk factors

All others risk factors are included in this section: weather
conditions (sunny weather, rain, hail, wind, fog, snow), emer-
gency service conditions (which is a risk factor of injury severity
and not crash), traffic conditions (crowded, lane traffic …) and
of course the social organization of life and transport.

All main risk factors were presented here one by one. However
a global approach to study the root causes of crashes is nee-
ded, since it helps to detect some hidden dangers. Indeed all
safety actions are devoted to counter one or several risk factors,
either by Engineering (roads and vehicles), Education (driving
skills, risk consciousness, etc.) Enforcement (regulation and
enforcement of regulations) or Encouragement (information
campaign). This approach is advocated by the OECD and was
developed by academics such as Kare Rumar.

SYSTEMATIC APPROACH OF RISK FACTORS

Road crashes are rare events that always seem to happen to
other people, if they happen at all to anyone that we know
(OECD, 2008). This observation may seem to ring true for road
users in countries all over the world, yet the statistics tell us that
1.2 million people are killed annually on the road, and between

20 and 50 million are seriously injured (WHO, 2013). At a personal level (per trip, per kilometer and per citizen/year) the probability of being involved in a road crash and being fatally injured is very low. We are in road traffic every day and almost all of us arrive safely at our destination. We expect to arrive safely and this happens to almost all of us.

Are those who experience a crash simply unlucky and are crashes happening to just crash prone people? Many of us, as well as the media, the police and also quite some road safety professionals tend to believe that people who have a road crash are more likely to do so as they are more accident prone. This may be related to poor road behaviour, such as making errors or violating the rules of the road, both leading to a higher likelihood of being involved in an accident. A next step in this way of thinking is that we blame the ones who are involved in a crash. This view is shared by the police when commenting on the causes of crashes. They are trained to investigate whether illegal behaviour was a causal factor. The media often frame road crashes using the police's perspective, and as a result the popular view. However, research and data tells us that this perspective is not based on facts, or at least not fully.

Several studies have shown that the great majority of road crashes have involved human factors, such as errors, impairment, and violations on the part of the driver. In a minority of crashes, road related or vehicle related factors played a role. For many a solution to this finding is just to better educate and train road users, and in so doing prevent future crashes. Nonetheless, we have learned in the past that simply educating and training people for better road skills is not the best solution. More recent studies on the causes of road crashes, which used in-depth data, coroner reports or data from naturalistic driving studies, suggest a somewhat different story (see for example Elvik et al., 2009 and Wundersitz and Baldock, 2011). This viewpoint is also a result of the broader perspective the researchers have adopted. Elvik et al report that in about half of fatal crashes and over two-thirds of non-fatal injury crashes, driver error that was not related to breaking the law was identified. Wundersitz and Baldock arrived at the similar conclusion that road crashes leading to injuries are not a result of extreme risky or illegal behaviour, which is the case in more than 50% of fatal crashes. Here one can speak about a paradigm shift: not only does (extreme) unlawful road behaviour cause crashes, but so does the ordinary behaviour of drivers who make errors whilst behind the wheel. Secondly, road user characteristics and behaviour are similarly important, but only when not removed from their respective contexts. This paradigm shift has resulted in the development of the Safe System approach (OECD, 2008). The aim of this approach is to design and operate a road transport system that is better able to accommodate human error and manage kinetic energy in a crash to such levels that the risk of serious injuries in a crash is severely limited, if not removed altogether.

Recent studies have shed light on another factor. It is rare for there to be only one causal factor behind a road crash. In the majority of cases we have a variety of contributing factors and causes. This is illustrated when considering a road crash in the Netherlands (Wegman, 2012): an 18-year-old driver, who just passed his driving test, is driving his friends home in an old, second hand car from a party on Saturday night. It is raining, and he drives along a winding road with trees on either side. He is driving fast to impress his friends and misjudges a bend. What was the overlying cause of this crash? A young, inexperienced driver, driving at night under demanding conditions? Peer pressure? Inappropriate speed, an unexpected bend, bald flat tyres, trees on the bend? All factors might have influenced the chance of a crash and the severity of the outcome. The lesson to learn is not to look for a single cause or factor! Put differently, it is usually that the crash itself is preceded by a whole chain of pre-existing, contributing factors (Wegman, 2013). This means that it is not only one or a series of unsafe road user actions that cause a crash. Hiatuses in the traffic system also contribute to the fact that unsafe road user actions can in certain situations result in an accident. We should see the road user – in terms of his or her limitations and capacities – in the context of the total system.

These hiatuses are also called latent errors (Reason, 1990). These latent errors will not result in a road crash on their own; however a combination of latent errors and active, unsafe road user action will. This model developed by Reason is often called the Swiss Cheese model. The model contains multiple slices (of Swiss cheese) that double as layers of defence. Holes in the slices represent weaknesses in defence. The model has been adapted to road safety (see Fig. 1). A crash can only occur if several layers in the defence fail. This is a perfect demonstration of the well-known concept of road safety management, and that is the shared responsibility concept (WHO, 2004). In order to eliminate holes or make holes in the different slices considerably smaller, different actors have to act: from system designers (e.g. road authorities, car manufacturers, legislators), system operators (e.g. police forces, educators) to road users. Potential causes or contributing factors of road crashes, as introduced in the Dutch example above, can be located in different slices and not only in the two slices on the right hand side.

One of the first road safety experts in the world who fully understood this idea was the Swedish professor Kare Rumar (Rumar, 1999). In an excellent lecture Rumar introduced three levels of road safety problems:

›› Problems that were outwardly evident even at a superficial level of analysis (first order problems)
›› Problems revealed by deeper analysis (second order problems)
›› Problems that remain almost totally hidden (third order problems)
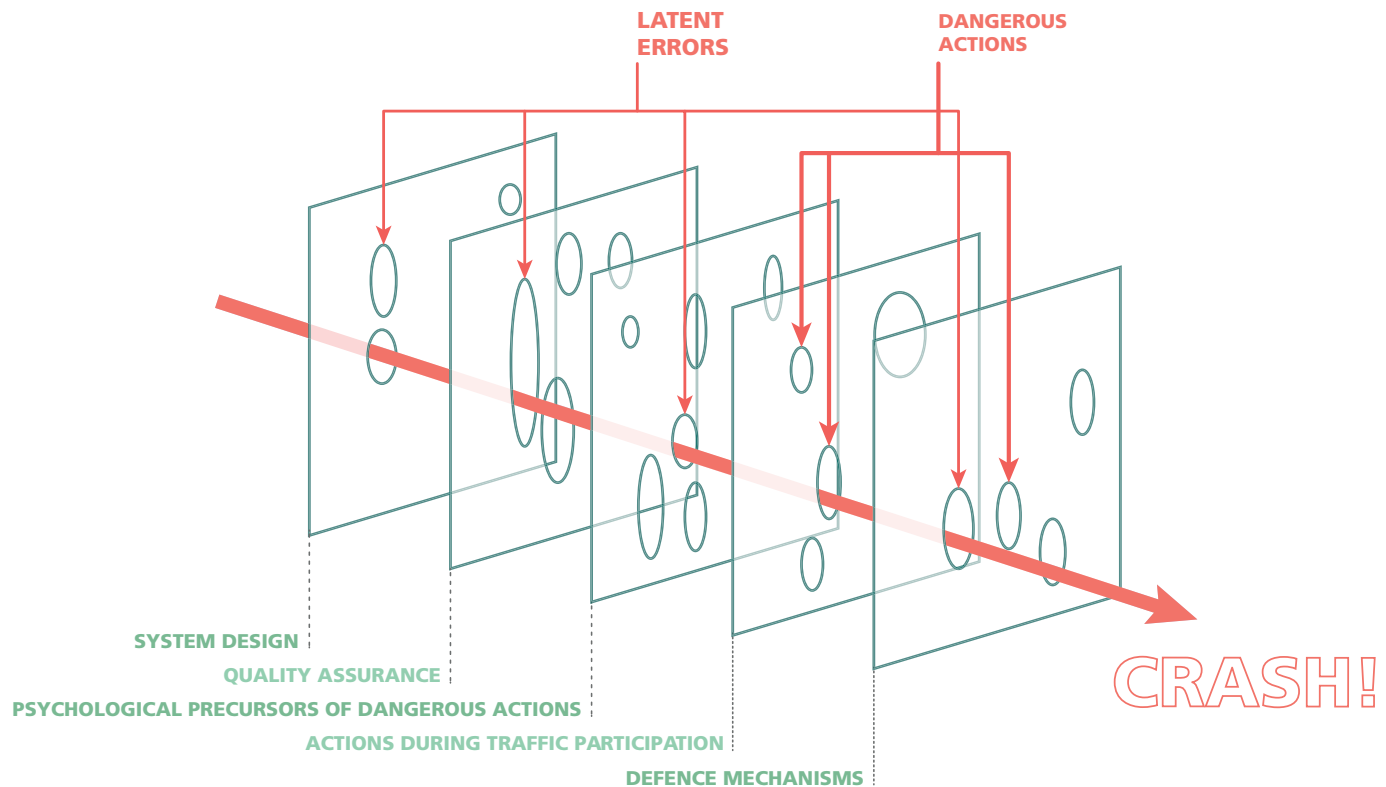
Fig. 1: Reason's Swiss Cheese model as applied to road safety indicating how crashes occur (Wegman and Aarts, 2004)

First order road safety problems come directly from the way we analyse our accident and injury statistics. When doing that, according to Rumar, countries have common first order problems, whereas the ranking of the problems is not identical. Examples include driving speeds, increased risk resulting from alcohol and drug abuse, vulnerable road users and the elderly who are at risk, inexperienced drivers, risks associated with winter weather.

Second order problems are defined by Rumar as 'reducing the effectiveness of countermeasures aiming at solving the first order problems'. Such second order problems are, for example, that legislation is not clear, logical and consistent. Moreover, enforcement is not efficient enough, the control of road and vehicle conditions from a safety point of view are insufficient, and training for and examination of drivers licenses are not good enough. Third order problems are often of a more general character, not dealing directly with the traffic situation but with underlying processes or conditions. These conditions may include the organisation of road safety work, decision processes, resources, coordination and roles. They may concern the awareness, the values and knowledge of road safety measures that are typical for ordinary citizens, decision makers, road safety workers as well as road users. Third order road safety problems prevent or block the possible solutions of the first and second order problems.

One can say that first and second order problems are depicted as holes in Reason's Swiss Cheese model. When trying to eliminate these holes third order problems have to be solved.

When it comes to the question of how Connected Mobility can help to improve road safety it is clear that its development and implementation should address the real nature of road safety issues and causes of crashes. Connected Mobility, if developed and deployed well, is to be considered as a very promising approach for addressing holes in the Swiss cheese model of Reason and the first and second order problems as identified by Rumar.

CONNECTIVITY UNDER STUDY

Mobile connectivity is linked to the ITS (Intelligent Transport Systems) and the notion of connected vehicle. However, connectivity is a larger concept which includes not only Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I) and Vehicle to Other (V2X) communication devices developed by vehicle manufacturers, but also computers, smartphones, tablets. Also some less known devices that don't involve drivers may save lives on roads thanks to connectivity. A peculiar example of such a technology can be found in Prague where blind residents

have a connected device that notifies them when the bus is approaching, and they are able to inform the bus driver of their intention to take the bus[7]. It is important to remember that the notion of connected mobility covers all means of transportation from two-wheeled vehicles, automobiles, trucks, buses. It can also concern pedestrians, if they use an electronic device which connects them. That is why it seems relevant to include inter-modal transportation and more broadly new mobility forms into the scope of the present analysis.

Connectivity may be motorized-, non-motorized-, vehicle-, pe-destrian- and infrastructure- related as following:

›› Driver to subject vehicle
›› Driver to other subject vehicle or objects
›› Driver to other personal devices
›› Subject vehicle to its own devices
›› Subject vehicle to other vehicles
›› Subject vehicle to external devices
›› Subject vehicle and infrastructure
›› Infrastructure/institution to vehicles or to drivers (encourage alternative use of vehicles)
›› Infrastructure/institution to pedestrians.

As a consequence, connected mobility may be defined as network platforms with multi-actor and multi-modal traffic environment. Also called mobility 2.0., it embraces several as-pects: vehicles, infrastructure, information and energy.

Having determined these definitions and typologies, the following question may be asked:

How can connectivity be a contributing factor in a further reduction of people killed and se-riously injured in traffic crashes?

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[7] Tifloset, http://www.apex-jesenice.cz/tyfloset.php?lang=en

›I. CONNECTED TECHNOLOGIES AND APPLICATIONS DESIGNED TO IMPROVE ROAD SAFETY

Connectivity may perform several road safety functions. Before we deal with the typology of road safety connected technologies and applications, connectivity functions need to be clarified.

I.1. CONNECTIVITY AND ITS IMPACT ON TRAFFIC SAFETY

I.1.1 ›› Connectivity related to the road traffic

Professionals and also the public now seem to be very much aware of what we call 'the connected vehicle', meaning vehicles connected to other vehicles, to infrastructures or to other surrounding devices. This is actually a technical definition that hides two different functional definitions of connectivity:

›› A driver or a passenger can be connected with the external world via a nomadic device (for example a smartphone or a tablet) which has nothing to do with the vehicles. He (or she) just uses the device while driving (or during a trip as a passenger) as he or she would use these devices outside the car. This is just the general continuation in the car of the very popular 'connected life'. Let's call him (her) the 'connected user'

›› A driver or a passenger can be connected via an integrated device which is embedded in the vehicle and can offer different types of services. In this case, the vehicle offers some services, which could overlap the services available with a nomadic device. Let's call it the 'connected vehicle'. Of course the connected vehicle mediates between the driver (and the passengers) and the external world. The connected vehicle can also give information to the rest of the world in case it is itself a sensor (for example if it detects a slippery road and then sends the information to surrounding traffic).

In both cases, the services provided by connectivity (whatever the technologies behind and whatever the medium, nomadic or integrated) can be classified according to the following taxonomy:

›› **Safety systems (crash prevention system)**: the service has a primary objective to prevent crashes and injuries. For example car-to-car communications can help in preventing crashes at intersections where visibility is reduced by buildings, trees, bus stops, whatever kind of fixed or mobile masks to visibility

›› **Driving assistance:** the service has a primary objective to help the drivers in performing a driving task (navigation, guidance or control). For example a navigation system helps the driver in choosing his (her) route and to follow directions that are proposed by the system.

These two categories can easily be grouped together since driving assistance systems often have a safety aspect too.

›› **Traffic information:** the service has a primary objective to help the driver know more about the traffic ahead, e.g. whenever a route is congested, road works are present ahead of the trip or whether a route is closed for whatever reasons

›› **Services related to transport,** usually called Intelligent Transport Systems, such as highways remote payment

›› **Services not related to transport,** often called infotainment (internet in the car, watching or downloading videos and many other applications currently available on smartphones and tablets…)

The connection is ensured by different kinds of technologies (3G, 4G, DSRC, etc.), which are beyond the scope of this paper but which present high performances as well as limits. Therefore, and especially for connected safety systems and driving assistance systems, the functions work under particular circumstances called 'use cases' and not in any circumstances. For example, as connected technologies usually use GPS to localize a vehicle or a person somewhere on earth, this information is known to be not very accurate (a few meters accuracy) which prevent from using it for crash avoidance for example (at least for the moment).

Moreover, international standards of principles edict some consensual rules for HMI (Human Machine Interaction) in order to properly design interfaces that are not distracting drivers (e.g. ESOP, 2006). These apply for any kind of manipulation in charge of the driver (radio tuning, navigation system use, etc.).

More broadly, connectivity of some nomadic devices may provide safety services to pedestrians. Also infrastructures can be connected to these road users to send them some alerts through their smartphones.

I.1.2 ›› Connectivity's safety functions

As mentioned above, connectivity offers services, some of them related to driving activities (and safety), some of them not related to driving activities. Therefore, the expected impact of connected services on traffic safety depends on the nature of these services:

›› As for services connected to driving activities and safety, one can expect a positive effect on safety due to reduction of risks (as this is the motivation of these kinds of services)

›› As for services not connected to driving activities, on can expect a negative effect on safety due to the increase in driver distraction.

Moreover, connected driving and safety services come in addition to already existing safety systems and driving assistance systems. These systems address specific risk factors or specific crash types or a combination of factors and crash types. For example, Electronic Stability Control addresses loss of control crashes that can occur in case of over speeding or in case of improper action due to physical impairment (fatigue, alcohol impairment, inattention, etc.) or in case of a bad road surface.

We suggest to categorize these existing safety applications according to the following split (Page et al, 2009; Barrios et al, 2008):

›› Primary (Pre-Crash) safety: these systems are intended to assist, inform or alert the driver by addressing one or several driving tasks (e.g. a navigation system helps the driver in his search for the right direction), by amplifying driver actions (e.g. the emergency brake assist reduces the time necessary to reach ABS regulation), by correcting a problem (i.e. ESC recovers loss of control), or even by relieving the driver of certain tasks (e.g. Intelligent Speed Adaptation systems can, to a certain extent, replace the driver for speed regulation).

›› Secondary (Crash) safety: Passive safety systems are now being referred to as «Secondary safety systems». These systems have been designed in order to protect and reduce the risk of injury to the vehicle occupants' in the case of a crash occurring. Two of the most common examples include the use of airbags or seatbelts.

›› Tertiary (Post-crash) safety: Tertiary safety is concerned with the alerting of rescue services after a crash has occured and providing them with relevant information (location, time,

vehicle model etc.) about the crash which will significantly reduce rescue times through increasing efficiency. The advancements in the field of electronics have helped develop new methods of alerting rescue services, one such system is Emergency Calling, with more common systems such as roadside call-boxes and mobile telephones also proving to be particularly useful.

I.2. SAFETY SYSTEMS: FROM ADAS TO CONNECTED VEHICLES

Here below the task force made a selection of systems and functions, designed and developed for passenger cars only, sometimes referring to the relevant technology. Other devices are also available for trucks, light commercial vehicles and motorised two-wheelers (rarely). They are most of the time close to those developed for cars. We intentionally separate stand-alone systems and integrated connected systems, even though the fact that they are connected or not is most of the time transparent for the end user. What is important to user is the service behind, not the technology which is used for the service.

Some of these systems are widely deployed in western countries and are slowly coming to emerging markets. Some are deployed only in luxury cars, some are under development and some others still need a bit of research. We did not mention systems based on V2X (vehicle to vehicle or vehicle to infrastructure communications) since their deployment is planned but not imminent. We propose to review only 'stand-alone' systems.

We also do not present passive safety systems, which are out of the scope of this contribution.

I.2.1 ›› Stand-alone systems and driving assistance systems

There are four kinds of systems that we classified the following way (Page, 2010):
›› Park assist systems
›› Over-vision systems for night driving
›› Co-pilot systems
›› and so-called 'Angel Guards' systems.

As there is, for each category, a large variety of systems, with variable parameters and various HMI, we chose to report about general or generic functions. The examples and illustrations are used to better understand what the general function does.

Park Assist Systems

These systems basically help drivers to park in tight spots with additional comfort and ease. They are not strictly speaking safety systems but they can help, as far as safety is concerned, detecting pedestrians in parking situations and also allow drivers to be relaxed, especially elderly drivers by making parking manoeuvers less difficult.

Over-Vision Systems

These systems operate mainly at night. Basic ideas are to enlarge lit zones, illuminate appropriately zones that must be lit, and avoid glare in rural areas where drivers have to switch between high beams and low beams depending on the traffic ahead.

Co-Pilot Systems

Manual Speed limiter (the driver chooses the maximum speed he does not want to exceed and the system does not enable him to exceed this speed) and cruise control (the system fixes the driving speed at the level selected by the driver) are the two main devices currently on the market concerning speed management.

The generic term Intelligent Speed Adaptation (ISA) encompasses a wide range of different technologies aimed at improving road safety by reducing traffic speed and homogenizing traffic flow, within the limit of posted speed limits. «Fixed speed limit» systems inform the vehicle of the posted speed limit whereas «variable speed limit» systems take into account certain locations on the road network where a speed below the posted limit is desirable, such as sharp curves, pedestrian crossings or crash black spots. Taken one step further, speed limit systems may also take into account weather and traffic flow conditions. These systems are known as «dynamic speed limit» systems and benefit from real time updates for a specific location.

Angel-Guard Systems

There are several technologies under this denomination:

›› Electronic Stability Control (ESC) aims to prevent the lateral instability of a vehicle. Linked to the braking and powertrain systems, it prevents the car from running wide on a corner or the rear from sliding out. It also helps the driver control his trajectory, without replacing him, in the case of loss of control where the driver is performing an emergency manoeuver (confused and exaggerated steering wheel actions). An additional ESC function optimizes ESC action in curves with hard under steering (situations in which the front wheels lose grip and the vehicle slides towards the outside of the curve). A complementary feature prevents the wheels from spinning when pulling away and accelerating.

›› Advanced Emergency Braking (Collision Imminent Braking) Systems allow an automatic braking in follow-up driving situations when they detect that an impact is imminent. It is generally constituted by a system of medium-range or long-range radars and possibly (but rarely) coupled with a frontal camera. The radar works together with braking systems such as the ESC and EBA (Emergency Brake Assist) to help the vehicle stop quickly and avoids, or rather, mitigates the impact severity. Current systems typically work as follows. The radar detects the target vehicle ahead and determines the relative speeds and time to collision. It works only in follow-up driving situations and operates on moving obstacles that suddenly slow down or stop. Forthcoming developments concern fixed obstacles ahead. Some current systems can also detect pedestrians at low speeds.

The driver is first notified about the danger by a tone or visual warnings or by haptic feedback in the brake (this variant of AEBS, alone is then called 'Forward Collision Warning'). If the driver does not act and if the impact is considered as inevitable, an automatic braking is applied to help mitigate the consequences of the crash. Braking strategies vary across systems in terms of adjusting the level of the braking force and the time when impact is considered inevitable. The value of deceleration is generally limited to 0,6 g, and it often depends on the relative speeds between the car and the target vehicle or obstacle. Of interest, the Mercedes system initially brakes at 0,4g (approx. 4m/s2) then 0.6 seconds before the crash when impact is inevitable, increasing the braking level to 9.8 m/s².

›› City Safety monitors the traffic in front with the help of a laser sensor that is built into the windscreen's upper section of the car. It can detect the rear-end of a vehicle in front of the City Safety equipped car. If the driver is about to drive into the vehicle in front and does not react in time, the car brakes itself. The scope for the system is low speed scenarios, like cues or entering roundabouts, situations where a large portion of collisions appear due to distracted drivers. City Safety is active at speeds up to 30 km/h (or higher in recent versions). If the relative speed difference between the vehicles is less than 15 km/h it can help the driver to avoid a collision completely. In relative speed differences above 15 km/h up to an absolute speed of 30 km/h the objective is to reduce speed as much as possible before a collision occurs.

›› Lane Departure warning Systems are often based on a camera, which looks at the road and detects markings. When the car is suspected of leaving unintentionally its lane, by crossing the markings or just after having crossed the markings (without the driver switching the indicator on for example), the system delivers a warning to the driver. Once again nature and HMI of the warning can vary a lot between systems and car manufacturers warning strategies.

›› The Lane Change Assistant or the Blind Spot Detection systems and Rear Cross Traffic Alert systems continuously monitor the rear blind spots on both sides of the vehicle. For example, before overtaking or changing lanes, the driver looks in the side mirror which confirms that the lane is free – but suddenly a car comes into the visual field from behind, just when the driver is about to change lanes. Such critical situations often arise in urban traffic and result in a crash if the vehicle in the blind spot is overlooked. When the turn signal is activated indicating that the driver is about to change lane, these systems warn the driver either visually or by discreet vibration of the steering wheel, or whatever (once again HMI varies a lot) if changing the lane is not safe at that moment.

These systems are currently based on radars, cameras or ultrasonic sensors, depending on warning strategies and costs, ultrasonic sensors being cheaper than cameras, themselves cheaper than radars.

I.2.2 ›› Tertiary Safety Systems

Automatic Collision Notification systems or eCall is an emergency call when a crash occurs. The procedure of the telematic device can be triggered manually or automatically. In the PSA system for example, in an emergency situation, the occupant of the vehicle presses the SOS button on the telematic terminal for at least two seconds. In a severe impact, if the vehicle's pyrotechnic equipment has been triggered (airbag or seat belt pre-tensioner), the vehicle itself sends out the SMS message containing the basic information of the crash and the request for voice contact. As soon as the button is pressed or an automatic trigger happened, the telematic terminal sends an SMS message to the call centre assigned to cover the area in which the vehicle is located. This SMS message contains vital information for dealing with the emergency. The rescue services can then hurry to the crash location and apply first aid and appropriate care to the victims.

I.2.3 ›› Safety impacts of ADAS and Tertiary Safety Systems

There are other in-development safety features that we haven't presented here, such as night vision, improvements in vehicle dynamics, alcolocks, improvements in navigation systems, driver drowsiness detection, linked to safety and traffic information, EDR's (Event data recorders), etc. that would also deserve interest. Room is missing to present all current developments.

Secondary safety devices have been largely evaluated and the effectiveness of belts, load limiters, airbags, car structure and other stuff have been largely disseminated. As for existing safety functions already on the market, available results show that, for example, if all cars were Euro NCAP five stars and fitted with Emergency Brake Assist (EBA) and Electronic Stability Control (ESC), compared to four stars without ESC and EBA, injury crashes would be reduced by 47%, all injuries would be mitigated by 68% and severe + fatal injuries by 70% (Page et al, 2009).

Unlike secondary safety systems, ESC, ultrasonic park assist, cornering lights and manual speed limiters, most of these primary safety systems are not, or just poorly, deployed in the market. There are several reasons for this. First, their maturity and their capacity to work well without too many counter effects are recent, technological barriers have been strong for a long time. They were launched first in luxury cars in the USA, Japan and Western Europe and democratization is just starting. Secondly, these features are costly, in terms of unit price but also in terms of investment and their deployment demands progress in cost reduction. Thirdly, their expected safety benefits are, to a certain extent, not really known. If it is now epidemiologically demonstrated that secondary safety features bring safety, as well as ESC, the positive effectiveness of not-yet largely de-

SOURCE : http://ec.europa.eu/digital-agenda/en/ecall-time-saved-lives-saved
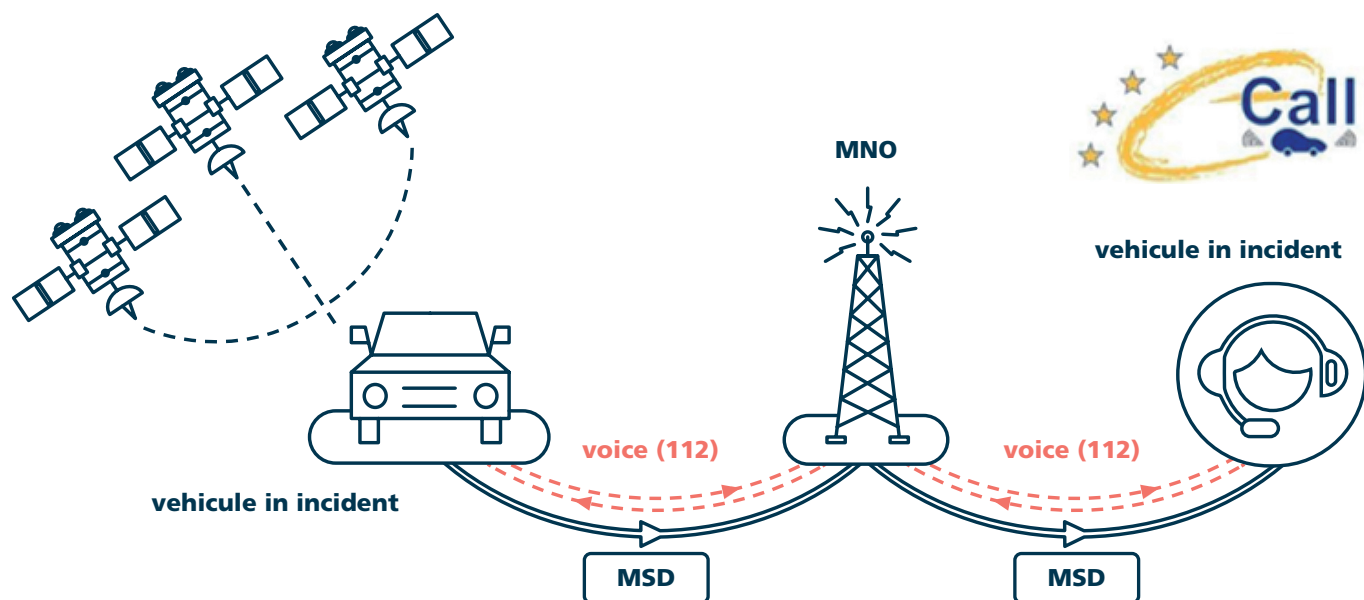
Figure 2: Emergency vehicle pre-emption technology delivers the «right-of-way» to ambulances or fire and rescue vehicles at traffic lights so they can act speedily in case of collisions.

ployed primary safety devices is only estimated and not yet proven. Studies about the effectiveness of these devices take into account the potential in saving lives of generic functions, but a lot is still unknown about real-world usage and acceptance by drivers and pedestrians of these applications. As there are many variants of these features, and especially concerning the mode of restitution to the driver of the information, the alert, or the warnings, the genuine efficiency of each variant is still a mystery. Of course, in-house studies by suppliers and car manufacturers anticipate positive acceptance by drivers and have identified and countered possible adverse effects. Of course, current research is evaluating their potential to safety and to cover real-world driver needs, via Field Operational Tests (FOT's) for example, but a large field of research is still open for their safety assessment in real-life.

Tentatively, best estimates of the safety benefits of a selection of primary safety functions are presented in figure 1 (Page, 2010). These estimates are extracted from the TRACE project and subsequent work. Overall, safety benefits seem rather low if each system is considered separately, because each of the driving assistance system address just a part of the safety issues but the total of all of the systems, even partially overlapping, is supposed to bring large benefits.

On the other hand, the pressure of the market, competition between OEMs, forthcoming regulation, interest of consumerist information tests and ratings devoted to vehicle safety (such as NCAP's), political willingness to increase vehicle advanced driving assistance systems, and considerable progress in technology and affordable and cost effective sensors, will in the short term end up with an unprecedented deployment of these features in the coming years. A lot of cars are launched with new devices or are expected to be launched with improved devices in the near future.

The systems studied above are exclusively stand-alone technologies, embedded in passenger cars and without any communication with the outside world (except for navigation systems). It has, by nature, limitations. Radars, cameras, bending lights, etc. cannot see through an obstacle. And yet, one major crash mechanism is visibility masking. Vehicle-to-X communication would then be a good candidate to detect masked objects, especially at intersections and at night.
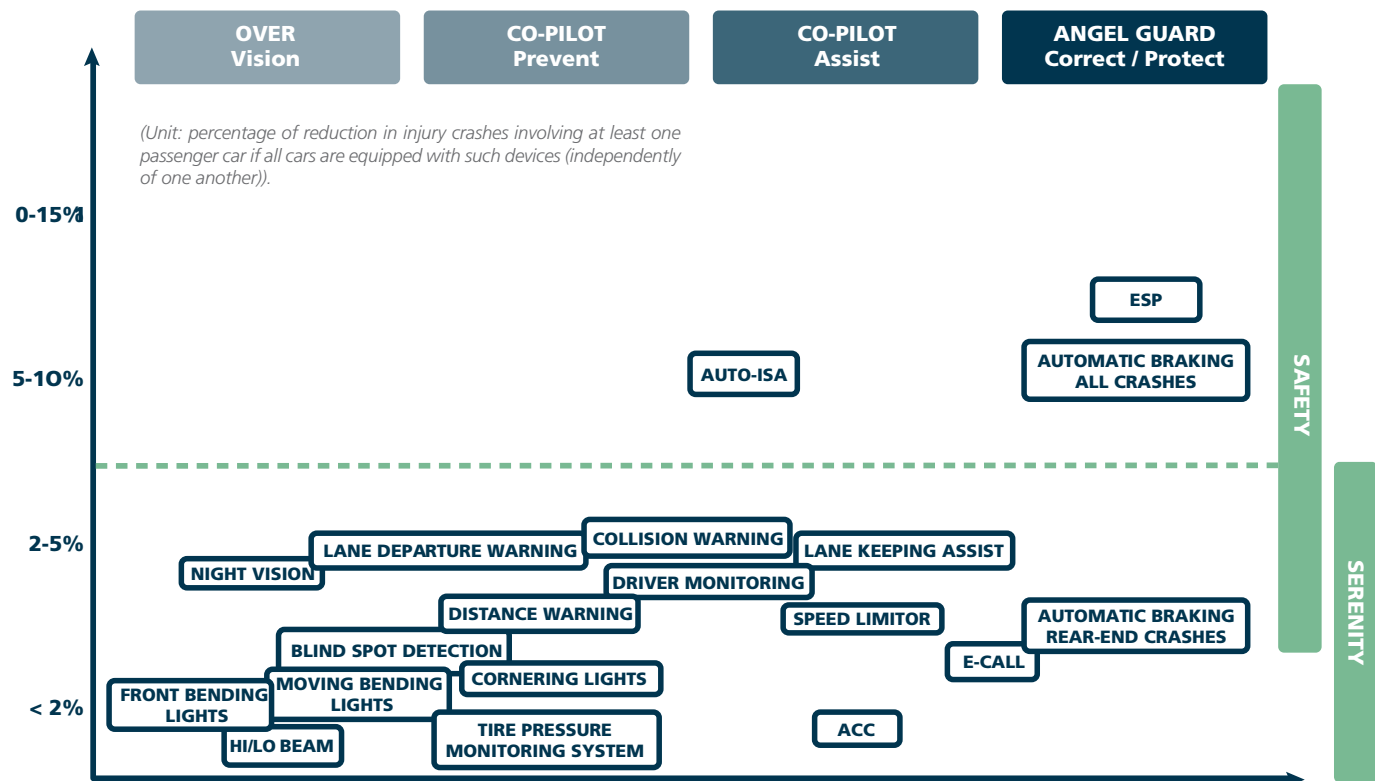
Figure 3: Estimates of the potential safety benefits of primary safety functions

I.2.4 ›› Connected safety and driving assistance systems

Connected technologies for safety and driving assistance systems in the current world of stand-alone technologies have 3 additional values:

›› Improving the robustness of current systems by enhancing/duplicating capabilities & functionalities;

›› Replacing existing systems at a lesser cost;

›› Adding new functionalities to current ones and then expanding the potential of coverage of various crash configurations and risk factors.

The EU-funded Drive C2X has selected 9 applications that are mainly safety related (most of them address the so-called 'risk awareness' issue, i.e. a crucial information needed by users and preventing them from a potential road hazard. The danger does not require an immediate action from the driver but requires an increase in attention and situation consciousness), but that can have also an impact in efficiency, mobility and environment. These are the following:

1/ **Road work warning (RWW)**: vehicles approaching road works are warned in due time before they are reaching the road works area. The function works for stationary road works as well as for moving road works as they can be found typically on motorways.

2/ **Traffic jam ahead warning (TJAW):** the driver is warned if he/she is approaching an end of a traffic jam to avoid running into the last vehicle in the queue.

3/ **Car breakdown warning (CBW):** approaching traffic is warned in due time before reaching a broken down vehicle to avoid running into the broken down vehicle or endangering people in the vicinity of the broken down vehicle.

4/ **Weather warning (WW):** information about bad weather conditions ahead is communicated to oncoming traffic to avoid entering areas with adverse weather conditions at too high a speed.

5/ **Emergency electronic brake light (EEBL):** in case of a hard braking manoeuvre following traffic is warned to avoid rear end crashes and backing up.

6/ **Approaching emergency vehicle warning (AEVW):** approaching emergency vehicles warn surrounding traffic about their presence to ensure that they can proceed quickly even in very dense traffic.

7/ **Post crash warning (PCW):** if a crash has occurred oncoming traffic is warned to ensure that drivers slow down and do not run into the vehicles that had a crash.

8/ **In-vehicle signage & regulatory and contextual speed limit (IVS):** traffic sign information such as «ban on passing» is communicated into the vehicles and indicated in the instrument cluster or in the head unit. Information on fixed and variable speed limits as well as on the recommended optimal speed is communicated into the vehicles and indicated in the instrument cluster or in the head unit. This application addresses variable message signs in particular.

9/ **Green-light optimal speed advisory (GLOSA):** signal phases of traffic lights are communicated into vehicles in order to inform their drivers about the optimal speed to pass traffic lights at green.

These applications are quite similar to the ones suggested by the Car-to-Car Consortium in their Memorandum of Understanding. Compared to the Drive C2X final list, they added 'Signal Violation warning'.

In the Safety Pilot Program (Ann Arbor, Michigan), various safety applications are being evaluated (table 1):

SAFETY APPLICATION	TYPE	DESCRIPTION
Forward Collision Warning (FCW)	V2V	A V2V application where alerts are presented to the driver in order to help avoid or mitigate the severity of crashes into the rear end of other vehicles on the road. Forward crash warning responds to a direct and imminent threat ahead of the host vehicle.
Emergency Electronic Brake Light (EEBL)	V2V	A V2V application where the driver is alerted to hard braking in the traffic stream ahead. This provides the driver with additional time to look for, and assess, situations developing ahead.
Intersection Movement Assist (IMA)	V2V	A V2V application where alerts are given to drivers as they begin to accelerate into, or across, another road, to help the driver avoid crashes with crossing traffic.
Blind Spot Warning (BSW)/ Lane Change Warning (LCW)	V2V	A V2V application where alerts are displayed to the driver that indicate the presence of same-direction traffic in an adjacent lane (Blind Spot Warning), or alerts given to drivers during host vehicle lane changes (Lane Change Warning) to help the driver avoid crashes associated with potentially unsafe lane changes.
Do Not Pass Warning	V2V	A V2V application where alerts are given to drivers to help avoid a head-on crash resulting from passing manoeuvers
Left Turn Across Path / Opposite Direction (LTAP)	V2V	A V2V application that alerts the driver of a transit vehicle if another vehicle intends to make a right turn in front of it while the transit vehicle is stopped at a bus stop near an intersection.
Right Turn in Front	V2V	A V2V application where alerts are given to the driver as they attempt an unprotected left turn across traffic, to help them avoid crashes with opposite direction traffic.
Signal Phase and Timing (SPaT)	V2I	A set of V2I applications where intersection traffic signals broadcast the current state of signal phasing (red, yellow, or green) and time remaining in that phase. The SPaT data would be used by the vehicle to achieve safety, mobility and environmental benefits.
Curve Speed Warning (CSW)	V2I	A V2I application where alerts are provided to the driver who is approaching a curve at a speed that may be too high for comfortable or safe travel through that curve.
Railroad Crossing Warning	V2I	A V2I application that alerts the driver of approaching trains at railroad crossings without warning signals or gates.
Pedestrian Detection	V2I	A V2I application that alerts the driver of turning transit vehicles if a pedestrian has pushed the crosswalk button at an upcoming intersection, or a remote sensor system detects a pedestrian in the crosswalk at the intersection.

Table 1: Connected Driving Assistance Systems tested in the Safety Pilot Study US, UMTRI, 2013

Some of them are redundant with stand-alone safety systems, but work with connected technologies, and some others are not addressed by Drive C2X or the C2C Consortium.

Additional applications are also possible, even though not retained by the above projects. This is the case of **wrong way driving warnings** (a vehicle is driving on the wrong way on dual-carriage ways) or **human presence on roads** (a pedestrian on a road at night for instance). Actually safety applications permitted by connectivity are numerous (see for example **C-ITS services catalogue, Com eSafety 2**). Currently, the available safe-proven technology does not permit applications that warn of an imminent danger and need immediate actions by the driver (such as emergency braking), but it might come as a second step in these kinds of connected applications, with improvements in technical capabilities.

All these systems are under research or development but they are not available on the market for final clients. **Their deployment is currently being tested and, in the current state of our knowledge, there are just a few published studies that have addressed their potential safety benefits. As these studies are not really convincing so far, we do not report their results here**.

> **However, the present task force has done its best to assess the safety functions of some of these technologies. You will find the assessment in the second chapter «Conclusions on the implementation of road safety connected technologies».**

I.3. AUTONOMOUS VEHICLES: TOWARDS ZERO FATLITIES ON ROADS?

It is a fact that the human driver is «embodied within the car as an assemblage that can achieve automobility» (Sheller, 2004). Driving needs routine actions, conscious and unconscious attention. The e-connection technologies disconnect the car user from the task of driving. A new concept emerges from the convergence of all the systems and sub-systems encompassed by ITS: the «autonomous motion». According to the UK Automotive Council, «autonomous control is a state where vehicles are controlled entirely by the system without any input from the driver[8]. In the US, the State of Nevada and California have already a legal definition of the «autonomous vehicle». They describe it as the one that «uses artificial intelligence, sensors and global positioning system coordinates to drive itself without the intervention of a human operator»[9]. The term «Artificial intelligence» is also legally provided as «the use of computers and related equipment search to enable a machine to duplicate or mimic the behaviour of human beings»[10]. Those American states plus Florida have already passed laws governing the autonomous vehicle experimentation on public roads[11]. In the case of driverless vehicles, Nevada and California have delivered a license for «Google's self-driving prototype» to be experienced on public roads (Teigen, Wheet, and Rall, 2013). Google CEO Sergey Brin recently foresaw driverless cars as a reality for common people within 5 years[12].

1.3.1 ›› Road safety arguments in favour of autonomous vehicles

Indeed, the development of various levels of driver assistance systems has been very rapid over the last decade. These systems with various levels of autonomy make the vehicle take over the responsibility from a driver, for a shorter or longer duration. For car manufacturers, this development is very much in line with the goal to reduce the number of injuries and fatalities on the roads. With the application of these technologies some of the driver inadequacy and inattention issues become less acute and will open up for the discussion of what secondary task is it acceptable or desirable for the driver to perform while being in control of the vehicle.

With these technological advances many questions have been raised: how far this development can be taken, how far it should be allowed to be taken and how far it is desired to be taken.

It is clear to all safety stakeholders that autonomous driving is very much part of the future. The technology level has already reached a stage where initial tests are possible. In addition to dealing the technical challenges other issues such as legality, liability, infrastructure usage and driver acceptance will be critical in order to make this truly a part of the future.

Supporters of intelligent vehicles consider that more than 90% of automobile crashes are the consequence of human negligence. **Driverless vehicles** are intended to **eradicate human error**, by recognising objects, cars and dangers, and by selecting the best itinerary to reach a destination (Teigen, Wheet,

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[8] Automotive Council , Intelligent Mobility A National Need?, UK, November 2011, http://www.automotivecouncil.co.uk/wp-content/uploads/2011/12/ITS_Report_15_11_11.pdf
[9] CHAPTER 482A - AUTONOMOUS VEHICLES, http://www.leg.state.nv.us/NRS/NRS-482A.html
[10] CHAPTER 482A - AUTONOMOUS VEHICLES, http://www.leg.state.nv.us/NRS/NRS-482A.html
[11] Driverless Car : Look no hands, The Economist, 20 April 2013, http://www.economist.com/news/special-report/21576224-one-day-every-car-may-come-invisible-chauffeur-look-no-hands
[12] Niccola James, Self-driving cars a reality for 'ordinary people' within 5 years, says Google's Sergey Brin, Computer World, http://www.computerworld.com/article/2491635/vertical-it/self-driving-cars-a-reality-for--ordinary-people--within-5-years--says-google-s-sergey-b.html26718513

and Rall, 2013). The idea enhances also the idea that techno-
logies are able to «observe» dangers, obstacles and road mar-
kings more precisely than the human perception, and actuators
are capable of applying the brakes, or turning the wheel, quic-
ker than humans.

1.3.2 ›› Other benefits of Autonomously Driven Vehicles

From a driver perspective, autonomously driven vehicles offer a
number of potential advantages both from a safety and from
a comfort and convenience perspective. The time spent in the
car during long haul journeys may be made useful by offering a
possibility for working, relaxing or eating.

Besides, autonomous vehicles could also provide mobility to ol-
der and disabled people, a specific growing population with an
extended life expectancy[13]. It is a safe **mobility option for the
elderly:** ageing drivers would still be capable of moving safely
and comfortably according to the UK Automotive Council. For
instance, in the US, the baby Boom generation is soon retiring
and will need «smarter alternatives» to move around. While in
2010 one out of eight American licensed drivers was aged 65
or older, in 2030 it will be one out of five[14].

According to Volvo Cars, **self-driving vehicles will improve
our mobility in several ways:**
›› Improved punctuality due to fewer disturbances;
›› Improved traffic flow and well optimized use of the road
space;
›› Fewer traffic disturbances due to less crashes;
›› Interaction between vehicles and infrastructure for handling
of unforeseen events;
›› Use according to the need; more attractive possibilities for
transportation;
›› One step towards crash-free road traffic;
›› Improved urban planning and reduction of infrastructure
investment;
›› More even traffic flow and optimized driving lead to lower
energy consumption and lower emissions.

I.4. SMARTPHONES AND ICTS AS CONNECTED SOLUTIONS TO ROAD SAFETY ISSUES

The massive spread all over the world of nomadic devices
connected to the internet and particularly of smartphones can't
be ignored. Some developers of smartphone applications are
pointing out the road safety potential of such technologies.

I.4.1 ›› Smartphones as a short term alternative to some embedded safety technologies

According to the GSMA report, consumers seem reluctant to
pay additionally for embedded connectivity, while their smart-
phones can be used for many in-car connectivity needs. In fact
in the short run, car manufacturers have been integrating the
smartphone as to satisfy the consumer desire for connectivity.
For instance Bluetooth devices and so called «mirroring» are the
reflection of this situation. These types of solutions are referred
to as «tethered» since the driver merely uses his/her phone as
a modem (via wires, Bluetooth or Wi-Fi) to allow connectivity.
In the case of GPS, the expensive cost of integrated devices
(many of them in premium models) led to the development of
affordable GPS available on the market in the form of exter-
nal technologies. The high price of the hardware of embedded
solutions is actually a factor that boosts the development of
tethered solutions, which rely on the communication module
and processing power of the mobile phone. There are also high
communication costs for the embedded connectivity in which
an additional Internet subscription is necessary for users. It is
true that for some services such as eCall, car manufacturers
were able to embed the total lifetime communication cost into
the overall price of the system.

In addition, the GSMA report considers that the consumer has
a strong relationship established with their smartphones, such
attachment and dependence to them could impede the deve-
lopment of embedded solutions. The table below shows the
GSMA estimations of how tethered solutions will grow. In the
case of China and Brazil, this type of connectivity will prevail,
while for the US and EU, it looks like it will actually decrease
since it is considered as a short-term solution.

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[13] Driverless Car : Look no hands, The Economist, 20 April 2013, http://www.economist.com/news/special-report/21576224-one-day-every-car-may-come-invi-sible-chauffeur-look-no-hands
[14] A White Paper by Transportation for America, ITS America, the Association for Commuter Transportation and the University of Michigan's SMART Initiative, Smart Mobility for a 21st Century America, October 2010, http://t4america.org/wp-content/uploads/2010/10/ITS-White-Paper-100710-FINAL.pdf

Tethered Global Sales   Forecast of OE Connectivity in Passenger Cars (2010-2015)
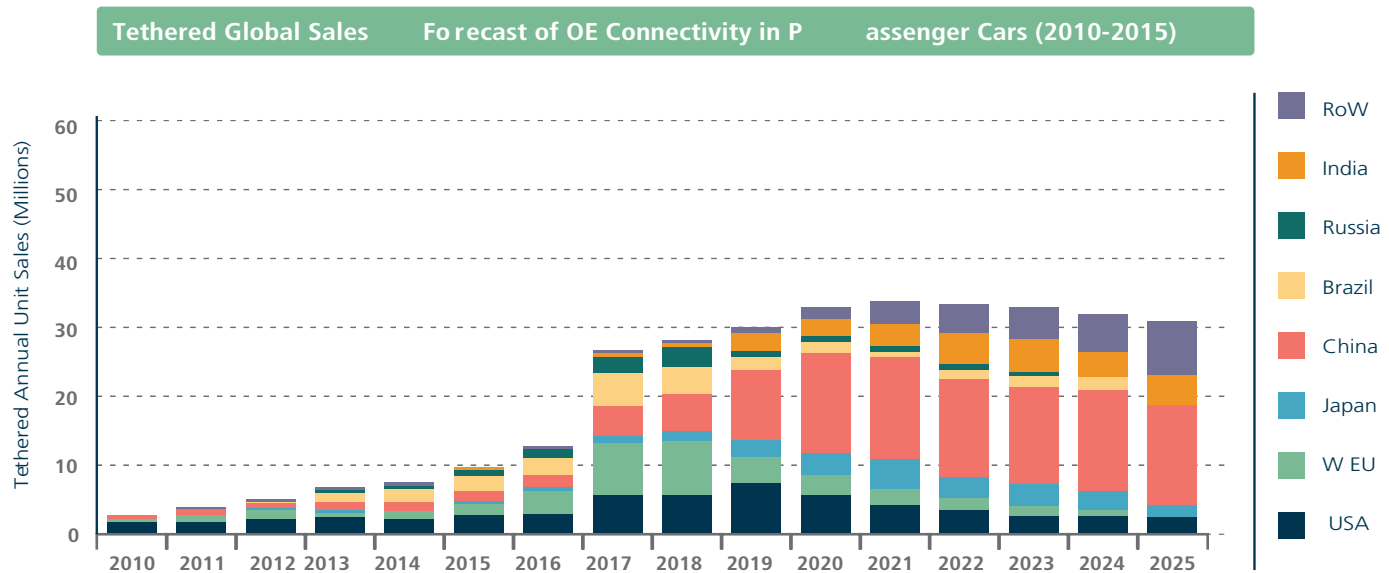
Figure 4: GSMA report: Every Car Connected: Forecasting The Growth and Opportunity

I.4.2 ›› Smartphones applications with road safety benefits

First of all, please note that this report doesn't deny that some uses of smartphones while driving or even crossing a road, such as texting or web surfing are highly risky and should be discouraged. These activities involve hand use that makes them even more distracting.

Having said this, one needs to **highlight potential safety benefits** of the use of some smartphone applications, which may be very similar to embedded connected technologies. For example, voice commands may allow drivers to use some applications of embedded devices that can offer them more safety. Drivers can receive some alerts on their smartphones or tablets connected to their car or even some suggestions to change their movement pattern. Furthermore some carmakers such as Honda are already developing smartphone applications that will connect pedestrians to cars and vice versa to help both types of road users to perceive dangers[15]. The example of the Honda application shows a pedestrian that looks at his /her smartphone while crossing the road. The application will alert the driver about a pedestrian who isn't paying attention to the road and will alert the pedestrian about the car that is approaching. Of course this behaviour is very dangerous and should be strongly discouraged, but one needs to take into account the reality of

today's world, where people are literally addicted to technologies. Saying that don't mean to be permissive, the point is that we should try to understand the actual world, lifestyle and behavioral factors.

Technology capable of restricting abusive use of mobile phones and other types of technology while vehicles are moving is being developed. There are safety warning systems that can alert depending on drivers' state and task demand. For instance, some car manufacturers have developed «smart keys» that let a young driver and his/her parents share a car, but each one has it own keys: the young driver's key is «computer coded», parents are then able to fix specific maximum speed limits, limit maximum stereo volume and block mobile phone reception. Another example of sophisticated technologies is the "workload manager". This on-board technology uses sensors to estimate the driver workload and impedes mobile phone calls and other forms of distraction until driver workload decreases. Some technologies are also capable of preventing text messaging access while the motorist is driving.

[15] https://www.youtube.com/watch?v=ElNPC_xP56g

› II. CONNECTED MOBILITY: BROADER APPROACH TO SOLVE ROAD SAFETY ISSUES

Holistic approach is necessary to deal with road safety issues: connected solutions are global; they are not related only to the vehicle user or infrastructure.

One needs to think less in terms of the existing systems of vehicles and roadways, and more in terms of the emerging technologies and infrastructures for a «new mobility». This means thinking not just about how to avoid accidents on roads today, but how to intervene in road design, transport policy and urban planning so that: roads are made safer for pedestrians, cyclists, and others; new forms of connectivity emerge that may reduce demand for the use of roads and private vehicles.

We should think more about the next generation of moving people, moving goods, and moving less, in ways that are connected, cleaner, greener, safer, healthier, more equitable, inclusive, innovative, technology-enabled, etc. This is called a «whole system» approach. This involves how we use information technology across the board (big data, open data, mobile tech, interoperable systems, GIS and mapping, etc.). It also involves thinking about the implications of fractional use systems of shared/collaborative consumption; mobility management, aggregation and integration; mobile locative social networking and crowd sourcing; new strategic alliances such as public-private partnerships and city-to-city policy transfer; innovative financing mechanisms; and more.

II.1. THE IMPLICATIONS OF CONNECTED TRANSMOBILITY FOR ROAD SAFETY IN HIGH INCOME COUNTRIES

The integration of mobile information and communication technologies (ICT) into vehicles, streets and cities is leading to a lacing of technologies of transportation with capacities for conversation, entertainment, information access, navigation, automation, tracking and surveillance. New ICT involved in mobility includes apps and maps on smart phones, digital public display screens with real-time transit or traffic information, navigational and other information on demand, use of smart phones and communication media while travelling, digitally-enabled public car sharing and bike sharing systems, etc. This type of mobile ICT facilitates social connectivity, mobile socializing, mobile work, and complex coordination in a hybrid physical-plus-digital space. Mobile ICT can also feed into big data collection and visualization methods that can support fleet management and infrastructure responsiveness.

The question we address here is whether this kind of connected mobility also has implications for road safety. Driver distraction by mobile devices is a key risk, of course, and needs to be addressed; however, that is not our focus here. In this section we focus instead on the potential of such technologies to increase road safety in a number of ways. This means extending our notion of connected mobility beyond V2X technologies (which are centred on the vehicle itself), to instead explore how mobile ICT broadly impacts on all road users, road design, and the general reshaping of urban mobility space to potentially promote safety. In other words, the transformation wrought by connected mobility might go far beyond vehicles or infrastructures, to include changes in the social practices of mobility, in the planning and design of road-use itself, and in the wider cultural landscape of mobility. This general set of trends can be referred to as «trans-mobility» because it reaches across multiple modes of mobility and multiple modes of communication.

Decline of Driving in the Developed World

Before beginning it is important to note that in the United States – and to a lesser extent in other developed countries -- it is becoming empirically evident across a range of different measures that over the last decade there have been fewer car trips per driver fewer miles driven per driver, and fewer young people getting drivers' licenses (Pickrell and Pace, 2013; Short, 2013; Sivak, 2011, 2013). «Driving light» has become a new trend. The total number of vehicles on the road has not risen since 2006, according to the Bureau of Transportation Statistics, while ridership on subway trains and light rail has been rising steadily over the last decade across the USA according to the National Household Travel Survey (nhts.ornl.gov/det)[17].

The trends are even sharper among young people. Between 2001 and 2009 average annual vehicle miles travelled by young people (16-34 years old) in the USA decreased from 10,300 miler per capita to 7,900 miles per capita, a 23% drop (as compared to a 9% drop for all ages). In 2009, this same group reported taking 24% more bike trips than in 2001, walked to destinations 16% more frequently, and their miles travelled on public transit increased by 40% (USPIRG 2012). The pattern continues through data collected up to 2013 and the fall in young people's driver licensing rates also suggests that these trends will not reverse any time soon. Given that younger drivers are most at risk for accidents, the sharp and continuing decline in driving amongst the millennial generation (Sivak and Schoettle, 2011), in itself, suggests overall improvements in accident rates can be expected.

There is further evidence of a wider cultural shift in attitudes toward driving and preferences for other kinds of mobility. A 2011 poll by KRC Research and car-sharing company Zipcar found that 45% of 18-34 year olds said they consciously made an effort to replace driving with transportation alternatives, which was higher than for older groups, and 70% indicated a preference for using alternate modes of transportation to the individually owned car, including public transport, car sharing, and carpooling. These preferences correlate with higher rates of ICT-use among this age group, and in particular use of mobile social media. The idea of an «access economy» (rather than an ownership economy), supported by rich mobile geolocated information and communication technologies, supports a shift of demand away from private cars and hence a reduction of the number of road-trips and vehicles on the road.

Does this rise of ICT-rich, multimodal, «connected commuting» offer any benefits for road safety? What other developments in new ICT technologies might support such benefits? In the following we explore how these kinds of widespread shifts in social practices may have great implications for road safety, at least in the developed world (in contrast to middle-income countries, where car-ownership and driving rates are increasing).

Connected Commuting and Road Safety

Connected transmobility offers new opportunities for a transition away from the dominant pattern of «automobility» despite its strong lock-in to built environments and embedded institutions (Dudley et al., 2011; Sheller 2011, 2004; Sheller and Urry, 2000, 2006). Convergences between transportation systems, mobile communications, locative media, and «smart» infrastructures are generating new kinds of social coordination, real-time scheduling, and multimodal flexibility. Paaswell suggests that the «impacts of the combination of modern wireless communications and ubiquitous computing power are having profound impacts on the supply [of transportation], demand for transportation and on the culture of those using transport» (Paaswell, 2009).

For example, the Smart Cities Group at the MIT Media Lab, has been designing Sustainable Personal Mobility and Mobility-on-Demand Systems through a collaborative project that has now gone into commercial production. Their project relies on mutual adaptation amongst multiple newly designed vehicle types (light-weight electric cars, bikes, motorcycles), abundant access nodes for re-charging and parking the vehicles, and continuous feedback loops from GPS tracking and real time information flow between users and mobility managers (including dynamic pricing systems). In this way the entire system is able to adjust in an evolving process of dynamic equilibrium. The system is flexible, scalable, and responsive, and has the potential to reduce the use of private automobiles in city centres.

Car companies have already invested in car sharing systems, such as Daimler's partnership with Europcar to operate Car2Go, which operates in 18 European cities, although they recently pulled out of the UK due to «the UK's strong culture and tradition of private vehicle ownership» according to a company spokesman[18]. Nevertheless, even in the USA, GM has announced that is partnering with Google to conduct a ride-sharing pilot program using Chevrolet Spark EV's on their main campus, which could serve as a model for other campuses, colleges, and bases. «This learning pilot combines commuting data, analytics, telematics, navigation and smartphones to run

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[17] In the USA as a whole the average number of miles driven collectively peaked in August 2007, dropped sharply during the recession, and then remained at that level despite the economy picking up again, according to statistics from the National Household Travel Survey (Pickrell and Pace, 2013). For individual drivers the average number of miles driven peaked in July 2004 (above 900 miles per month) and has continued to decline since then, reaching around 820 miles per month in July 2012, a nine percent drop in eight years. Declines since 2004 can be noted in data measuring distances driven per person, per licensed driver, per household, and per registered vehicle (Sivak, 2013)

[18] Enda Mullen, Car sharing scheme car2go pulls out of Birmingham, Birmingham Post, May 23, 2014, http://www.birminghampost.co.uk/business/business-news/car-sharing-scheme-car2go-pulls-7163852

a smart, real-time system that mixes and matches drivers, riders and cars during morning and evening commutes,» GM says in its 2013 sustainability report. «Convenience through door-to-door service and flexible scheduling are key goals.»[19]

The widespread deployment of ubiquitous computing, sensor networks and mobile media into the urban environment furthermore leads to emerging technologies that can sense and react to what is happening around them. Mobility data increasingly populates urban or vehicular media interfaces, which is to say the wide variety of shared, situated display screens and interaction surfaces of all sizes, from large public screens, to vehicle dashboards, to personal screens such as Google Glass. Such data may also be expressed as a dynamic alteration to the physical form or other performative qualities of vehicles, buildings, circulation networks, roads, and other infrastructural systems. And such data increasingly will be conveyed to us in the form of data visualizations that may be both dynamic and interactive. Adam Greenfield calls for these systems to be «bound together in a mesh of finely-grained and fully interoperable networked services – a transmobility field. Information is the substance of this new urban mobility.»[20]

How does connected transmobility information support road safety?

II.1.1 ›› Reduction of exposure to risk

First, mobile ICT may help to promote «connected commuting» which will reduce the number of road trips made and hence the reduction of exposure to road risks. To measure effects on commuter sentiment and changes to commuters' behaviour, researchers would need to «quantify how much time is saved per passenger on average due to information gained from connected commuting. The measurement of time saved could serve as a proxy to calculate [not only] the reduced cost of fuel to passengers, reduced Co2 emissions, increased productivity» but also contributions to road safety by reducing the amount of time or vehicle miles travelled and thus spent at risk on the road[21]. The features that «connected» commuters have found most important and useful, according to the New Cities Foundation survey, include:

›› Voice-activated alerts via mobile phone, warning of an upcoming traffic incident or public transport service disruption.

›› Real-time web and app-based comparisons of multiple routes or transportation modes and how long they would take.

›› Recommended departure times to avoid being stuck in traffic and/or public transport delays.

›› GPS navigation visible on car windshield.

The immediate aim of all of these connectivity features in terms of road safety is to empower travellers to avoid hazardous situations, decrease their exposure to risks, and choose the safest routes. The medium-term effect, however, is to make multiple modes of transport easier to use and thereby to decrease road trips by car, or to make trips by car shorter (in some cases, where real-time parking space maps are incorporated, including finding parking spaces more quickly). In the long term these connected mobility potentials can contribute to better transport planning and urban design that maximizes multimodal transport options, reduces cars on the road, and – as described next – increases demand for the design of safer «complete streets» as more people give up driving.

II.1.2 ›› Safer design of pedestrian spaces

Second, connected mobility may contribute to the design of safer pedestrian spaces in cities, including «complete streets», traffic calming measures, and sensor systems within vehicles and infrastructures that adapt to the presence of pedestrians. Pedestrian accidents are the fourth most common cause of fatal accidental injuries, which, in turn, constitute the leading cause of death for people under 45 years of age (Murphy, 2012). People with limited financial resources are more likely to travel on foot, placing them at higher risk of being fatally struck by a motor vehicle (Loukaitou-Sideris, Liggett and Sung, 2007). Meanwhile, design features such as the size of roadways and the spacing of intersections affect the likelihood of being injured by a motor vehicle for those who travel on foot (Ewing et. Al., 2003).

New dataveillance methods that collect accident data across large urban areas have sought to identify pedestrian-vehicle collision «blackspots» and to identify road design failures that are contributing to those hazards. Traffic flows and speeds can also be more accurately measured. And crucially, customized information can be distributed back to pedestrians and cyclists about the most hazardous and/or safest routes to use at particular times of day and to reach particular destinations. According to its promoters, including IBM's Smart Cities initiative, «The benefits are beyond just having better traffic management. Insight from all the Big Data collected from mobile devices connected to sensors could improve road safety. City planners and transit agencies could use the information to build

[19] The Detroit News, http://www.detroitnews.com/article/20140519/AUTO0103/305190065/-1/rss12
[20] The City Is Here For You To Use: 100 easy pieces, Speedbird, December 3, 2012,
Speedbird.wordpress.com/2012/12/03/the-city-is-here-for-you-to-use-100-easy-pieces/
[21] New Cities Foundation, Ericson, Connected Commuting,
http://www.newcitiesfoundation.org/wp-content/uploads/New-Cities-Foundation-Connected-Commuting-Full-Report.pdf

new housing developments or public transportation routes. Emergency responders and law enforcement officials could get a more accurate sense of how to use their resources.«[22]

Above all, the practice of «mobility design» (Jensen, 2014) could draw on connected mobility data to assist in the design of safer (and more accessible) urban environments, safer interchanges between modes, and better protections for the most vulnerable road users.

II.1.3 ›› Automated vehicles and «smarter cities»

Third, some argue that automated vehicles will have major impacts on improving road safety. «Designer and engineer Bran Ferren says autonomous vehicles will fundamentally change how cities are built and how society interacts, and the emergence of the technology in a meaningful way on our roads is only a few short years away…. Ferren is also optimistic about how beneficial autonomous vehicles will be. He says they will significantly reduce accidents and vehicle-related deaths. They will enable much more efficient driving, lowering carbon emissions and pollution. They will boost productivity by freeing drivers from their commutes. And they will change the way society builds cities, and enables people to interact, as vehicles and drivers become disconnected and vehicles are used in smarter ways.[23]»

While all these benefits remain to be seen, they are suggestive of the distribution of possible positive effects on road safety not only between the driver, the vehicle, and the road, but also more widely affecting urban design, transport planning, and mobility practices. Reducing air pollution and carbon emissions is a secondary benefit of this kind of connected mobility, but one which may have significant impacts on public health which could be considered an extension of the meaning of «road safety». Healthier cities are also better able to promote «active transport» (i.e., walking, bicycling), which in turn will feedback into the advocacy for and design of safer connected transmobility spaces. The challenge would also be to make higher exposure of vulnerable road users safer.

II.1.4 ›› Driver Emotional State Estimation

Fourth, even within the vehicles, connected technology may improve the interaction between the driver and the vehicle rather than contributing to driver distraction. For example, Intel announced a collaboration with Jaguar Land Rover to develop better ways for consumers to sync their personal devices with their vehicles. Intel has a similar effort with Toyota, to develop user-interaction systems involving voice, gesture and touch. The goal is to make built-in technology more seamless and supersede a driver's reflex to reach for a hand-held device. If built-in technology is not good enough, drivers will use more risky handheld devices: «Although carmakers have embedded voice-command systems and the like in their vehicles with the idea of reducing distracted driving, the researchers found that when drivers were bored in traffic, they often picked up their hand-held personal devices anyway.»[24] Seamless integration of information and communication technology with car systems can therefore help to minimize driver use of outside media.

Some technology writers have suggested that wearable technologies could make driving safer by detecting the emotional and physical state of drivers, or conveying warning information to drivers in more direct haptic forms [SEE BOX]. «Driver State Estimation» systems can be combined with augmented reality displays or other warning systems to alert drivers of hazards. For example augmented reality visuals could alert drivers to:

›› driving directions

›› approaching hazards

›› real-time traffic alerts

›› pedestrian warnings

›› approaching cyclists warnings.

It is reported that «Tests already have been done on driver interfaces such as augmented reality pop-ups on windshields or audible devices, both in simulated labs and on open highways, with motorists communicating with the car by voice or by gesture, such as «sweeping» away information on a screen with the wave of a hand.» The point here is to find the best information display methods to increase awareness rather than distract drivers. «The key is to contain vital information fast, accurately, and as required….the framework being designed and subsequently documented as a set of design principles will serve as a reference guide by designers of apps and driver systems for connected automobile and related wireless devices, with driver safety and ease of use as a focus.»[25]

Ultimately all of these potential contributions of mobile information and communication technologies to road safety extend the concept of «connectivity» beyond the technological emphasis of V2X possibilities, although they may draw on

[22] Kristen Lauria, Let's Embed Mobile Sensors in Cars to Avoid Traffic, The Atlantic
http://www.theatlantic.com/sponsored/ibm-mobile/lets-embed-mobile-sensors-cars-avoid-traffic/46/#ixzz3EtujYAuI
www.theatlantic.com/sponsored/ibm-mobile/2013/10/lets-embed-mobile-sensors-cars-avoid-traffic/46
[23] Katie Fehrenbacher, Self-driving cars are coming soon and will revolutionize cities and society, Gigaom, March, 2014,
http://gigaom.com/2014/03/18/self-driving-cars-are-coming-soon-and-will-revolutionize-cities-society/
[24] Natasha Singer, «Intel's Sharp-Eyed Social Scientist», New York Times, February 2014,
http://www.nytimes.com/2014/02/16/technology/intels-sharp-eyed-social-scientist.html?_r=0
[25] Steven D Mackay, Researchers to design vehicle-to-vehicle communication integration framework, Virginia Tech News, February 14, 2014,
http://www.vtnews.vt.edu/articles/2014/02/021414-vtti-connectedvehciletechnology.html#

these technologies. The concept of «connected transmobility» broadens a vision of connected mobility to encompass those moving through urban space who may not be in motorized vehicles, and may not even be on the roadway, but whose use of other means of transport (walking, bicycling, public transit, vehicle sharing) will benefit from connected mobilities. As car trips are reduced, transport planning will have to take into account reduced demand for car travel and plan for accordingly increased use of other modes, potentially drawing on real-time data analysis to design safer forms of multi-modality.

This analysis also brings into view changes in social practices of mobility that may help to continue the momentum of an already existing generational shift away from private vehicle ownership, which arguably contributes to increasing road safety by reducing trips by car, reducing young drivers on the road, and reducing the amount of time and distance of each road trip. Improvements in connected transmobility can contribute to the design of safer urban mobility space and to «staging mobilities» (Jensen, 2013) in safer ways for all.

II.2. GROWING TRENDS IN MIDDLE INCOME COUNTRIES: INTERMODAL OPPORTUNITIES AND MOBILITY FROM ROAD SAFETY PERSPECTIVE

As mentioned above, connected technology is offering several benefits in improving mobility options, particularly in cities. New technologies are enabling people to take trips through either improved systems or entirely new applications and technology companies taking innovative approaches to vehicle use in a shared economy. These trends have the prospect of improving safety for all road users by reducing the need to drive, thus lowering overall exposure to traffic crashes, and providing safer mobility for all road users, from car drivers to pedestrians. Some of these trends are being implemented quite rapidly in growing markets. Following few paragraphs aim at presenting these connected mobility trends in middle-income countries.

II.2.1 ›› Car sharing and car service

Since its beginning in Zurich in 1987, there are now more than 1,000 cities all over the world with car sharing companies offering services (figure 5). The internet has brought about the emergence of companies and services allowing easier business
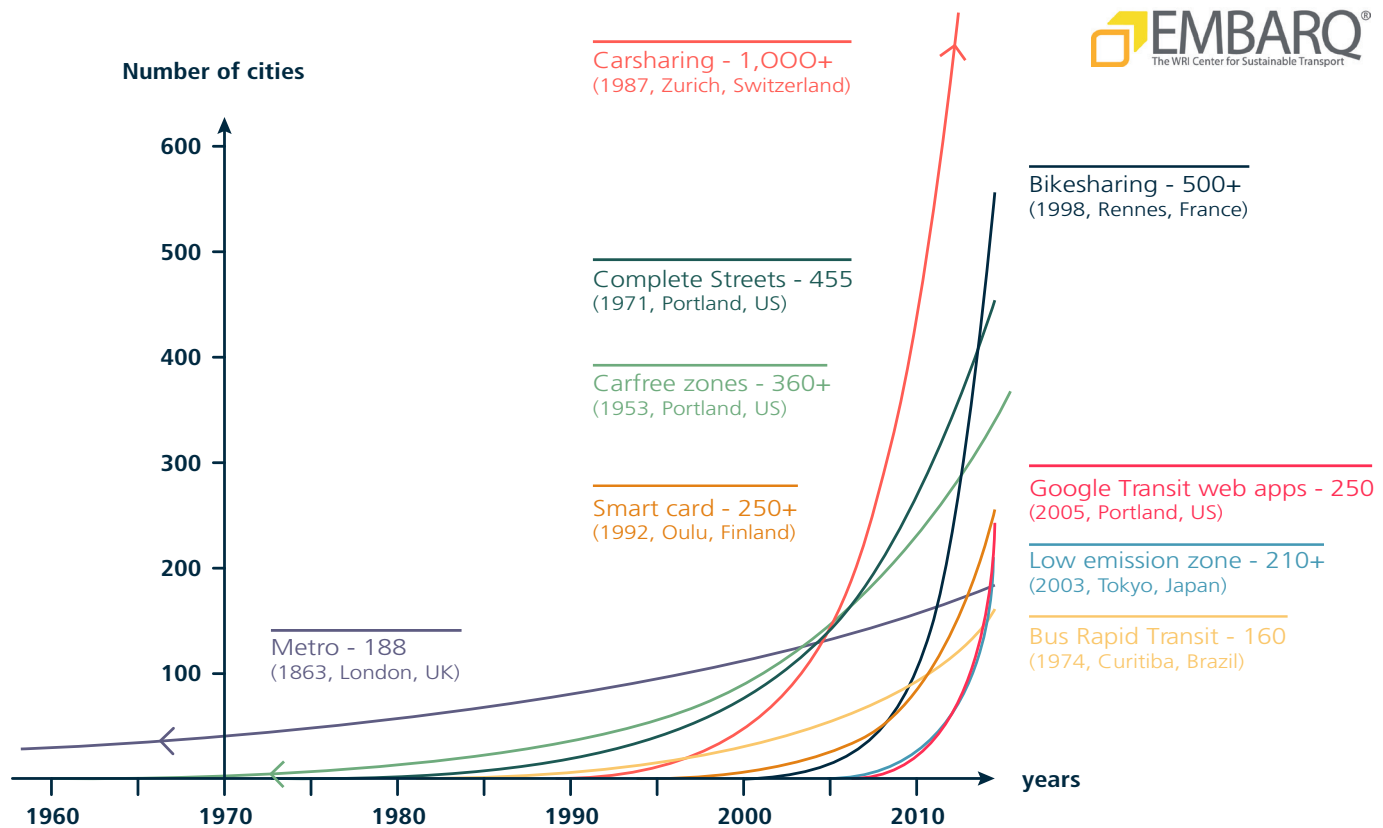

Figure 5: Sustainable Transport adoption, EMBARQ

models for car sharing services. The trend is also accelerating in middle-income countries because of informal car sharing, a very common practice in countries such as India for decades.

Today customers can reserve cars for hourly or even minute-by-minute use through the company website and customized mobile apps. This includes different types of models that cater to different needs. Models such as ZipCar or Volkswagon's Quicar rely on fixed location vehicles where users pick up and drop off vehicles from the same location. Car2Go, another car sharing model owned by Daimler made up of a fleet of SmartCars (a Daimler division) provides a service where users can pick up a car and drop off at essentially any on-street parking spot in the city, albeit with a few exceptions such as rush hour lanes that change from parking to travel lanes depending on the time of day. Lastly, services such as Buzzcar use web and mobile apps to allow individual car owners to share their vehicles for hourly rates.

In addition to car sharing, mobile apps have emerged to make calling a taxi or car service much easier. These apps allow users to request rides on demand from their phones. The apps have emerged in developed countries but also in emerging economies such as Brazil and Mexico, where calling a secure Radio Taxi has been popular in the past. Some companies, such as Uber and Lyft allow car owners to become drivers for the service and work outside the traditional taxi companies in cities.

II.2.2 ›› Bicycle sharing

Since its inception in its modern form in 1998, bicycle sharing has grown to be present in over 500 cities globally, from China to Brazil to Mexico. Although it appears like a new trend, bike-sharing dates back to 1965 and even before (in the 50s one could rent bicycles in most cities in India) and has already gone through three generations over the course of the past forty-eight years. The number of cities with bike-sharing has quadrupled in the past five years, with 204 cities today. China's 27th most populous city, Wuxi, now has 70,000 bikes in its bike-sharing system. Technology has helped the latest version become increasingly popular. In 2005, the city of Lyon, France, introduced «Lyon Vélo'v,» with bikes equipped with electronic components allowing for the bike to be identified by the stations, the distance travelled and conditions of the bikes (lights, dynamo, brakes, etc.) to be tracked, and detailed statistics about bike usage collected. Other cities such as Knoxville, Tennessee and San Francisco have also begun introducing electric bikes. This third generation «plus,» signalled the appearance of flexible, clean docking stations, touchscreen kiosks, additional bike re-balancing technologies, **smartphone apps on bicycle availability** and station location, as well as the integration of one unique card allowing a user to ride both bikes and public transportation. The latest bicycle sharing systems have also been found to have lower crash rates than regular bicyclists in cities, with few serious injuries and fatalities associated with their use. These new generation systems are strongly inspiring countries like China, which have to deal with road safety and congestion issues. In this countries bike sharing systems are not a simple alternative to other public of private transportation means. Bike sharing may be very efficient for intermodal transportation: in some Chinese cities, metro or bus stations are not as frequent as in city centres, bikes can be used for ways from home to nearest bus or metro station. Given that the population in Chinese cities is generally well equipped with smartphones, this intermodality may be very efficient.

II.2.3 ›› Mass Transit Technology Improvements

Over 250 cities in the world offer so-called Smart Card services for mass transit that can allow passengers to use one card with a stored value instead of paper ticketing. The card can also be integrated across mass transit modes, an example being moving from metro to bus or from a metro to BRT that may be run by separate agencies. **In addition, other advancements in mass transit technologies include applications on smartphones that offer a passenger real-time arrival and route information in the palm of their hand**.

II.2.4 ›› Bus Rapid Transit

One of the fastest growing transport innovations has been Bus Rapid Transit, or BRT which has been implemented in one form or another in over 160 cities worldwide. The increase in advanced bus systems and corridors around the world marks a monumental shift in attitudes and approaches over the past 20 years. Though busways were installed in a few cities – such as Lima and Curitiba – as early as the 1970s, advanced bus systems didn't really take off until several years later. Beginning in the early 1990s, advanced bus corridors began to be built around the world in earnest with dedicated lanes, off-board fare payments and at-level boarding. Rapidly middle-income countries have made the most use out of these new ways to move people towards job opportunities, leisure activities, or closer to their families. Latin American countries have built BRTs in over 55 cities, serving 18.33 million people every day. Asian countries have built BRT corridors in 33 cities, which serve over 8 million people every day. The affordability and speed of construction for BRT lines in comparison with the construction costs of rail systems (metros, or light rail) have made it a clear choice for middle-income countries with rapidly growing populations and transport needs. In addition, high quality BRT has been shown in some cases to reduce traffic accidents by half on the streets they are placed. (Duduta et al, 2013)

BRT is often a viable option for improving mobility in cities because it can move more people in a dedicated lane within densely populated cities than private cars in general traffic lanes. When considering the role of technology and connected mobility, solutions such as BRT continue to offer the prospect for both improving safety and mobility in cities, as well as a mode that can also use connected mobility technologies to improve its efficiency and experience.

EMBARQ®
The WRI Center for Sustainable Transport

AREA	CONCEPT	FIRST YEAR (CITY) Initial year of Implementation	CITIES Number of cities to date	STAGE
Car restrictions & pricing approaches	**Congestion pricing**	**1975** (Singapore)	**6**	**Emerging**
	Low emission zones	**2003** (Tokyo, Japan)	**200+**	**Mainstream in Europe**
	Vehicles quota system	**1990** (Singapore)	**5**	**On the rise in China**
Mass transit	**Metro**	**1863** (London, UK)	**188**	**Mainstream in EU & NA; tipping in China**
	Bus rapid Transit	**1974** (Curitiba, Brazil)	**153**	**Tipping in Latin America and China; emerging in India**
Shared mobility	**Carsharing** (2-way)	**1987** (Lucerne & Zurick, Switzerland)	**1,000+**	**Mainstream in EU & NA; emerging in developing countries**
	Bikesharing	**1998** (Rennes, France)	Nearly **500**	**Tipping in EU, the Americas and China**
Urban design for access	**Transit Oriented development**	**Late 1800s and Early 1900s** (New York, London & others)	**-**	**Mainstream in Europe, Japan, Hong Kong, Singapore; tipping in the US**
	Carfree zones	**1953** (Rotterdam, NL)	**360+**	**Mainstream in European cities; tipping in North and Latin American cities**
	Complete street	**1971** (Portland, Oregon, USA)	**455**	**Tipping in the US**
Multimodal integration	**Smart tickets**	**1989** (Zurick, Switzerland) **1996** (Seoul, South Korea) **1997** (Hong Kong, China)	**250+**	**Tipping in developped country cities and some emerging economies like China**
	Information Integration (example: google transit web app)	**2005** (Portland, Oregon, USA)	**250+**	**Tipping in most developped country cities; On the rise in emerging economies**

Figure 6: Adoption of Avoid and Shift Strategies, Source: Table by EMBARQ

› III. CHALLENGES TO OVERCOME FOR ROAD SAFETY EFFICIENCY OF CONNECTED TECHNOLOGIES AND APPLICATIONS

III.1. TECHNICAL CHALLENGES AND STANDARDIZATION

The standardization of connected technologies is quite a fundamental issue for their implementation since it has huge impacts on economy of scale and more generally, on road safety.

It is also quite a sensitive concern, since vehicle manufacturers are willing to produce unique products that would be competitive and original.

III.1.1 ›› Connectivity deployment

One of the difficulties for the deployment of connected technologies in vehicles and road infrastructures is availability and affordability of connectivity.

The easiest way of communication may be the use of 2.5 and 3G, because they are deployed all over the world. Nevertheless the quality of this type of connection is not always perfect and presents some risks. Indeed, if one uses connected technology for safety reasons, connection needs to be totally reliable since people would depend on these technologies. That is why 2.5 and 3G seem to be interesting for commercial applications but not for safety, at least not everywhere (some geographical zones are not covered by this type of connection).

There is also an option for deployment of short range communication technologies. This solution meets technical requirement for the V2V and V2I connection for the safety use. This type of connection the deployment of new infrastructures is required. Several questions are raised in this case: Would the user be willing to pay for this type of connection? Would public authorities be willing to invest in the deployment?

Moreover, connection may be hybrid and differ according the type of use and geographical area: one can imagine that a short range communication may be most relevant on highways to connect commercial vehicles, in cities, where 3G and 4G are quite deployed, this type of connection may be sufficient:

«*This type of hybrid system may be a compromise solution combining the rapid rollout and capability of the telecommunications operator-based system with the responsiveness of short range technologies. An example of this approach is the development of the CALM architecture by ISO TC 204 which gives access to the most suitable communication media available. There are, of course, cost and complexity implications which have still to be fully evaluated*»[26].

For more information on technical challenges of connected vehicles you can refer to the report «*The Connected Vehicle*» written by World Road Association.

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26 World Road Association, The connected vehicle, FISITA, 2012, http://www.ssti.us/wp/wp-content/uploads/2012/08/connected-vehicles-report.pdf

III.1.2 ›› *The risk of inappropriate responses by drivers to warning signals*

Driver response will condition the level of benefits of connected technologies. In fact, it is expected that drivers address an appropriate response to warnings. Also the response needs to be rapid: if driver is distracted, a collision may occur even if connected technologies have sent the warning. The risk of a wrong response may come from applications that give too many false alarms. In this case drivers will start ignoring warnings and a collision may occur. «For example, the Insurance Institute for Highway Safety reported that as many as 41 percent of drivers of certain makes of vehicles with sensor-based lane departure warning systems found the systems «annoying» due to false alarms and unnecessary warnings»[27].

«The challenges posed by human factors are in many ways similar to those posed by sensor-based crash avoidance technologies and some other vehicle technologies. However, human factor issues may present even greater challenges to V2V technologies. One automobile manufacturer explained that, since not all vehicles in the United States will be equipped with V2V technologies in the early years of their deployment, it is unknown how drivers will adjust their behavior to account for the fact that not all of the vehicles on the road are not capable of providing data. By contrast, with sensor-based technologies, drivers know that their vehicle's warning system is not dependent on the presence of similar technologies in nearby vehicles. Further, the potential introduction of aftermarket V2V devices with a lower level of integration with a vehicle's existing internal network could create additional human factors challenges if aftermarket device warning messages and data are less robust than fully integrated systems. For these reasons, one automobile manufacturer said that it is unrealistic to expect aftermarket devices to perform in all situations»[28].

More generally, behavioural adaptation may be a problem for the road safety potential of connected vehicles. Indeed, people tend to change behaviour when the environment changes, it is actually the capacity adaptation. Nevertheless, the adaptation can produce involuntary or unpredicted outcomes.

If intelligent systems and technologies enhance the safety perception of a driver, then he/she may adopt riskier behaviour. In that sense, technologies can «induce the driver to a false sense of security» and thus encourage a dangerous driving conduct. For instance, drivers of car equipped with Antilock Braking Systems (ABS) tend to be over-reliant on the systems and have riskier attitudes like hard brake manoeuvres, because he/she believes the vehicle will not slide. Such drivers have then transformed the patterns of crashes they are involved in, and the crash reduction purpose of ABS systems is not fulfilled (Mohan, 2009). Another illustrative case can be collision warning system,

where motorists who used to be otherwise concentrated on the driving task tend to be easily distracted since they believe the systems will alert them on time in case of danger. The safety perception provided by such technologies, could also influence drivers to use cars under hostile meteorological conditions like snowfall, frost and torrents. For example, a motorist who otherwise would not drive under short visibility circumstances might do it if his/her vehicle is equipped with vision enhancement system.

Moreover, there could be an indirect impact on non-equipped drivers, who would imitate the behaviour of ITS equipped drivers such as driving nearer to the preceding vehicle or quicker than they should. The interaction between motorists and unprotected road users is also at risk of being altered (Draskoczy, Carsten and Kumala, 1998).

III.1.3 ›› *Standardization safety concern because of cultural and technological gaps*

The operating environment in different parts of the world has many common issues but as many local differences. For example, most cities have congestion; some will have highly developed urban traffic control systems and disciplined drivers and pedestrians. Others have little control, unsophisticated vehicles and a lack of respect for regulation. Different solutions may be required in different regions.

These differences do not mean that world standards are not very desirable. Global harmonization enhances economies of scale in equipment manufacture and would result in wider cross-border mobility and more competition. Delegates' seminars and workshops for the joint task force made it clear that there are strong economic reasons for a global approach at the communications level, but accepted that connected vehicle applications may be very different for different regions. International harmonization of connected vehicle standards is an important and difficult issue.

Standardization is highly important also from the safety point of view. Different signalization systems may confuse drivers who have changed from one vehicle to another and provoke inadequate reactions. Indeed drivers may react incorrectly if they receive different kinds of warnings in the same type of situation when driving a different vehicle, a rental car for example. In order to avoid confusion among drivers, all manufacturers need to have the same system of warnings even if it seems quite acceptable that the system may vary a little between automobile manufacturers.

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[27] United States Government Accountability Office (GAO), Report to congressional requests, intelligent transportation systems, November 2013, p. 19
[28] United States Government Accountability Office (GAO), Report to congressional requests, intelligent transportation systems, November 2013, p. 19

III.2. LEGAL CHALLENGES

Connected vehicles are a real innovation that will certainly change the way we use roads (drive, cross). It will also have an impact on how cities and highways will be built, how goods will travel from one point to another, i.e. some urbanisation experts say that roads will become much narrower if vehicles drive connected in line; there will be more space for pedestrians and cyclists. The legal framework will have to be adapted to all of the changes that connected technologies will produce in the society.

This statement is even truer for autonomous vehicles, which may be seen in continuity with connected vehicles, even though, legal barriers for their implementation would be much more important because of the definition of the responsibility in case of crash.

The notion of driver's and constructor's responsibilities in case of a crash will have to be clearly defined to make possible the implementation of connected and autonomous vehicles.

III.2.1 ›› Legal adaptations

Connected technologies will change our way of driving vehicles, it will also change the environment of road users. That is why the adaptation of the legal framework will appear necessary in most countries. For example, connected and autonomous vehicles will change how infrastructures are built; legal adaptation may be needed in this case. Some changes will also be necessary within the Highway Code to pass the driving licence. Already today some countries have introduced some legal modifications to facilitate the entry on the market of some connected technologies.

The need to introduce some modifications to the legal framework is even more obvious when it comes to autonomous vehicles. Indeed, in the self-driving reality, who would be accountable in the case of a crash: the driver, the car manufacturer, the developer of the vehicle's software, the road designer in the case of an intelligent road system that helps control the vehicle?

While drivers are usually found guilty in case of collisions, they are removed from the «liability equation» when using automated vehicles (Marchant and Lindor, 2012). If the driver error is removed, the frequency of road crashes should diminish. It is taken for granted that autonomous vehicles would be safer than conventional vehicles. The safety issue is a leading factor for the implementation of autonomous vehicles. Google engineers believe that «robot drivers react faster than humans, have 360-degree perception and do not get distracted, sleepy or intoxicated»[29]. Nevertheless, even if autonomous vehicles are safer, they could be accountable when malfunctions or faults provoke crashes and related injuries. For instance, in the US car manufacturers have to encounter similar lawsuits after integrating road safety features in car such as anti-lock systems and airbags. The legal responsibility aspect could be a serious obstacle for the development and commercialisation of driverless vehicles, even when such technologies are socially advantageous. However, legal and policy tools to protect manufacturers from lawsuits (immunity or other defences) could be developed. For example, the «risk defence» mechanism is established when the consumer knows and assumes the possible risks when buying the product. In that case the manufacturer has to fully disclose the potential threats and a likelihood percentage. Other protective instruments can be legislations which protect against, or limit, liability since the driverless vehicle will represent an asset for road safety. In the case of the European Union, a Code of Practice has been developed to protect manufacturers and providers from abusive accountability claims related to the ITS safety technologies deployment. Such code details the standard of caution that protects them and promotes further deployment of such devices.

III.2.2 ›› Vienna Convention revision

However, the Vienna Convention on Road Traffic may be the major obstacle for the deployment of connected technologies and autonomous vehicles. This convention was initially designed to facilitate road traffic all over the World. «It defines a driver as «any person who drives a motor vehicle or other vehicle (including a cycle)». It states that every vehicle shall have a driver who has the requisite knowledge or skill to control the vehicle and that «every driver shall at all times be able to control his vehicle»»[30].

UN-ECE, has recently updated the Vienna Convention. However amendments and changes didn't allow highly and fully automated driving. There are discussions within the Working Party 29 at UN-ECE on which detailed regulations are needed in relation to autonomous vehicles. It is clearly a risk, however, that the urge for regulating autonomous vehicles may be an obstacle for the development of autonomous driving systems. We know that regulations take a long time to enact and to become effective and since the technical development is very rapid, this could mean that technical solutions for autonomous driving will not be legal due to antiquated regulations.

III.3. DATA PROTECTION CHALLENGES

Connected vehicles will produce a huge amount of Data. It is obvious that this information will be very valuable and a great amount of actors will be willing to take advantage of it at a lower cost. This Data will be possibly used to improve infrastructures, for traffic management, for road safety alerts but also for

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[29] Markoff John, Google Cars Drive Themselves, NY Times, 9 October 2010
[30] World Road Association, The connected vehicle, FISITA, 2012, http://www.ssti.us/wp/wp-content/uploads/2012/08/connected-vehicles-report.pdf

commercial purposes, i.e. some insurance companies may use collected Data for risk evaluation. This means that Data ownership will have to be defined. Also this Data will raise the key issue of privacy and of the danger of being hacked.

III.3.1 ›› Personal information protection

The associated increase in vehicle/infrastructure electronics and communications can raise security and privacy issues. These dangers could jeopardise their deployment. Since these technologies collect detailed travel data, they could violate drivers' expectation of privacy. People could feel that they are under surveillance by a «Big brother» camera. The disclosure of data to third parties could lead to commercial misuse, public corruption or identity theft[31]. That is why the European Commission, other organisations and governments consider that the development of these technologies must ensure the integrity, confidentiality and protect the handling of personal data respecting citizens' rights. For example, licensing agreements could be given to specific organisation to access date under restricted conditions and for legitimate purposes[32]. Some studies have delivered suggestions against privacy and security threats. For instance, authentication and data analysis should be managed by separate entities; the connected vehicle architecture should incorporate encryption, tamper-proof hardware and data refining techniques[33]. Other recommendations are the «defence-in-depth» (each layer of hardware and software has its own security functions), «data aggregation near the source» (data aggregation at the vehicle level before transmitting it to service providers) and «user defined privacy policies» (specific virtual contracts between consumers and solution providers).

III.3.2 ›› Risk of being hacked

According to a technical report by computer scientists from the University of California, San Diego and the University of Washington and a TED[34] presentation, unauthorised intrusions to cars' computer systems can take place without direct physical access. The study showed that nowadays the internal networks for control systems in cars are rudimentary and not secure, but did not speculate about the possibility of interfering with

a vehicle's control system to provoke a crash. In the case of vehicle network threats, another study[35] suggests that security requirements such as vehicle authentication and verification of data consistency are necessary. The American National Highway Traffic Safety Administration (NHTSA) has established an Electronics Systems Safety Research Division focused on cybersecurity. This division will set up a preliminary baseline of possible cyber threats for connected vehicles, and how such dangers could be approached in the vehicle environment[36]. Moreover, protocols to support V2V security system are being developed by the NHTSA to deploy reliable and secure connected vehicle technology.

III.4. CHALLENGES OF MASSIFICATION OF TECHNOLOGIES

Equipment of the major part of the fleet is a condition of efficiency of connected technologies.

III.4.1 ›› Demand challenges

The survey from UMTRI[37] deals with public opinion on connected vehicles in English-speaking developed countries: USA, UK and Australia. This study replays to two following questions:

›› Are consumers willing to have these technologies?

›› Are consumers ready to pay for these technologies?

72% of people who were questioned appeared very interested in having connected technologies within their vehicles.

Nevertheless connected vehicles remain broadly unknown: the majority of respondents had never heard about them before the survey. After the presentation on connected vehicles was read, a strong majority of respondents said they had a good impression of the technology.

85% of respondents stated they were very confident about the safety benefits of connected vehicles.

The following arguments in favour of connected vehicles were presented to the participants of the survey: «fewer crashes», «reduced severity of crashes», «improved emergency response to crashes», «less traffic congestion», «shorter travel time», «lower vehicle emissions», «better fuel economy», «lower insurance

[31] Michigan Department of Transportation, Center for Automotive Research, Public Perceptions of Connected Vehicle Technology, July 2012,
http://www.michigan.gov/documents/mdot/MDOT_PublicPerceptionsCV_394490_7.pdf
[32] Michigan Department of Transportation, Center for Automotive Research, Public Perceptions of Connected Vehicle Technology, July 2012,
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[33] Baik Hoh, Marco Gruteser, Hui XiongEnhancing, Ansaf Alrabady, Security and Privacy in Traffic-Monitoring, PERVASIVEcomputing, 2006,
http://research.nokia.com/files/hoh_trafficmonitoring.pdf
[34] TED Talks, http://www.ted.com/talks/avi_rubin_all_your_devices_can_be_hacked.html
[35] Sastry Duri and al., Data protection and Data sharing in telematics, Mobile Networks and Applications, Kluwer Academic Publishers, Netherlands, 2004,
http://home.arcor.de/ille999/Data%20protection%20and%20data%20sharing%20in%20telematics.pdf
[36] Gareffa Peter, Government Focuses on Cybersecurity Risks Linked to Connected Cars, Edmunds.com, May 16, 2013,
http://www.edmunds.com/car-news/government-focuses-on-cybersecurity-risks-linked-to-connected-cars.html
[37] Brandon Schoettle, Michal Sivak, A survey of public opinion about connected vehicles in the U.S., the U.K. and Australia, UMTRI, April 2014

rates», «fewer distractions for drivers». To all of these potential improvements respondents replied «likely» and «very likely».

Concerns that were expressed by respondents about connected vehicles were related mostly to risk of being hacked, to rely too much on technology and to Data privacy.

83% of respondents identified the safety aspect as the most important in connected vehicles. The second most important aspect was «mobility».

Only half of respondents to the survey said that connection of nomadic devices with the vehicle was important to them. Also the importance of internet connectivity in cars was rated as important only by 50% of potential users.

A little more than the half of respondents in the USA, the UK and Australia were willing to pay for this technology. «*In the U.S., 25% of respondents (75th percentile) were willing to pay at least $500 for this technology. The corresponding amounts in the Australia and the U.K. were $455 and $394, respectively. However, a sizeable proportion of respondents said they would not be willing to pay extra for this technology (a response of $0 was given by 45.5% in the U.S., 44.8% in the U.K., and 42.6% in Australia)*»[38].

Another interesting fact is also highlighted by the survey: «*Respondents who had previously heard of connected vehicles were more likely to expect crash-reduction benefits and lower insurance rates. These respondents were also more interested in having the technology on their vehicle, and were more likely to say that integration with personal communication devices and Internet connectivity were important features of connected vehicles. Those having previously heard of connected vehicles would be willing to pay more for the technology than those who had not, and were less likely to say they would not pay anything extra.*»[39] This means that if the success factor of the connected vehicles is massification, the population needs to be better informed on these new technologies.

III.4.2 ›› Mass deployment requirements

The condition of efficiency of most of V2V, V2I and V2X communications is massive equipment with these technologies of vehicles on the road. If only a small part of the fleet were to be equipped with these technologies they will be inefficient or even dangerous since road users won't be able to rely on warning signals (since they wouldn't be systematic).

A real difficulty is in equipping all vehicles on road with real communication capabilities in a reasonable time-frame. As far as infrastructure-to-vehicle communication is concerned, it is even more difficult to deploy such capabilities throughout a region or a country because of the enormous investment necessary. Even if all new vehicles are obliged to have that capability, it might take 25

or more years to penetrate the entire fleet (say 300 million vehicles on the road) of vehicles in a region with this sort of capability. So at best communication capabilities can only come into vehicles at a slow rate. It is not that old vehicles cannot be so equipped. It is a matter of getting acceptance from the public for equipping older vehicles. To derive the benefits of connected technologies (if they are proven to be beneficial), we need to have the technologies available in a significant portion of the vehicle fleet. Additionally, the proportion of new and old vehicles in the fleet would vary from country to country and region to region.

Smartphones may be a short-term alternative for those who will not be willing to pay high prices for connected safety services, however, one needs to take into account that different types of technologies will spread in different ways: it is quite obvious that embedded technologies and smartphone apps won't need the same time to be implemented.

Moreover, in different countries technologies won't spread in the same way. Technical development in middle-income countries is unlikely to follow the same path as developed countries. Emerging technologies may take hold faster in growing market countries than in developed countries. For example technologies that are independent of established infrastructure give a middle-income country the opportunity to leapfrog developed countries. This is particularly important for the communication technologies we are considering. Research in high-income countries may give a misleading impression about suitability in middle-income countries.

III.4.3 ›› Financial limitations

Funding restraints represent a significant challenge to transportation organisations due to competing concerns and the actual economically constrained situation. ITS projects compete for finance with other infrastructure necessities such as building and maintaining highways and roads. Other aspect concerns the ITS already installed but that are not maintained due to a lack of funding. Constant operational and repair costs of such systems can even surpass those of deployment. It seems that such technologies could have the risk of becoming obsolete or require retooling within a short time. For example, some public administrations purchased traffic data from private companies in order to avoid such technologies. Nevertheless a 2005 study of a model ITS deployment in Tucson, Arizona estimated that the average annual cost for implementing, operating, and maintaining all 35 ITS technologies was calculated at $72 million, while the estimated average benefit from the ITS deployments to road safety, environment and other areas was calculated at $455 million annually. The economic benefit of the South Korean Traffic Management System attributable to reduced transportation time, crashes, and pollution has been about $109 million annually[40].

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[38] Brandon Schoettle, Michal Sivak, A survey of public opinion about connected vehicles in the U.S., the U.K. and Australia, UMTRI, April 2014, p. 15
[39] Brandon Schoettle, Michal Sivak, A survey of public opinion about connected vehicles in the U.S., the U.K. and Australia, UMTRI, April 2014, p. 17
[40] Stephen Ezell, Explaining international IT application leadership: Intelligent Transportation Systems, IITIF, January 2010, http://www.itif.org/files/2010-1-27-ITS_Leadership.pdf

CONCLUSIONS ON THE IMPLEMENTATION OF ROAD SAFETY CONNECTED TECHNOLOGIES

›EXPLANATORY NOTE

This chapter addresses some conclusions and guidelines to public and private decision makers on the implementation of connected technologies and applications to solve some road safety issues. Technology assessment and recommendations on public policies and business models are the fruit of an 18 month collaboration between international experts of the task force «Road Safety & Connected Mobility».

These guidelines are an outcome of the first chapter on the state of art of connected technologies for the road safety.

This book doesn't aim at saying that connected technologies and applications are THE solution to road crashes. The experts realize that in order to be road safety-efficient, some connected technologies need to be supported by basic passive safety devices and some ADAS[41].

Connectivity should be embedded in a human factor approach (systematic vision), distraction problems should be prevented and road users need to be able to react if systems/devices fail to work. These are important conditions for the road safety efficiency of connected technologies.

The task force made an attempt to assess road safety efficiency of some well-known connected applications through analyse of existing studies and literature. Even though some technologies seem quite promising, experts encourage developers to deepen their studies on road safety impacts of connected vehicles, infrastructures and applications.

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[41] Advanced Driver Assistance Systems

›I. PUBLIC AND PRIVATE DECISION MAKERS' INTEREST IN THE IMPLEMENTATION OF CONNECTED TECHNOLOGIES

Briefly…

ITS and other connected applications have several functions; Road Safety is only one of them. The development of ITS may represent high social benefits since it can also address the following issues:

›› reduce congestion

›› reduce energy consumption and traffic emissions

›› improve quality of life in city centres

›› increase market share of clean vehicles in private and public fleets

›› increase efficiency of the transport system

›› increase attractiveness of public transport/ encourage modal shift

›› facilitate freight delivery and servicing

Also the benefits of the implementation of such technologies may have positive impacts on economic growth (research, infrastructure building, more efficient freight transport…).

I.1. PUBLIC AUTHORITIES' MOTIVATIONS TO IMPLEMENT CONNECTED TECHNOLOGIES

Summary

Governments are concerned about the big picture: security, mobility, safer roads, greater transport efficiency, employment and job creation, sustainability and lower emissions. No public investment can happen without a strong economic case based on evidence of benefits to the economy and society.

The promoters of co-operative systems need urgently to deconstruct the benefits of the technology and sell solutions to problems, especially with politicians: safety benefits, security benefits, economic benefits, job creation, environmental benefits, etc.

The available evidence points to a strong case for action by governments based on improvements in road safety and by road operators based on greater efficiency in maintaining and operating roads. VICS in Japan has shown that a government-led approach can lead to a significant uptake of connected systems. The Japanese system, VICS, connects through infrared beacons in urban areas as part of the police-led Universal Traffic Management System. On freeways DSRC microwave beacons have been installed to carry travel information and for electronic toll payments.

In order to act governments need to be satisfied that the chosen road-map for deployment of co-operative systems is viable and has the backing of all the main stakeholders. The public for their part will expect guarantees on the complete reliability of co-operative systems and sound proposals for the management of risks when things go wrong. Reassurance on issues of privacy and the «fairness» of these systems, perhaps with legislation, will also play a big part in what will be politically acceptable.

Background

Public policy objectives for most countries are driven by the need to maintain or improve the mobility of people and goods to support businesses and encourage economic growth. Generally economic growth is linked to a growth in traffic volumes and corresponding growth in congestion. There is a requirement to manage the impact of these increased traffic volumes so that congestion does not undermine the benefits of growth and traffic does not damage the quality of life of those living close to the road network.

Advanced economies have invested heavily in sophisticated traffic management for the urban and inter-urban road networks with Urban Traffic Control (UTC) systems, motorway control systems, softened infrastructure and road safety design along with sophisticated driver licensing and road user education systems. The vehicle fleets of more advanced nations are modern and regularly updated. **It follows that these nations are well placed to benefit from the development of vehicle connectivity and will be encouraged to do so by an ageing infrastructure with constraints on its development**. There

is a focus on environmental improvement and carbon emission reduction. The transition to an intelligent connected vehicle is no longer a matter of decades; it can be made in years.

The situation in the less advanced economies is different. There is a focus on improving the infrastructure but greater benefit is available from improving standards of road and vehicles' engineering rather than investing in technologies benefiting only a wealthy few. However many of these nations are also investing in high quality road infrastructures financed from free flow tolling. **Countries such as India and China are currently building new infrastructure because of the substantial annual increase in motorised traffic. This may be a real opportunity for the implementation of connected technologies in growing markets**. Also they have embraced wireless telephone technology for mobile phones and have a strong installed commercial data and internet service.

The economic case for investment

Most governments face issues of increased levels of vehicle ownership and usage. Investment in new highways and improvements to the existing road infrastructure is part of a modern economy. But new roads take time to build, there is often opposition and it can be difficult for governments to keep pace. Everywhere as traffic volumes grow congestion becomes more widespread, traffic noise and air pollution levels become more serious and collisions increase in number. In the less developed world governments often face additional pressures concerning people's lack of mobility especially in rural areas, and poor levels of security (crime) affecting the transport of goods. The social political and legal issues that road networks face are diverse and can vary greatly not only from country to country but also on a regional scale.

Some issues may be universal or apply to more than one region or country but they often differ in importance. This makes it difficult to provide generic solutions, which means that there can be different priorities regarding the use of co-operative systems in different regions. There are many examples to demonstrate the disparate nature of priorities in different countries:

›› for the US and Canada, security at border crossings is extremely important;

›› the long distances covered by road networks in Australia result in issues that do not affect smaller countries;

›› Europe suffers from traffic problems requiring alternative routing and therefore the priority is to make the best use of limited road capacity and encourage alternative modes;

›› Africa has a large number of older vehicles and poor road quality;

›› in some countries such as Sweden, safety is the over-riding priority.

Road safety is a common thread to public policy decisions. Many governments now set road safety targets as a means of focu-

sing attention on the measures needed to prevent road accidents from happening and to lower the negative effects of crashes. For example, in 2000 the UK set a target of a 40% reduction in the numbers killed and seriously injured over the following 10 years.

The next generation of targets, such as the vision of zero accidents which Sweden has adopted, will be even more of a challenge. Almost inevitably they will require active safety systems which use mobile connectivity and co-operative systems.

Safety is on the political agenda particularly with the recent launch of the United Nations initiative the Decade of Action for Road Safety 2011-2020. The goal is to stabilize and then reduce the forecast level of road traffic fatalities around the world by increasing activities conducted at the national, regional and global levels. One hundred governments co-sponsored the UN resolution establishing the Decade of Action, committing to work to achieve this ambitious objective through an action plan with targets for raising motorcycle helmet and car seat belt use, promoting safer road infrastructure and protecting vulnerable road users such as pedestrians and cyclists.

After safety, most countries battle with the need to maintain a good standard of mobility on roads. Efficient road transport is increasingly important to economic growth, serving the mobility needs of people and goods. Without it a modern economy would grind to a halt. Governments therefore have a close interest in the many improvements that the connected vehicle may bring, notably:

›› improvements in traffic flow. Recent tests in the Netherlands show a 25% penetration of connected co-operative vehicles could give up to 30% improvement in flow on congested major highways;

›› reductions in collisions, which adversely affect congestion even if there is no injury;

›› improved incident response and management of traffic with less delay though better communications;

›› better navigation and routeing leading to more efficient routing and less wasted mileage;

›› enabling of congestion charging based on precise knowledge of a vehicle's location and the prevailing traffic conditions.

Road freight is another area where the connected vehicle could impact. Efficient freight transport is vital to economic growth and stability, important for both developed and less-developed countries. More efficient journey planning and better freight logistics will improve commercial vehicle utilization and keep freight on suitable roads. It will be possible to better organize truck parking and vehicle security with important local benefits. From the government's perspective the connected vehicle can support a tough regulatory environment (lorry routing, truck parking, load tracking) and contribute significantly to quality control. From the operator's perspective the connected vehicle can improve utilization and reduce operating costs. Both parties can gain.

There are, nevertheless, a number of practical issues that will affect the willingness of governments to embark on a programme of investment. Long term planning of government programmes is problematic, particularly at times of economic difficulty with falling tax revenues. Another issue is the way government business is placed through competitively awarded contracts. By implication this means there must be choice of suppliers. When procuring systems or services Governments are, in general, obliged to work through contracts framed in terms of functional specifications and seek offers from multiple suppliers. This requirement to test the market militates against adopting an original (single-source) proprietary technology, however powerful or multi-featured it may be. Finally, there are areas of public and political concern, such as equity, privacy and security (both real and imagined) that have to be managed before government can fully endorse the new technology.

In summary, there are strong arguments in favour of governments encouraging the wide-spread deployment of connected vehicles. However, in general governments prefer to support R&D and standardization, relying on industry to deploy and exploit new technologies. Hard evidence of safety, efficiency or environmental gains is required to set policy. There has to be a strong economic case for government action because public investment will have to compete with other public expenditures in fields such as health.

Research suggests that connected vehicles and co-operative systems will bring economic savings in transport and across other economic sectors along with environmental benefits, but for most countries (Japan is an exception) the evidence is not yet sufficiently compelling to justify a government investment programme. More work is required.

I.2. BENEFITS TO ROAD NETWORKS OPERATORS (PUBLIC OR PRIVATE)

Summary

From the perspective of the road operator, the connected vehicle and co-operative systems taken together offer a powerful new approach to managing roads and traffic. Road network operations have much to gain from the introduction of the connected vehicle. The technology can be harnessed to develop applications that will enable:

›› *better, cheaper information services and knowledge of network usage;*

›› *road facilitates management, charging and access control;*

›› *reduced delays from accidents and congestion;*

›› *tracking of secure or hazardous loads;*

›› *charging and tolling without delaying traffic;*

›› *improved options for traffic management and control;*

›› *non-invasive data capture with less damage to the infrastructure; and*

›› *travel and traffic information (for road users and for road authorities).*

Road users demand that the network provide a reliable, predictable and safe journey. The network as a whole is shared between different authorities, often with a division between urban roads operated by city authorities and inter-urban trunk connections run by a private toll-road company or public sector highways agency. If there is an obstruction or failure action has to be taken to re-route or delay traffic and this often involves more than one jurisdiction. This division of responsibilities means that road operators must work together in concert if the full potential of connected vehicles is to be realized.

Road operators and road network operations have an increasingly important part to play as traffic volumes grow and the road network itself gets more congested. The network operator may be part of a government department, an arms-length government agency, a local authority or city, or a private organization. All of these entities are responsible in various ways for roads and traffic. Moreover, privately financed organizations can be operating roads either for government or independently of government. In general terms their objectives are to plan and provide and maintain a safe road network which provides efficient c ost-effective services for goods and passenger vehicles.

Road managers are expected to meet public expectations on journey time reliability, congestion, condition of carriageways and structures and safety. In cities air quality is an important issue. Budgets for capital and revenue are critical. Investment in connected systems will have to compete on merit with investment in conventional engineering and other intelligent transport systems. If road managers are to invest in the roadside infrastructure to support connected vehicles the case has to be well made.

This case will be based around the prevention of accidents, better management and control and the reduced need for expensive infrastructure. There is evidence from research that short range communications may reduce accidents, but this is dependent upon the number of equipped vehicles. Better management can be achieved by broadcasting traffic management information and traffic signal timings. Better informed drivers should have smoother, more economical journeys which make better use of the available road space.

Broadcasting information in this way also provides the opportunity for a reduction in roadside equipment, signs VMS and gantries, all expensive to provide and maintain. In USA the State of Michigan estimates some $250,000 could be saved each time on structures work by using DSRC and in-vehicle signage to replace expensive electronic variable message sign- boards.

The cost of providing infrastructure support for the connected vehicle is unclear. Where applications can be implemented using available telecommunication systems (cellular and Wi-Fi) the costs are minimal and there is a mechanism in place for recovering the cost from the user. However, if a purpose designed short range wireless infrastructure is required the cost will be significant, even if installation is restricted to «hot spots».

As traffic volumes grow, real-time data on road traffic and weather conditions becomes essential to the operation of the network. This data consists of real time information about traffic flows and speeds at different points of the network. In many countries winter maintenance brings its own special need for data involving warnings of snow, ice, floods etc. and management of events and emergencies requires a need for specific data. Normally this data is collected from sensors and cameras at specific points on the network.

Similar data can be obtained from the vehicle fleet using connected technologies. The data may not be the same as the data used today and will need statistical and modelling treatment to turn it into useful information. Carefully developed the connected vehicle has the potential to provide better, cheaper information suitable for both planning and real time information applications. Connected vehicles have potential for savings in capital and revenue expenditure.

These vehicles can also provide information that is not readily available from normal sources. Applications on systems embedded in modern vehicles can store geographically referenced data about the roads on which the vehicles travels. This information may relate to road condition, noise level, vibration or discontinuity. A measure of road surface friction is available and may have value for carriageway assessment or for use in winter conditions.

Other benefits will come from a more complete understanding of user demand through data from the connected vehicle, which will enable more efficient use of the network. Prototypes are being tested for data analysis and decision support in Singapore, Germany and New Zealand, with near-term prediction (because real-time is already too late if you are still some distance away). One company claims to have achieved 85% predictive accuracy on arterials, higher on freeways. Having this information available should enable better journey planning. There are also some potential gains from learning the origin and destination. Air, rail and maritime have the huge advantage of nearly always knowing this. Road network management becomes significantly easier once a vehicle connects and relays automatically the origin and in many cases the destination. Some countries plan to reduce tolling charges for users who were to 'reserve' a travel slot.

The road operator may need to work hand in hand with automotive companies and/or third party specialist organizations to collect this type of data. Already, probe data from both vehicles and mobile phones are growing in importance and are increasingly being used by road operators, sourced from traffic information suppliers. The data supplements other forms of traffic condition monitoring, both for real-time reporting and historical analyses. This can be very cost-effective for developing countries where little investment has been made in conventional traffic monitoring equipment or for monitoring traffic movements in complex urban networks.

In some countries digital mapping companies have contracts with the authorities to supply their data on point-to-point journey times for traffic management purposes, often partnering with and a local vehicle operator to provide a core fleet of traffic probes.

I.3. PROFITABILITY OF CONNECTED TECHNOLOGIES FOR PRIVATE COMPANIES

Summary

The commercial business perspective is focused on commercial opportunities, new products and services, revenue streams and a quick return on investment. A business case already exists for the development of viable services in a number of areas, using the current level of connected vehicle technology:

›› Consumer applications and «infotainment»;

›› Freight management applications;

›› Charging and payment applications;

›› Personal applications and social networking; and

›› Navigation, journey planning and location-related applications.

From the perspective of the automotive industry there are significant technical, commercial and political risks that have to be managed. The way forward for industry is to continue, as now, making use of proven existing communication technologies, collaborating in field trials and operational tests and developing applications that bring added value to their customers. Criteria for major investment are:

›› A convincing plan for investment in and operation of the infrastructure needed for a V2V security network as part of co-operative systems;

›› Confidence that infrastructure-sourced data will be well managed and bring added value;

›› A legal and regulatory framework that covers the deployment of co-operative systems;

›› Clear market opportunities and transparency in the political, regulatory and competitive environment;

›› Partnership agreements and leadership among the partners[42]; and

›› Well-developed plans for customer support and back office arrangements.

For telecommunications companies the connected vehicle is more than just another consumer device. It is a completely new user environment where services fit in, which brings together the home, the car, business and the mobile internet. New business models that make use of the smartphone and smartphone applications are emerging.

The taxonomy for connected vehicle services will need to distinguish between those that are consumer market-based (value-added), automotive-based, communications based taxation based, or infrastructure-based. At the moment it seems unlikely that telecommunications companies will provide the ground infrastructure associated with DSRC.

Background

The issues arising from the development of the connected vehicle from different business perspectives are many and various. Trials have shown that the connected vehicle promises more than enhanced safety and improved journey times. It opens up commercial opportunities for the automotive industry Original Equipment Manufacturers (OEMs), provides a new market for connected vehicle applications («apps»), new business opportunities for navigation companies and transforms the vehicle into a telecommunications platform to be exploited by the telecommunications industry.

Most of the research undertaken has focused on the safety, capacity and efficiency and environmental benefits. These are benefits to individuals and to society as a whole but not necessarily profitable to the companies themselves. The commercial challenge is to work out how to bring these co-operative systems to market around a business case that makes sense for all the stakeholders.

Up to now the telematics boxes for cars have been stand-alone solutions which are developed for different OEMs. Integrated solutions will be more of a challenge, to integrate or interface between the boxes for different OEMs; also for interfacing between low-value and high value cars.

Co-operative applications need stable long-term technology - for the life-time of the vehicle. Co-operative driving will need internationally harmonized standards and trust protocols for communications between vehicles and with the infrastructure.

Safety systems will need very reliable low-latency communications with a split-second response. The auto industry has explained (Detroit ITS World Congress 2013) that 4G/LTE is sufficiently stable and future-proofed to be the main channel with DSCR at selected positions such as complex intersections.

However it is not completely clear at this point who would own and operate connectivity or how it would be funded initially and for on-going operations. The long-term costs of fitting all vehicles with DSRC communications would not be high, but supporting roadside infrastructure for the security or certificate systems will be needed for ultimate implementation of V2V.

Infrastructure for V2I applications may have more flexibility although few road authorities currently have plans to put in infrastructure needed for V2I unless it can be incorporated into traffic signal upgrades. Japan is a notable exception in rolling out an extensive network of DSRC beacons at 5.8 GHz.

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[42] There is still a debate in Europe regarding the 'ownership' of the wireless interface. Automotive companies, telecom companies as well as other third party organizations are arguing over the «ownership» of the data. This all reinforces the case for the three major industry sectors to start a sensible collaboration and partnership.

Automotive Sector

In the meantime the automotive industry is moving forward adding stand-alone safety and mobility features to their cars. These are both practical tools for drivers and marketing tools for the companies. They demonstrate that there is an appetite for the use of more advanced technology in cars and that the cost has been reduced to a point that there is no customer resistance.

Dominant issues for the industry are fuel efficiency, customer care, customer loyalty and infotainment. Manufacturers see new technology as a means of maintaining or improving their market shares with features that enable their products to be differentiated in style and equipment from the models of other suppliers. To some extent this is at odds with government interest in having all vehicles carrying similar equipment functionality to enable a universal service available to all road-users.

Concerns about stand-alone safety are informed by a strong ethic of customer care. However, in practice, developments in vehicle safety systems and driver support are motivated by what is commercially viable. The industry is interested in market gains that are attainable in the short to medium term, hence they are focusing on connected technologies which make use of the available mobile telecommunications networks.

At the same time the development of nomadic devices and smartphone apps using mobile telecommunications is proceeding apace. The time from development to market for these devices is very short, less than a year. It is a major challenge for the automotive OEMs to get their business cycles to fit.

From a business point of view OEMs need applications to bring into the business plan quickly. There is industry-wide pressure to benefit from the globalization of production by developing models that can be sold into different regional markets worldwide, with as much standardization of equipment as possible. Short-term focus is on in-vehicle consumer products that use mobile communications and GPS. In the medium-term the industry anticipates the commercial development of vehicle to vehicle communications.

The industry is actively seeking new markets in the form of added-value customer services. Service relationships are potentially a profitable growth area. A service relationship is long-standing, more so than just selling cars, trucks and buses.

Margins for OEMs are being driven down on their products as they become more like commodities and so OEMs want more of the value chain accruing to them. New connected vehicle services already offer to customers:

›› remote engine health management and vehicle diagnostics;

›› emergency and breakdown handling;

›› personal preferences and upgrading;

›› event recording for insurance and claims;

›› theft recovery and security; and

›› entertainment, through the mobile internet.

Automotive insurance is another important business area. Once installed, GPS can be used for stolen vehicle tracking, automatic crash notification (eCall) and crash data management. Personal safety and security can be linked together as a service package. In Sweden, Germany, USA and elsewhere insurance companies are starting with a «Pay as you drive» concept. The data from in-vehicle telematics is powerful for user-based insurance profiling and has the benefit of GPS location referencing for incident analysis. The subsequent use of collected data which shows traffic flow, origin and destination information etc. is normally aggregated to protect privacy before being supplied for other (non-personal insurance) services. The prospect of changing driver behaviour through smarter analysis of personal driving profiles is one of the key potential benefits of these systems. However, it is true that road users may be quite reluctant to the idea of being tracked.

The pressure to avoid costly product recalls and litigation when things go wrong is a major factor. There is an over-riding need to split the safety related applications from consumer applications so that basic vehicle functionality is not compromised. For example, the idea of having a docking station so that mobile devices and after-market units can connect with the vehicle's systems is an attractive concept, but is viewed with extreme caution (it is necessary to clearly define cooperation conditions). However, there is also a proposal that a smartphone will detect when it is within the vehicle environment and will switch automatically to a «safe driving mode».

Truck manufacturers are generally positive towards applications like lane departure warnings which help counter driver fatigue. However the freight and haulage industry operates tight margins and is notoriously resistant to any features increasing the capital and maintenance cost of a vehicle.

There are three significant applications for the connected commercial vehicle: Fleet management, emergency roadside assistance and stolen vehicle recovery. In Brazil and Mexico stolen vehicle recovery is required by law. «Connection» allows the incident to be dealt with, with speed and accuracy. It also benefits the security of shipping containers for freight. A public private partnership may be a potential solution.

In summary, the automotive industry is engaged in bringing connected vehicles to market as rapidly as possible, based on profitable consumer-led features (GSM, hands-free mobile phones, mobile internet, Infotainment). The business case, in the near-term, is based entirely on using existing telecommunications services rather than develop new dedicated systems. Connectivity is not just to the vehicle but enables connectivity though the value chain by adding partners. Embedded phones provide the basis for four main services: emergency call, traffic information, destination information downloads and remote diagnostics.

Information technologies and telecommunications

Progress with IT and mobile telecommunications is fundamental to the concept of the connected vehicle. Telecommunications Companies are investing billions of dollars in the telecommunications infrastructure and expect a return on investment in 3-5 years.

Having made a massive investment in mobile infrastructure for consumers the telecommunications industry is interested in exploiting that investment by selling bandwidth, hardware, applications and information services. There has been strong growth in cellular-based services into the vehicle, leveraging the 2.5 and 3rd generation mobile phone networks. Companies are interested in connecting with mobile consumers to tap the revenue potential, for example from driving utility applications and location-based services paid for by advertising content, social networking and interactive games.

The connected vehicle is a new user environment that brings together home, mobile telephone and car. With mobile internet there can be rich content and social networking coming into the vehicle. Future generations of mobile telecommunications will further improve bandwidth, speed of communication and reliability. The long-term future of cellular phone systems has been agreed globally and is based on internet protocols. Fourth and 5th generation mobile phone networks will have the potential to create an «internet of things» (cars, smartphones and nomadic devices as terminals) each with a 1-2-1 interface with the customer.

Along with the expansion of mobile phone networks there have been far-reaching developments in smartphone handsets and other nomadic devices. Many handsets now come equipped with GPS and digital maps. The number of models with advanced features is growing and retailers are offering them on attractive terms. Applications for them are easy to develop, for example to download maps and traffic information or to view Internet sites with traffic camera images, but there is no control over the quality of these applications. There are also serious safety concerns about the use of handsets when on the move because of the risk that the driver will be distracted from the driving task.

Mobile phones are continuing to evolve. Handsets which incorporate near-field communications and DSRC are under development. Phone manufacturers are pressing for a standard to enable connectivity between the device and the vehicle, so that hand set controls are presented on the vehicle screen and can make use of the vehicle's HMI but vehicle manufacturers are cautious about the idea. Quality of the service is the issue, especially if the application is safety critical. They are concerned about the possibility of degrading the performance of the vehicles' own equipment.

With the growth in mobile bandwidth proceeding apace there is continuous content innovation and an insatiable need to increase capacity to service the development of new applications. Linked with this are new mobile tariffs and roaming charges.

Products are updated every six months, affecting the choice of handsets and the bundling of services. In contrast the vehicle manufacturing cycle is 5 to 10 years and the lead-time on producing a new model from finalising plans to production is at least 30 months. Upgrades to the road infrastructure take much longer, from 10-20 years to work through.

This astounding pace of development in the telecommunications sector is fuelling the development of new businesses and is even having an impact on changing social conditions. Given the mismatch of product cycles vehicle manufacturers will always lag behind and road operators will be even further back. Experience with electronic tolling shows that new technology when applied to road traffic is adopted more quickly if there is take-up of after-market devices.

At the present time there is no evidence that there is a business case which will encourage the telecommunications industry to provide an infrastructure to support DSRC services.

In summary the road traffic environment take-up and adoption of mobile connectivity will be much quicker using existing portable technology and after-market devices. Developments in smartphones are significant, but they cannot rule out an independent in-vehicle platform in for safety-critical applications. Market-driven consumer applications alone are unlikely to produce large-scale safety benefits and there could even be dis-benefits arising from driver distraction.

Digital mapping and information services

Digital mapping and information services have been among the leading applications for the connected vehicle. Digital map providers are in partnership with mobile phone operators to expand the market for their products either in partnership with an OEM or by providing equipment for the after-market.

Advanced mapping systems are a platform for location-based services that can be sold into the vehicle. A great deal of innovation is expected around the so-called «Freemium» business model: free applications plus the map, based on selling air time and data transfer. Premium navigation services will be pay-per-use, with strong visual content such as realistic road sign graphics and 3D displays.

There is a close synergy between digital maps and information services. For example a major provider of digital maps also markets a traffic system that links real-time traffic information with map data for wireless transmission directly to in-vehicle navigation systems, personal navigation devices and mobile phones. The system is available in a growing number of cities in North America and Europe and for long haul international truck navigation, for example in Argentina, Brazil and Chile. It delivers detailed information about current traffic conditions, based on data sources such as GPS probe data from consumer devices.

Map-makers draw on information from a wide range of third party sources for their databases. Their aim is to provide information that is relevant to all types of user. Recent years have

seen the development of a method of gathering this detail with the passive help of the community of map users themselves. It works by exploiting the opportunities provided by the connected vehicle for automatic reporting of errors in the map database. Details detected by GPS measurements such as one-way traffic flow, the changes in the layout of a roundabout, road gradient measurements and new road geometry can all be captured in this way.

Mapping could be extended in various ways to include road information useful to the operation of the vehicle, notably:

›› static information about the roadway, such as contours, road and traffic signs, height and weight restrictions, fixed speed limits, environmental indicators (e.g. Low Emission Zones, quiet zones);

›› variable information about road conditions, such as temporary road closures and diversions, «virtual» Variable Message Signs, weather conditions, variable speed limits, road surface data; and

›› other journey-based applications, such as location, local communication with other travelers (where are my friends?), tourism information and advertising of local services.

These features can be incorporated in digital maps today but a significant improvement in the accuracy of satellite-based positioning technology is expected in the next few years.. To take full advantage there will need to be a corresponding improvement in the accuracy and detail recorded in map databases.

An important concept is the Local Dynamic Map which holds spatial data in real-time for a small area, like a road intersection or roundabout. Each intersection has a roadside station that holds the local map database and stores dynamic information on traffic and movements in the immediate vicinity, constantly updated in real-time. The roadside stations are an add-on to existing traffic control technology. Research is evaluating how the Local Dynamic Map can be used as a platform for collision avoidance applications using always-on communications with vehicles.

These significant developments point to the need for a four-way partnership between the map-makers, telecommunications companies, vehicle manufacturers and road operators to develop the connected vehicle to its full potential. Digital mapping and information services have already introduced systems with dynamic traffic data using information from other road users. Commercial arrangements with telecommunications companies will mean that communication charges are covered by a one off payment. In addition, portable units could have capability for incorporating DSRC into which would provide a platform for vehicle-infrastructure communications.

Equipment and control system suppliers

The manufacturers and suppliers of traffic control systems and equipment are an important commercial group. These companies are central to the development of Urban Traffic Control (UTC), controlled motorways, electronic toll and congestion charges, speed enforcement and other traffic control systems. They are involved in equipping and maintaining the traffic control centres and may train and provide the operational staff for these centres.

Traffic control technology needs to be reliable in all weather conditions, in all traffic conditions and on a 24/7 basis. The companies are actively involved in research and standards development work and require a stable operating environment in order to develop new equipment. Important design considerations are the need to maintain safety on the road at all times and prevent catastrophic failure. Systems need to be fail-safe, robust against vandalism and secure from malicious tampering.

Wireless equipment suppliers are an important sector of the market with established products for electronic payment and tolling. Their business stands to expand greatly if DSRC beacons are adopted as the accepted basis for vehicle-vehicle and vehicle infrastructure communications and are rolled out across the road network. The companies have developed and demonstrated prototypes and are awaiting agreement on stable international standards. A few technical issues remain to be solved, for example to test the performance of these systems when scaled up to communicate with large numbers of vehicles in heavy traffic. Current work by the USA through the connected vehicle safety pilot and model deployment will hasten these developments.

Suppliers are taking part in demonstration schemes involving connected vehicles and co-operative systems because their products, notably UTC systems, will need redesigning to take advantage of interaction at traffic signals and probe data. Given the huge installed base of older traffic signal controllers in towns and cities world-wide there will be a sizeable business opportunity if authorities demand new or upgraded controllers with these new features.

The commercial business perspective is focused on commercial opportunities, new products and services, revenue streams and a quick return on investment. A business case already exists for the development of viable services in a number of areas, using the current level of connected vehicle technology:

›› Consumer applications and «infotainment»;

›› Freight management applications;

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›› Navigation, journey planning and location-related applications.

From the perspective of the automotive industry there are significant technical, commercial and political risks that have to be managed. **The way forward for the industry is to continue, as now, making use of proven existing communication**

technologies, collaborating (telecoms, mapping industries and road owners) in field trials, operational tests and developing applications that bring added value to their customers. Criteria for major investment are:

›› A convincing plan for investment in and operation of the infrastructure needed for a V2V security network as part of co-operative systems;

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The taxonomy for connected vehicle services will need to distinguish between those that are consumer market-based (value-added), automotive-based, communications based taxation based, or infrastructure-based. At the moment it seems unlikely that telecommunications companies will provide the ground infrastructure associated with DSRC.

› II. GUIDELINES ON CHOICES OF TECHNOLOGIES FROM A ROAD SAFETY PERSPECTIVE

II.1. METHODOLOGY TO FOLLOW TO ASSESS CONNECTED TECHNOLOGIES AND APPLICATIONS FROM A ROAD SAFETY PERSPECTIVE

A thorough framework to assess the effect of ITS systems has been proposed by Kulmala (Ex-ante assessment of the safety effects of ITS, 2010) on the basis of previous research (Draskoczy et al, 1998). It proposes 9 (or 10) steps in the evaluation process, which are practically hardly possible because of a lot of missing data but has the advantage of presenting what should theoretically be done for assessing properly the incidence of ITS systems (or more generally ADAS) on traffic and traffic safety:

1. Direct in-vehicle modification of the driving task.
2. Direct influence by roadside systems.
3. Indirect modification of user behaviour.
4. Indirect modification of non-user behaviour.
5. Modification of interaction between road users.
6. Modification of exposure.
7. Modification of modal choice.
8. Modification of route choice.
9. Modification of accident consequences only.
10. Modification of speed

II.2. EVALUATION OF SOME CONNECTED TECHNOLOGIES AND APPLICATIONS FROM A ROAD SAFETY PERSPECTIVE

Summary
It is quite complicated to make a comprehensive assessment of the road safety function of connected technologies since all of them are still not on the market. Also it is quite complicated to find studies of connected technologies dealing with all road safety aspects.
One needs to pay attention to the fact that some connected technologies may only indirectly contribute to road safety, since their main functions are «infotainment».

Table 1 was filled in with information that is available in scientific literature or whenever there is convergence in most experts' opinions. Actually, the data to fill in table 1 in this level of detail may not be available at this point, since a lot of technologies and applications are still being developed and are not in the market or because they have simply not been evaluated so far. Please note that this table is driver-oriented and doesn't take into account all types of road users.

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[43] There are actually different definitions and understanding of attention and distraction (see for example 'Driver distraction and driver inattention: Definition, relationship and taxonomy' Reagan et al, 2011). For the sake of simplicity, we consider the following definition: Driver distraction is a «diversion of attention from driving, because the driver is temporarily focusing on an object, person, task or event not related to driving, which reduces the driver's awareness, decision making ability and/or performance, leading to an increased risk of corrective actions, near-crashes, or crashes» (Hedlung et al., 2005).

The first column of table 1 presents the different safety applications and other services commonly known as ADAS (Advanced Driving Assistance Systems), connected ADAS or ITS. The other columns have the following objectives:
›› **Distraction/ Inattention:** assess whether the application is a (potential) source of distraction/inattention or whether it prevents from distraction/inattention[43].
›› **Crashes addressed:** depicts what kinds of crashes the system addresses. For example lane departure warning systems address loss of guidance in the lane due to drowsiness, sleepiness or inattention. In this cell, the number of injury crashes (or the proportion of crashes) addressed by the system could be mentioned. For example, in Europe, 25 % of injury crashes are off roadway crashes and could be potentially addressed by lane departure warning systems. This is the so-called 'Target Population'
›› **Safety benefits:** this is explained above (1.3): safety benefits are the reduction in injury crashes or fatal crashes observed or expected if 100 % of the fleet is fitted with the system (and fitted with other systems for which we consider that the

fleet will be soon fitted with). Safety benefits for connected systems should be calculated in addition to the safety benefits brought by the stand-alone systems as they are assumed to be on the market sooner but these estimations are lacking. Therefore, we have reported here only the safety benefits brought by connected safety applications independently from the presence/absence of stand-alone applications in the vehicle.

Each cell is filled in with **+++, ++, +, -, - -, - - -** depending on whether we observe/expect a very positive, a positive, a negative, a very negative impact on different issues (including safety benefits). Division by world regions is somewhat unavailable in the literature since just a few estimates are made, mainly in Western Europe, Japan, Australia, and North America.
During the experts' work a column for growing markets was added to see if there may be some differences with developed countries. The result seemed interesting, since some gaps were underlined.

Influence of	Inattention/ Distraction	Crashes Addressed	Safety Benefits in developed countries	Safety Benefit in emerging market countries
Nomadic devices				
›› Telephone (dialing)	- -	All crash types	- -	Same
›› Telephone (Conversing)	~ 0		0 / -	
›› Telephone (Texting)	- - -		- - -	
›› Smartphone (Apps)	- - -		- - -	
›› Tablets	- - -		- - -	
Stand-alone Driving Assistance				
›› Parking aids	Unknown (un)	Reverse driving crashes	0	SAME Except, lane departure may have limted benefit for some time as lanes not marked
›› Co-pilots[44]	Un	Run-off road /rear end crashes/hypovigilance-related crashes/ Speeding	+ (++ for ISA systems)	
›› Angel guards[45]	Un	Speeding / Lane departure / rear-end	++	
›› Over-vision[46]	Un	Night crashes with vision problems	+	

[44] Speed limiter, Intelligent Speed Adaptation, Automatic High Beam Low Beam, Distance Warning, Cruise Control…
[45] Electronic Stability Control, Advanced Emergency Braking, Lane Departure Warning, Lane Change Assistant,…
[46] Cornering lights, Moving bending lights, Glare free high beam, …

Influence of	Inattention/ Distraction	Crashes Addressed	Safety Benefits in developed countries	Safety Benefit in emerging market countries
Connected Driving Assistance				
›› Road works warning	**+** (activation[47])	Detection/Anticipation failure	**+**	**~ 0**
›› Traffic jam ahead warning	**+** (activation)	Detection/Anticipation failure	**+**	**~ 0**
›› Car breakdown warning	**+** (activation)	Detection/Anticipation failure	**+**	**~ 0**
›› Weather warning	**0**	Detection failure	**+**	**~ 0**
›› Emergency electronic brake light	**+** (activation)	Detection/Anticipation failure	**+**	**+**
›› Approaching emergency vehicle	**+** (activation)	Detection failure	**~ 0**	**+**
›› Post crash		Rescue management improvements	**+**	**~ 0**
›› In-vehicle signage & regulatory and contextual speed limit	**+ / -**	Information taking failure / Speeding	**++** (ISA Systems)	**+**
›› Forward collision warning	**+ / -**	Detection / anticipation failure	**+**	**+**
›› Blind spot warning	**+**	Detection failure	**+**	**+ But behaviour adaptation and acceptance by driver not known**
›› Do not pass warning	**0**	Anticipation failure	**+**	
›› Left turn across path warning	**+**	Detection failure	**+**	
›› Curve speed warning	**+**	Detection/Diagnosis failure	**+**	
›› Railroad crossing warning	**+**	Detection/Diagnosis failure	**~ 0**	
›› Pedestrian detection	**+**	Detection failure	**+**	
Traffic Information systems				
›› Green-light optimal speed advisory	Unknown	Not applicable	NA	SAME
›› Recommended itinerary				
›› Lane use optimization				

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[47] Information systems are supposed to activate or re-activate drivers in case of inattention or distraction. In some minor instances, it also might distract drivers by capturing their attention that was previously focused on the driving scene

Influence of	Inattention/ Distraction	Crashes Addressed	Safety Benefits in developed countries	Safety Benefit in emerging market countries
Services related to Transport (integrated) ›› Controlled access to protected areas ›› Safe parking management for trucks ›› Co-operative stolen vehicle location and interception ›› Taxi calling ›› Multimodality and comparison of public/private transportation ›› Availability of parking lots ›› Energy station notification ›› Rest area notification ›› Mobility commerce notification	Unknown	Not applicable	NA	SAME
Services non related to Transport (integrated) ›› Local event notification ›› National Patrimony notification	Unknown	Not applicable	NA	SAME

Table 1: Connected Drivers and impact of (Connected) Driving Assistance Systems and connected services on traffic safety and other issues[48]

Explanations of the table:

Most of the evaluations reported in table 1 **have not followed Kulmala** (see the part above) **procedure, that shows the complexity of the impact of a single modification in the transport system** (for example introduction of ITS) to the whole system, and especially on exposure, crash risk and injuries. We chose to report here the safety benefits of ADAS and connected ADAS (fourth column) in summarizing what is published in scientific papers, regardless their compliance to this model. For some applications (ESC for example), many studies are published; for some others, just a few or even none. We did not report individually all results but just made a synthetic statement by using + or -.

The effectiveness of **Stand-alone Driving assistance systems** has been widely assessed in the scientific communities for two decades and especially over the last few years due to an increasing interest for these kinds of safety measures based on technologies. The effectiveness is assessed either prior to the deployment of such systems in the market (by numeric simulation, simulations based on driver behaviours in simulators, tracks or open roads) or after the system is largely fitted in cars (e.g. ESC). Both kinds of effectiveness show small expected effecti-

[48] Services related / non related to transport are numerous. Only some examples are given in the table.

veness (safety benefits) for each device separately but a large promising effectiveness of a constellation of assistances (e.g. ESC + AEB + LDW + Bind spot +…). However, f**inal and long term effects on driver behaviour and distraction is to a large extent unknown. Drivers might adapt their driving habits to the system and this adaptation might be positive or negative for safety: for example ACC decreases the number of lane changes but increases the likelihood to drive on the left-hand side lane. It also has an incidence on speed and headway time.**

Connected Driving assistance systems effectiveness is not yet widely assessed in the scientific communities. **Only a few studies exist**. In the US and in France, the systems seem to address a large variety and a large number of crashes (target population studies) whereas evaluation studies end up with small expected effectiveness of warning systems: they do attract attention of the driver (by reactivation in case he's inattentive) but they warn

of potential hazards a long time before they occur: these types of crash are not predominant. Two important projects (Safety Pilot and Drive C2X) should sooner or later release results in this matter and will be very important for the evaluation of the potential of such system which seems rather small by now. Drive C2X outcomes (presented at a Conference in July 2014 but not officially published yet) have been used in table 1.

As for the column 'Crashes' , Van Elslande et al. produced **an accident analysis model based on the examination of the production of Human functional failure** which shows what kind of mistakes are made by the driver, the failure being possibly explained by endogenous factors (driver state, experience, skills) or exogenous factors (infrastructure design and maintenance, traffic, car design and maintenance). The taxonomy of these failures can be used to define accident clusters as follows (Van Elslande et al, 2009).

Detection	Diagnosis	Prognosis	Decision	Action	Overall
Failure to detect in visibility constraints	Incorrect evaluation of a road	Not expecting (by default) manoeuvre by	Directed violation	Poor control of a difficulty	Lost of psycho-physiological ability
Focalised acquisition of information	Incorrect evaluation	Expecting adjustment by another user	Deliberate violation	Guidance	Impairment of sensorimotor and cognitive abilities
Cursory information acquisition	Incorrect understanding of how site functions	Expecting no perturbation ahead	Violation		Exceeding cognitive abilities
Interruption in information acquisition	Incorrect understanding of manoeuvre undertaken by				
Neglecting information acquisition demands					

Figure 2 - Delineation of functional failures found in In-depth accident data (Van Elslande et al. 'Analyzing Human Functional Failures in Road Accidents, Report D.5.1, TRACE Project, 2009)

This taxonomy is used in table 2 as it is really relevant to applications aimed at informing drivers about forthcoming events or hazard and prevent failures (such as detection failure or prognosis, or anticipation, failure).

Another point that needs to be clarified is about the use of phones at the wheel. For long it has been considered as a very risky activity. Recent research[49] is presenting argument that conversing seems to be less related to crash risk whereas other smartphone usage such as dialling, texting or browsing whatever apps highly increase risk. The reason is that drivers adapt their behaviour while phoning (delayed manoeuvers for example, or speed adaptation) which engages only cognitive distraction whereas other activities engage both eyes off, brain off and manual distraction (hands off).

Finally, scientific studies about potential effects of other connected services (traffic and non-transport related) are sparse. They do predict the intuitive effect on distraction and driver behaviour but a numeric assessment has not been published as yet.

II.3. RISKS AND BENEFITS IN TERMS OF ROAD SAFETY OF THE USE OF SMARTPHONES AND OTHER NOMADIC DEVICES

Summary
The use of smartphones while driving is quite a sensitive question. This chapter aims at presenting risky uses of smartphones that should be discouraged in all possible ways. Also the purpose here is to remain aware of the importance of phones and tablets in the everyday life of drivers, cyclists, pedestrians and see how this «addiction» may be used to save lives on roads.

Potential safety benefits of smartphones' applications
Some new applications have a great safety potential, which may be very similar to embedded connected technologies. For example, voice commands may allow drivers to use some applications of embedded devices that may increase their safety. Drivers can receive some alerts on their smartphones or tablets connected to their car or even some suggestions to change their movement pattern. Furthermore some car manufacturers such as Honda are already developing smartphone applications that will connect pedestrians to cars and vice versa to help both types of road users to perceive dangers[50]. The example of the Honda application shows a pedestrian that looks at his /her smartphone while crossing the road. The application will alert the driver about a pedestrian who isn't paying attention to the road and will alert the pedestrian about the car that is approaching.

You will find below the table with some explanations of potential positive impacts and risks of Information and Communication Technologies (ICTs) and especially smartphones:

Potential positive impacts	Potential threats	Threat Mitigation/ Benefit Optimization
Traffic management and road safety tools (crash prevention): ›› Alert about crashes ›› Alert about traffic jams ›› Dangerous intersections alerts ›› Warn drivers about traffic/ dangers ›› Weather detection and warnings	Distraction (in some cases only) Ex.: Use of a phone as a working tool while driving: taxi drivers	Distraction prevention: ›› Applications that deny access to call and texting while driving ›› Easy to use voice or hand gesture controls
Using Big Data from different communication networks may help to improve active safety devices (crash avoidance and crash mitigation), smartphones data may be even more complete then data from other V2X connections.	Growing risk of being hacked, since data is very valuable	Privacy control and close cooperation between private companies and public authorities

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[49] Richard A. Young, Cell Phone Conversations and Automobile Crashes: relative Risk is Near 1, Not 4, Wayne State University School of Medicine, Detroit, Michigan, USA, September 5, 2013
[50] https://www.youtube.com/watch?v=ElNPC_xP56g

Potential positive impacts	Potential threats	Threat Mitigation/ Benefit Optimization
Post-crash care: ›› call emergency services immediately after the accident (automatically or otherwise) and provide additional infor-mation regarding crash severity and potential injuries, crash location, etc. ›› immediately notify traffic authorities to re-route other traffic ›› sensors to detect driver condition «If a car breaks down on an interstate, sensors installed in the vehicle could pick up on the problem and immediately notify traffic authorities of a possible slowdown. Other drivers on the road could be warned about a disabled vehi-cle almost instantaneously, instead of waiting until they're stuck in gridlock traffic for more than 20 minutes. In the future, if a driver has a seizure or heart attack, sensors on a steering wheel may detect the event and notify emergency responders.» www.theatlantic.com/sponsored/ibm-mobile/2013/10/lets-embed-mobile-sensors-cars-avoid-traffic/46	Possibility of malfunction or false alerts	
Intermodal transportation: 1. Connected Commuting technology assists in: ›› The planning stage: deciding the mode of transportation or route. ›› Real time: re-routing around disruptions, traffic and other incidents. ›› Making commutes shorter and more efficient and the-reby reducing exposure to road risk **Example:** Features commuters found most important and useful: ›› Voice-activated alerts via mobile phone, warning of an upcoming traffic incident or public transport service disruption. ›› Real-time web and app-based comparisons of multiple routes or transportation modes and how long they would take. ›› Recommended departure times to avoid being stuck in traffic and/or public transport delays. ›› GPS navigation visible on car windshield. http://www.newcitiesfoundation.org/wp-content/uploads/New-Cities-Foundation-Connected-Commuting-Full-Report.pdf 2. Vehicle sharing systems using mobile phone payment and booking systems: ›› Reduce number of private cars on roads ›› Possibly reduce number of trips eventually integrate with automated vehicle systems for booking rides	›› Risk to make the trip longer, rise the exposure time and the crash risk (if re-routing and several transportation modes) ›› Some (poor) areas may remain inac-cessible by intermodal transport	
Drivers training tool: games, tests		
Tools to follow drivers' physical condition in order to alert in case of danger (even with existing phone applications?)	›› Privacy concerns ›› Possible misuse by insurers or litigants	

Figure 3: Potential positive impacts and risks of ICTs and smartphones, Mimi Sheller

More broadly, smartphones' connected applications may also be used for road safety education purposes. Training in order to refresh road safety rules may become fun thanks to connected technologies.

Toady social games such as those on Facebook are very popular. The only reward of these games is the accumulation of virtual points and classifications with friends or even gamers all over the World. Since road safety in everyday life is not very fun, maybe there are some ways to make it more attractive…

It is possible to imagine Road Safety games that will use GPS and accelerometers and will be able to check gamers' speed and respect of road safety rules. In order to avoid encouragement of speeding violation in online statistics, such as «speed record in the city», speeding violations will automatically exclude the person from the application.

Another suggestion may be the use of «rewarding points» for respectful driving that will allow people to have lower fines or to recover their driver's license points.

For privacy protection, the application wouldn't have to register the information on the route chosen by users but only information on the behaviour of the driver.

Insurances can also use this type of applications and reduce the cost of insurance if the driver is law abiding.

This type of encouragement is being developed by the Clever-Miles start-up. Their motto is «drive clever, get rewarded»[51]: accumulated Clever Points can be redeemed against products in the online shop.

It is true that such systems are aimed primarily to improve road safety and are expected to have a positive influence on the user and on the driving behaviour. However, reality is more complex and they can also have a negative direct or indirect impact on different situations because of the inattention risk that these applications may cause if they are used in an incorrect manner.

Position on risks of smartphones

Despite a great amount of studies on the danger of the use of phones while driving, the topic is still controversial. There are several reasons for this.

First of all, the functions of phones have changed: smartphones are used not only for calls and texting but also as a satnav, a music player, parking guides, ways to get alerts on traffic, etc. The latest technologies also allow drivers to use a smartphone as if it were an embedded device.

Secondly, studies by Richard Young (Ph.D., professor of research in Wayne State University's Department of Psychiatry and Behavioral Neurosciences in the School of Medicine) suggest that some of the dangers of phone use were overestimated. As mentioned in the chapter above, a study by Richard Young has shown that there is a bias **in a 1997 Canadian study and a 2005 Australian one** on the risk of calling while driving. These two studies «*used cellphone billing records of people who had been in a crash and compared their cellphone use just before the crash to the same time period the day (or week) before — the control window. Young said the issue with these studies is that people may not have been driving during the entire control window period, as assumed by the earlier study investigators*»[52]. For that reason the **risk** of a crash during the phone conversation appears **higher that it is if the bias is corrected**.

Behavioural adaptation (Luoma, 2007) explains also why some risks can't be absolute. Our brain adapts to changes that occur within the system (ex: a phone call). **On the one hand behavioural adaptation can partly compensate some inattention provoked by the use of smartphones, on the other hand, some safety benefits that smartphones and other connected devices may introduce, can be negatively compensated for by the driver, who is prone to paying less attention to the road because he/she excessively trusts technologies**.

Behavioural adaption studies are very complex and the effects of smartphones on driver behaviour need to be studied deeper. Indeed, it **is a controversial topic and for the moment there is no evidence that has garnered consensus from all of the experts**. That is why the task force **encourages continuing research on this topic**.

Both potential positive and negative impacts of the use of smartphones should be taken into account. That is why the task force recommends:

›› To make a distinction between the use of the phone (calling and texting) and the use of the smartphone as a connected device (warning, GPS, etc)

›› Not to use phones in an inappropriate or unsafe way (risky distraction): texting or calling manually when drive;

›› To use as much as possible (whenever necessary) hands free technology for road safety connected applications;

›› Further research on appropriate and safe use of smartphones.

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[51] www.clevermiles.com
[52] Wayne State University, http://research.wayne.edu/news.php?id=7802

› III. TOOLBOX: GUIDELINES ON THE IMPLEMENTATION OF CONNECTED TECHNOLOGIES FOR ROAD SAFETY

III.1. TECHNOLOGY STANDARDIZATION AS A STRATEGIC ISSUE[53]

Summary

The standardization of connected technologies is quite a fundamental issue for their implementation since it has huge impacts on economies of scale and more generally on road safety.

It is also quite a sensitive concern, since vehicle manufacturers are willing to produce unique products that are competitive and original.

The operating environment in different parts of the world has many common issues but also many local differences. For example, most cities have congestion; some will have highly developed urban traffic control systems and disciplined drivers and pedestrians. Others have little control, unsophisticated vehicles and a lack of respect for regulation. **Different solutions may be required in different regions**.

These differences do not mean that world standards are not very desirable. **Global harmonization enhances economies of scale** in equipment manufacture and would result in wider cross-border mobility and more competition. Delegates' seminars and workshops for the joint task force made it clear that there are strong economic reasons for a global approach at the communications level, but accepted that connected vehicle applications may be very different for different regions. International harmonization of connected vehicle standards is an important and difficult issue.

Standardization is highly important also **from the safety point of view**. Different signalization systems may confuse drivers who have changed from one vehicle to another and provoke inadequate reactions. Indeed drivers may react incorrectly if they receive different kinds of warnings in the same type of situation when driving a different vehicle, a rental car for example. In order to avoid confusion among drivers, all manufacturers need to have the same system of warnings even if it seems quite acceptable that the system may vary a little between automobile manufacturers.

If worldwide standardization is an impossible dream there needs to be, at least, a guarantee that equipment will work throughout linked geographical areas, e.g. equipment purchased in Europe must work throughout the whole European area; equipment operating in the USA should, if at all possible, continue to work in Canada and Mexico.

There are some applications, for example traffic signal and intersection control, which require high involvement from the infrastructure and standardization is vital. Significant progress has been made. Within Europe the Framework programmes of

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[53] World Road Association, The connected vehicle, FISITA, 2012, http://www.ssti.us/wp/wp-content/uploads/2012/08/connected-vehicles-report.pdf

the European Commission have led to the development of the technical and scientific background for European Standardization. These results are being transferred to the ETSI and CEN standardization process with the aim of providing wider technical standards and specifications.

In the US standards for co-operative systems have been developed as part of the ITS Standards Program. The current standards for connectivity include the IEEE 802.11p, 1609.x and the SAE J2735 standards that primarily support the V2V and V2I wireless interfaces. These standards allow establishment of a wireless link for V2V and V2I communications (IEEE 802.11p), establish protocols for information exchange across the wireless link (IEEE 1609.x), and define message content for communicating specific information to and from equipment and devices via DSRC or other means (SAE J2735).

In November 2009 the USDOT and the European Commission Directorate General for Information Society and Media (DG IN-FSO) signed the European Union-US (EU-US) Joint Declaration of Intent on Research Co-operation. As part of the declaration, the USDOT and the DG INFSO set a goal to support, wherever possible, global open standards in order to ensure interoperability of co-operative systems world-wide and to preclude the development and adoption of redundant standards. The Japan MLIT has since agreed to collaborate in these efforts.

Indeed **regional standardization compromises may be incomplete** since very often old vehicles from high income countries are exported to low and middle income countries. Technological incompatibility in these cases may cause some real safety issues.

<h2>III.2. NECESSARY REVISION OF THE LEGAL FRAMEWORK ON NATIONAL AND INTERNATIONAL LEVELS</h2>

Summary:

Connected vehicles are a real innovation that will certainly change the way we use roads (drive, cross). It will also have an impact on how cities and highways will be built, how goods will travel from one point to another, i.e. some urbanisation experts say that roads will become much narrower if vehicles drive connected in line; there will be more space for pedestrians and cyclists. The legal framework will have to be adapted to all of the changes that connected technologies will produce in the society.

This statement is even truer for autonomous vehicles, which may be seen in continuity with connected vehicles, even though, legal barriers for their implementation would be much more important because of the definition of the responsibility in case of crash.

The notion of driver's and constructor's responsibilities in case of a crash will have to be clearly defined to make possible the implementation of connected and autonomous vehicles.

Connected technologies will change our way of driving vehicles, it will also change the environment of road users. That is why the adaptation of the legal framework will appear necessary in most countries. Connected vehicles will change how infrastructures are built; legal adaptation may be needed in this case. Some changes will also be necessary within the Highway Code to pass the driving licence. Already today some countries have introduced some legal modifications to facilitate the entry on the market of some connected technologies.

The need to introduce some modifications to the legal framework is even more obvious when it comes to autonomous vehicles. Indeed, in the self-driving reality, **who would be accountable in the case of a crash**: the driver, the car manufacturer, the developer of the vehicle's software, the road designer in the case of an intelligent road system that helps control the vehicle?

While drivers are usually found guilty in case of collisions, they theoretically may be removed from the «liability equation» when using automated vehicles (Marchant and Lindor, 2012). If the driver error is removed, the frequency of road crashes should diminish. It is taken for granted that autonomous vehicles would be safer than conventional vehicles. The safety issue is a leading factor for the implementation of autonomous vehicles. Google engineers believe that «robot drivers react faster than humans, have 360-degree perception and do not get distracted, sleepy or intoxicated»[54]. Nevertheless, even if autonomous vehicles are safer, they could be accountable when malfunctions or faults provoke crashes and related injuries. For instance, in the US car manufacturers have encounter similar lawsuits after integrating road safety features in car such as anti-lock systems and airbags. **The legal responsibility** aspect could be a serious obstacle for the development and commercialisation of driverless vehicles, even when such technologies are socially advantageous. However, legal and policy tools to protect manufacturers from lawsuits (immunity or other defences) could be developed. For example, the «risk defence» mechanism is established when the consumer knows and assumes the possible risks when buying the product. In that case the manufacturer has to fully disclose the potential threats and a likelihood percentage. Other protective instruments can be legislations which protect against, or limit, liability since the driverless vehicle will represent an asset for road safety. In the case of the European Union, a **Code of Practice** has been developed to protect manufacturers and providers from abusive accountability claims related to the ITS safety technologies deployment. Such code details the standard of caution that protects them and promotes further deployment of such devices.

However, the **Vienna Convention** on Road Traffic may be the major obstacle for the deployment of connected technologies and autonomous vehicles. This convention was initially desig-

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[54] MARKOFFF John, Google Cars Drive Themselves, in Traffic, NY Times, October 9, 2010

ned to facilitate road traffic all over the World. «*It defines a driver as « any person who drives a motor vehicle or other vehicle (including a cycle)». It states that every vehicle shall have a driver who has the requisite knowledge or skill to control the vehicle and that «every driver shall at all times be able to control his vehicle»»*[55].

UN-ECE, has recently updated the Vienna Convention. However amendments and changes didn't allow highly and fully automated driving. There are discussions within the **Working Party 29 at UN-ECE** on what detailed regulations are needed in relation to autonomous vehicles. It is clearly a risk, however, that the urge for regulating autonomous vehicles may be an obstacle for the development of autonomous driving systems. We know that regulations take a long time to enact and to become effective and since the technical development is very rapid, this could mean that technical solutions for autonomous driving will not be legal due to antiquated regulations.

It seems obvious that there is a **need of agreement at the international level** in order to ensure the harmonisation of legal frameworks that will ease the implementation of connected and autonomous vehicles. However **work needs to be done at the same time at national or even regional levels**, since some countries may **need a lot of time** to revisit their legislation. India may be one of those countries. The stake would be to lead national works in coordination with international guidelines.

III.3. RECOMMENDATIONS ON THE DATA USE (OPPORTUNITIES AND RISKS)

Summary

Connected vehicles will produce a huge amount of Data. It is obvious that this information will be very valuable and a great amount of actors will be willing to take advantage of it at a lower cost. This Data will be possibly used to improve infrastructures, for traffic management, for road safety alerts but also for commercial purposes, i.e. some insurance companies may use collected Data for risk evaluation. This means that Data ownership will have to be defined.

The second issue this Data will raise is that of privacy and of the danger of being hacked.

Opportunities of data collection and use

Connected technologies and applications may be extremely useful for **traffic management**, road design, and development of **social policies** through Data collection. These technologies may be also an innovative means of learning safer behaviour.

Data is fundamental to understanding what is happening in our networks and to both managing and informing users. Data collection may also allow, by its value to finance some innovation in connected mobility and to have a reliable **business model** for the implementation of connected vehicles.

This relatively recent rise in storage and processing has led to the big data revolution which is now gaining momentum. Traffic modelling has long been a tool of planners and managers. Calibrating the models, accessing data and running various scenarios have always been complex and time consuming. While advances have been made with such models, the potential availability of improved quality and increased volume of data promises new insight and understanding.

Historically road administrations and operators have instrumented subsets of their road network to monitor conditions. The focus has been on the busiest and most important roads. When in 1973, Job Klijnhout of Rijkswaterstaat, first demonstrated automatic incident detection on a Dutch motorway, it heralded a new era in accident response and patient care. The advent and rise of mobile phones and the connected anywhere communications capabilities has enabled more mayday type services to be established even on uninstrumented roads.

Of course, the essential approach of ITS is to identify and collect a single event which can then be shared and used by multiple services and applications. This is the real challenge for connected vehicles and the data that they generate.

Unlocking the community wide benefits of ITS and connected vehicles is crucial for widespread deployment and acceptance. While vehicle manufacturers continue to launch services based on connected vehicle to vehicle communications some roadside infrastructure is still desirable and in some cases needed to enable these. However, there is no easy way for vehicle manufacturers to fully engage with road operators. While the main roads are normally the responsibility of a single organization (e.g. the English Highways Agency has responsibility for most Motorways and some strategic roads), the other roads may be the responsibility of a large number of operators or authorities (e.g. In England there are over 100 such authorities responsible for road operations). So, extrapolating this organisational structure (which has historically been adequate for the circumstances encountered) to a wider European or other such similar scale indicates the difficulty of gaining agreement and understanding.

Similarly, the business case for investment is rather complex. Early private data collection systems have established a revenue stream by selling traffic information to the road authorities. However, if the road operators are to invest in the necessary road side units, is it reasonable that they still have to pay for this data?

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[55] World Road Association, The connected vehicle, FISITA, 2012, http://www.ssti.us/wp/wp-content/uploads/2012/08/connected-vehicles-report.pdf

The availability of the big transport data promised by the connected vehicle is an opportunity to really improve entire transport networks. Big data, analytics and data visualization are already helping to identify trends and behaviour much earlier than was previously possible, but unlocking access, sorting out data ownership and satisfying privacy issues are fundamental requirements.

The existing practice of service providers of acquiring all rights to using data from individual users (generally included in the service terms and conditions) may seem a suitable short term approach, but as more integrated systems emerge and users become more aware of the nature and potential value of their data some user reaction is almost inevitable.

The introduction of pay-as-you-drive or pay-how-you drive insurance is an example of how collected data is used to set contract and pricing levels. Similarly analysis of accident data can help identify black spots and alert both the road authorities and drivers of the current and predicted situation.

However, there is a real data protection challenge that shouldn't be neglected.

Precautions for data collection and use

Personal information protection

The associated increase in vehicle/infrastructure electronics and communications can raise security and privacy issues. These dangers could jeopardise their deployment. Since these technologies collect detailed travel data, they could violate drivers' expectation of privacy. People could feel that they are under surveillance by a «Big brother» camera. The disclosure of data to third parties could lead to commercial misuse, public corruption or identity theft[56]. That is why the European Commission, other organisations and governments consider that the development of these technologies must ensure the integrity, confidentiality and protect the handling of personal data respecting citizens' rights. For example, licensing agreements could be given to specific organisation to access date under restricted conditions and for legitimate purposes[57]. Some studies have delivered suggestions against privacy and security threats. For instance, authentication and data analysis should be managed by separate entities; the connected vehicle architecture should incorporate encryption, tamper-proof hardware and data refining techniques[58]. Other recommendations are the «defence-in-depth» (each layer of hardware and software has its own security functions), «data aggregation near the source» (data aggregation at the vehicle level before transmitting it to service providers) and «user defined privacy policies» (specific virtual contracts between consumers and solution providers).

Risk of being hacked

According to a technical report by computer scientists from the University of California, San Diego and the University of Washington and a TED[59] presentation, unauthorised intrusions to cars' computer systems can take place without direct physical access. The study showed that nowadays the internal networks for control systems in cars are rudimentary and not secure, but did not speculate about the possibility of interfering with a vehicle's control system to provoke a crash. In the case of vehicle network threats, another study[60] suggests that security requirements such as vehicle authentication and verification of data consistency are necessary. The American National Highway Traffic Safety Administration (NHTSA) has established an Electronics Systems Safety Research Division focused on cybersecurity. This division will set up a preliminary baseline of possible cyber threats for connected vehicles, and how such dangers could be approached in the vehicle environment[61]. Moreover, protocols to support V2V security system are being developed by the NHTSA to deploy reliable and secure connected vehicle technology. V2I security mustn't be forgot neither, the control of these systems by hackers may be very harmful (possibility to change traffic signals).

[56] Michigan Department of Transportation, Center for Automotive Research, Public Perceptions of Connected Vehicle Technology, July 2012, http://www.michigan.gov/documents/mdot/MDOT_PublicPerceptionsCV_394490_7.pdf
[57] Michigan Department of Transportation, Center for Automotive Research, Public Perceptions of Connected Vehicle Technology, July 2012, http://www.michigan.gov/documents/mdot/MDOT_PublicPerceptionsCV_394490_7.pdf
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[61] Gareffa Peter, Government Focuses on Cybersecurity Risks Linked to Connected Cars, Edmunds.com, May 16, 2013, http://www.edmunds.com/car-news/government-focuses-on-cybersecurity-risks-linked-to-connected-cars.html

III.4. BUSINESS MODELS TO IMPLEMENT ROAD SAFETY CONNECTED TECHNOLOGIES

Summary

The implementation of connected technologies will require high investments from car manufacturers. It will also require infrastructure investments.

Actors of these investments will differ country by country, as will business models, since several factors will have to be evaluated before taking this decision, i.e.:

›› Actual state of infrastructures;

›› Public acceptance of investment in these technologies;

›› Data ownership;

›› etc…

In most scenarios, the Benefit-Cost Ratio of the implementation of connected technologies is expected to range between acceptable and excellent. However economists need to study in depth these scenarios to justify further investments.

It seems quite obvious that in order to make sure that technologies developed by engineers are implemented, **central questions that should be asked are:**

1. **How much it would cost to implement a technology in a precise context?**

2. **Can we make estimations of benefits of these technologies (lives that can be saved, injuries prevented, percentage of improvement comparing to the actual situation…)?**

3. **What are the other benefits (aside from road safety) of these technologies?**

4. **Who is willing to pay for/ invest in connected technologies/ infrastructures?**

5. **How much?**

Impact Channel of C2X
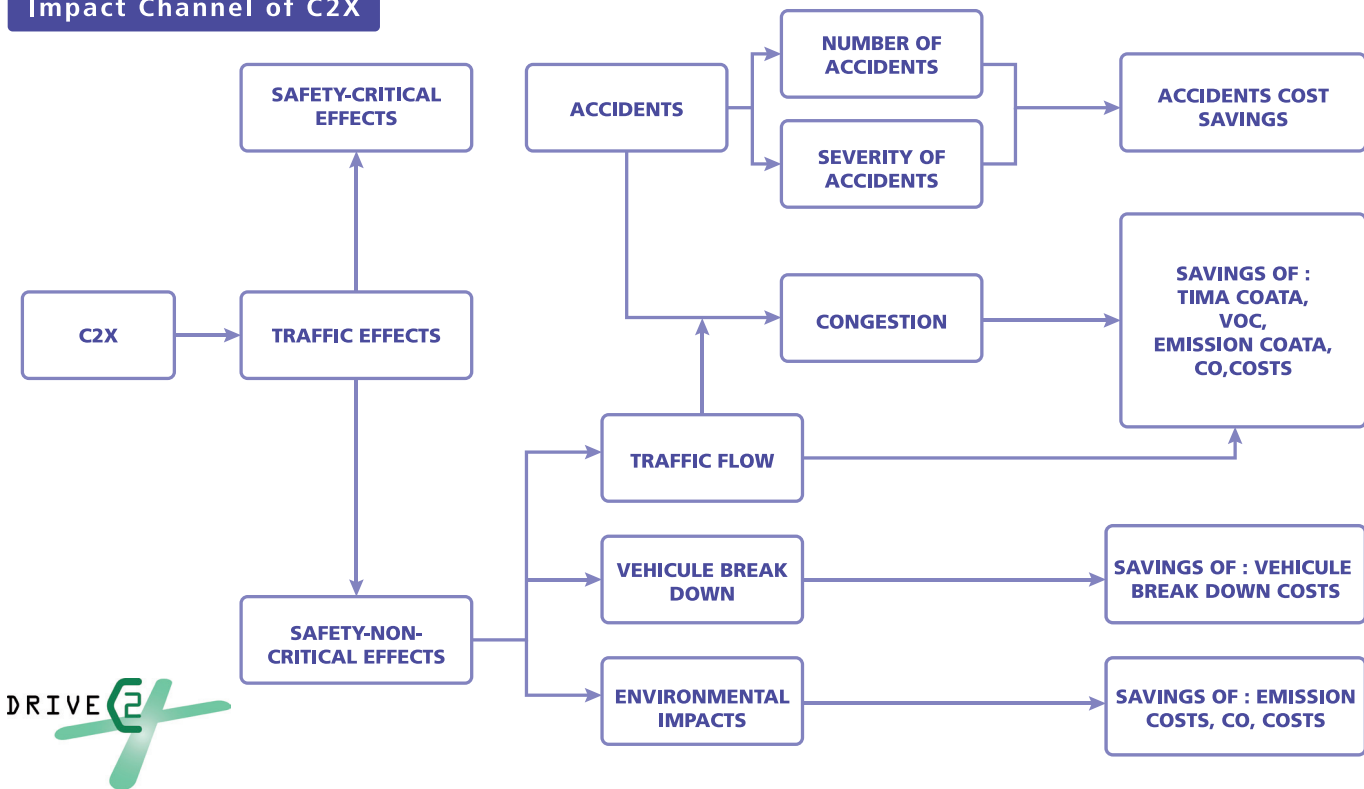
Business Models and exploitation

Figure 4: Drive C2X, deployment strategy options, Joerg Rech, Senior Consultant, Facit Research GmbH &Co. KG

This means, that the first step to build a business model should be the cost-benefit analysis in terms of business but also in terms of road safety and other social benefits.

Some developers of connected technologies have already studied this question. For example, the Drive C2X project developed several cost-benefit estimates, showing that some of the applications may save lives but also reduce fuel consumption.

Here is the «impact channels of C2X» that shows how different benefits are interdependent and therefore one factor may influence another.

The Drive C2X team numbered lives that may be saved and injuries that may be prevented according to different scenarios of market penetration. Also, safety benefits and congestion benefits were calculated in millions of euros. Of course, these estimates apply only to the European Union, thus the methodology can be adapted for middle income countries, where road congestion is an even more important issue.

Here are some estimates developed by drive C2X according to different functions of ITS they have implemented:

« Estimated safety benefits for fifferent penetration scenarios »:

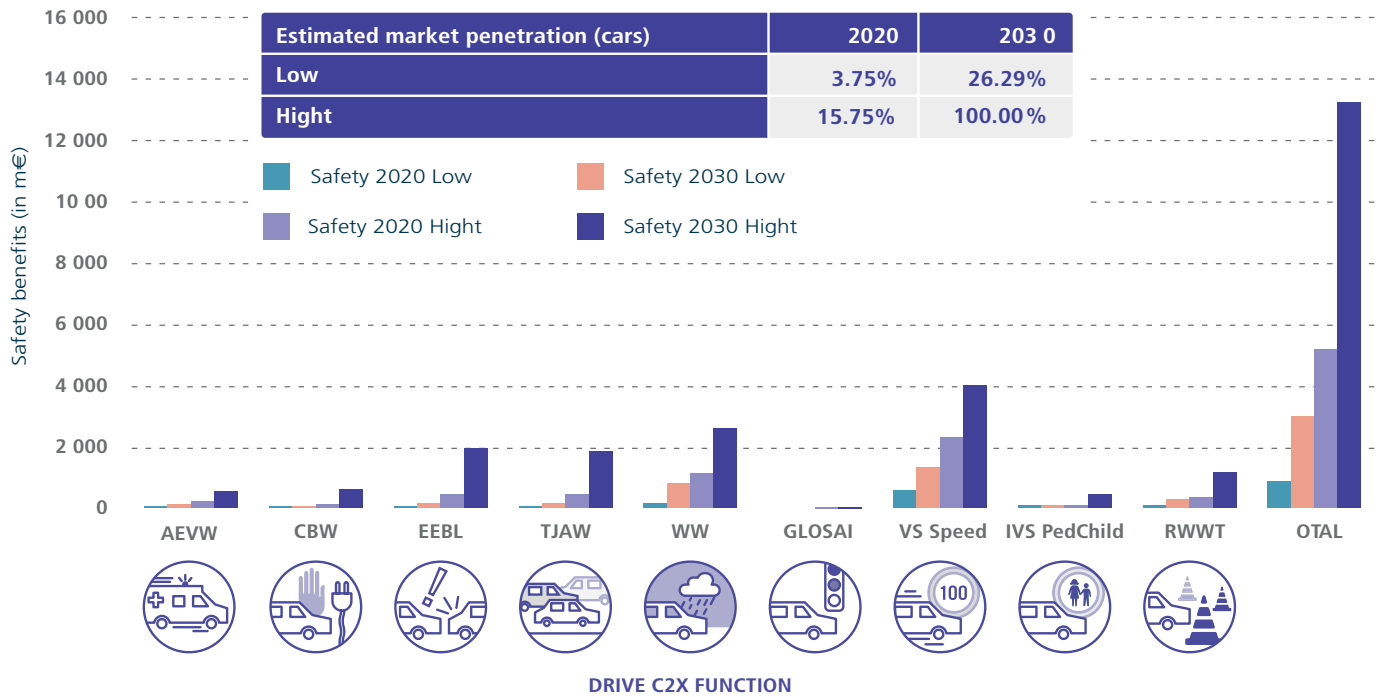| Estimated market penetration (cars)	2020	203 0
Low	3.75%	26.29%
Hight	15.75%	100.00 %

Figure 5: Drive C2X, deployment strategy options, Joerg Rech, Senior Consultant, Facit Research GmbH &Co. KG

« Estimated congestion benefits for different penetration scenarios »

Estimated market penetration (cars)	2020	203 0
Low	3.75%	26.29%
Hight	15.75%	100.00%

Legend: Congestion 2020 Low, Congestion 2030 Low, Congestion 2020 Hight, Congestion 2030 Hight
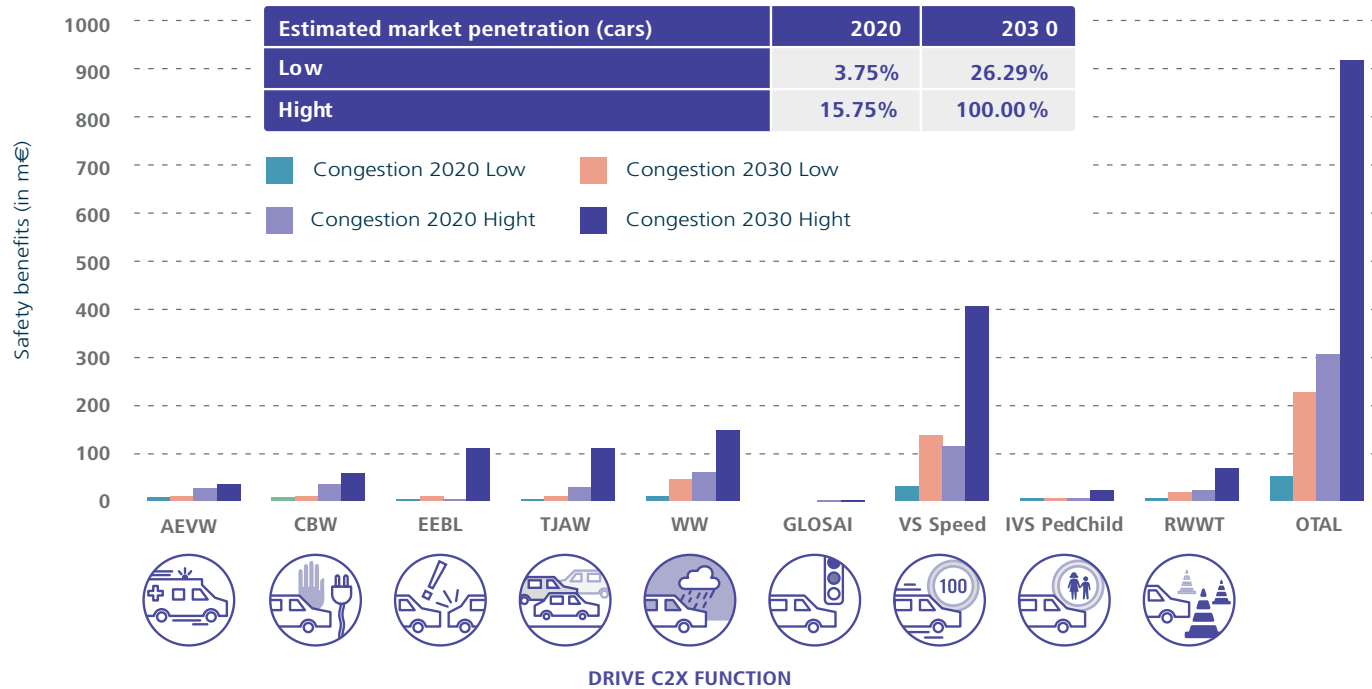
DRIVE C2X FUNCTION

Figure 6: Drive C2X, deployment strategy options, Joerg Rech, Senior Consultant, Facit Research GmbH &Co. KG

To learn more on functions that has been evaluated by Drive C2X you can follow this link: http://www.drive-c2x.eu/tl_files/publications/Final%20event/DRIVE%20C2X%20-%20Press%20backgrounder.pdf

According to Drive C2X[62] socio economic benefits justify investment in these technologies since the Benefit-Cost Ratio is expected to range between acceptable and excellent, depending on the level of market penetration. However properly quantified estimations still need to be addressed.

The challenge is to see if the system of connected technologies may be profitable, how soon and under what conditions.

Indeed, in order to implement most of ITS, huge investments are needed. These investments have to pay off within a timeframe that would be reasonable.

Road investments

There are three different scenarios to finance the implementation of infrastructures:

›› **Road charging**
›› **Finance with data and derived services**
›› **Public private partnerships.**

Road charging solutions mean that infrastructure funding may be paid with tolls. Drive C2X suggests making a link between toll services and other secondary services to make the model more attractive. The problem is that the investment needed remains too high and public & political acceptance is quite low.

Use of data information and derived services as a means to finance new equipment investments may be economically viable even though some uncertainties in the legal framework remain.

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[62] Drive C2X, http://www.drive-c2x.eu/tl_files/publications/Final%20event/DRIVE%20C2X%20-%20Press%20backgrounder.pdf

Public private partnerships appear to be highly strategic, however the question of data property will have to be raised.

Onboard unit investment

As for onboard units, several paths may be followed to make sure the whole fleet is equipped:

›› **Direct sales (classic)**

›› **Customer relationship management**

›› **Sale of onboard services**

›› **Sale of data**

For the first solution, low willingness to pay for safety functions is a real barrier for massive deployment. Also the model seems quite outdated to sell this type of innovative products.

Customer relationship management models increase customer retention and bring more adapted services. Sales of onboard services allow also a high adaptability. In this case entertainment services may be sold at the same time as safety services, traffic information, etc.

The last model of **funding of investment with data** is very interesting. Nevertheless in order to be able to sell data to private companies and finance onboard units, market penetration needs to be high enough (to produce sufficient amount of data).

These three last models can be complementary. Nonetheless, several studies show that customers' willingness-to-pay for safety and traffic efficiency is quite low, which is why the development of commercial services and customer relationship management is crucial. Commercial services may be plural: media, parking, insurance, *etc…*

Commercial services - Overview
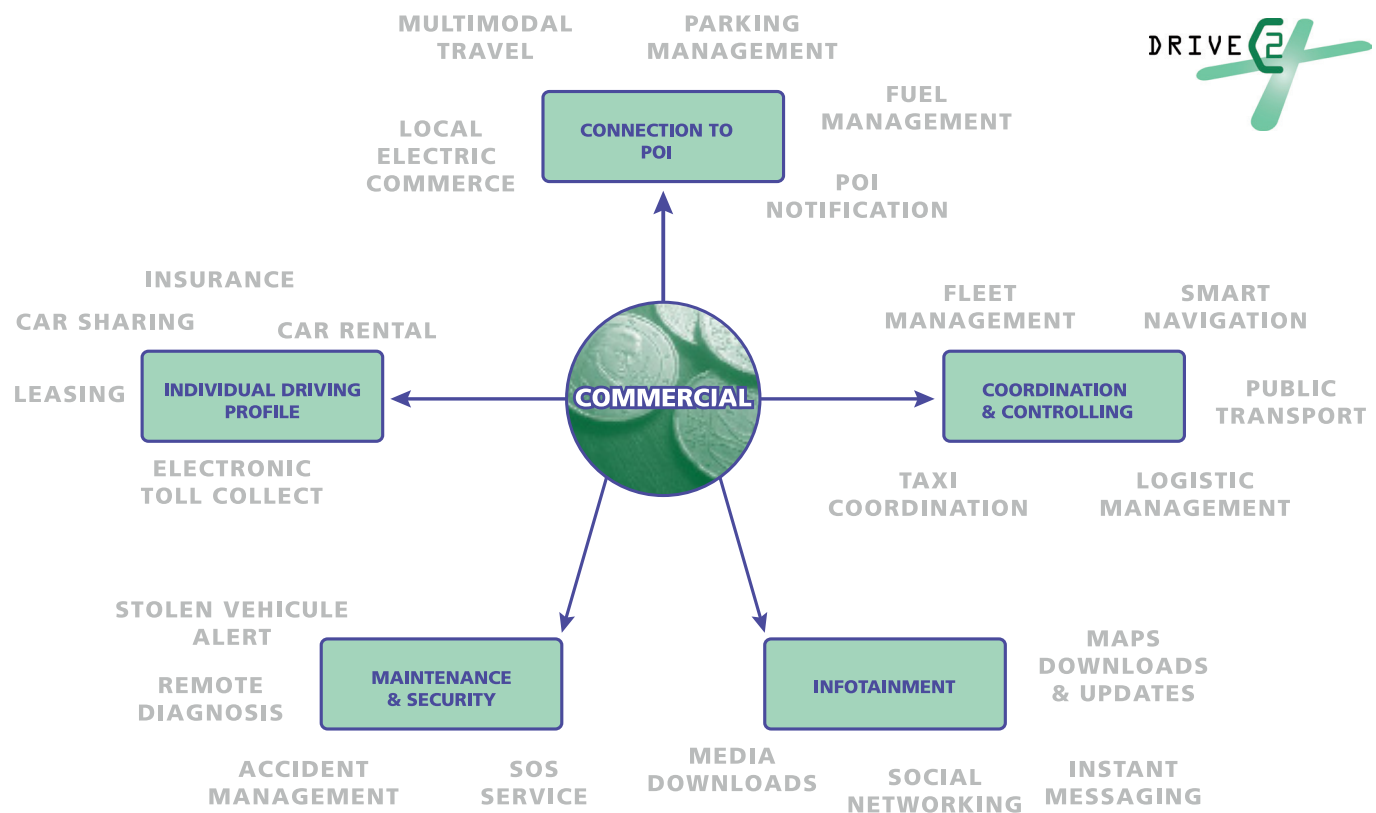
Business Models and exploitation

Figure 7: Drive C2X, deployment strategy options, Joerg Rech, Senior Consultant, Facit Research GmbH &Co. KG

III.5. EDUCATION AS A KEY OF SUCCESSFUL DEPLOYMENT OF CONNECTED TECHNOLOGIES

Summary
Since the aim of the connected technologies we are dealing with is to be efficient from the road safety point of view, drivers need to be trained to use it. The best solution will consist in making this training mandatory by integrating it for example in Highway Codes or specific training for commercial drivers. Public authorities also need to think about ways to train drivers that own already a driving licence.

Connected mobility will, of course, have several implications on liability and training of all road users. With the aging population and expected driver shortages, in vehicle systems must not become an obstacle for entering or staying in the profession. Training architectures should flexibly integrate new technologies to allow the drivers to become familiar with them.

Vehicle manufacturers have always worked to ensure that drivers know intuitively what a vehicle is 'doing' through well designed integrated devices which are embedded in the vehicle and can offer different types of services. There is an ISO 26262 standard called "Road vehicles – Functional safety" describing, from a functional perspective, how systems must be designed and are intended to prevent systems from catastrophic failure by providing redundancy in operation. This functional safety standard is the part of the overall safety of a system or piece of equipment that depends on the system or equipment operating correctly in response to its inputs, including the safe management of likely operator errors, hardware failures and environmental changes. Additionally, vehicle manufacturers have endorsed a Code of Practice (CoP) covering the development of Advanced Driver Assistance System (ADAS) which is an attempt to protect vehicle manufacturers from liability law suits, as the main design guideline is always to have self-explaining interactions with the driver.

Connected vehicles, able to communicate wirelessly with each other (V2V) and with road infrastructures (V2I) or else (V2X), are expected to appear on slowly in 2015 on several markets. Direct communication between vehicles and infrastructures will ensure safer and more efficient traffic flows, with great benefits for drivers & pedestrians, our environment and our economy.

Autonomous driving seems today to be the ultimate goal for road safety but it is difficult to know what will happen when connected mobility reaches its limits and when it is necessary give the hand back to drivers or all road-users. One of the key challenges will be that while autonomous driving systems will take over some aspects of vehicle handling, the driver will always have to be in a position to intervene and take over. Drivers will have to remain alert at all times. So, there are key human factor issues to address.

However, although road-users recognize the benefit of connected mobility, a majority feels that they need to be shown better how to use it. Vehicle manufacturers and infrastructure mana-gers should undertake more efforts to increase the awareness of transport operators, private and professional drivers about the opportunities and challenges of connected mobility and there is a feeling that **road-user training should include instruction on new systems' use**. This lack goes along with insufficient work on policy and legislation for all road-users testing, certifying and training on advanced technologies. **At present, some integrated devices inform via a sound or vibration about a correction measure, but no guided response is taught.** Given the heterogeneous nature of society, there is a presumption that not all road users struggle with a common set of driving problems, but all of these can have an effect on driver's levels of trust of a system or comfort as to where the attitude of control lies between the driver and technologies.

As known today, there is a huge gap between use and learning, because people do not learn how to use and to behave with future technologies that they barely scratch the surface of features and capabilities, therefore we cannot simply rely on owners and drivers reading vehicle manuals. A lot more evidence is needed on how drivers react to advance technologies in order to familiarize road users with connected technologies.

The solution is maintaining tight control of integrated devices and training drivers. Governments, aware of the economic and social benefits of a highly qualified private drivers and commercial driver workforce, are placing increasing emphasis on driver training. Creating training for advanced vehicle safety systems in intelligent road infrastructures shall definitely be considered and training focused on advance technologies shall be elaborated by vehicle manufacturers and/or accredited training institutes.

For instance in the European Union, it is now mandatory for truck, bus and coach drivers to undertake initial qualification to possess a Certificate of Professional Competence (CPC), and complete 35 hours of periodic training every 5 years. More countries and regional organizations are expected to introduce similar requirements.

aThe CPC Driver Program covers both initial qualification and periodic training, and is available for road haulage as well as road passenger transport. By working with local experts, great care has been taken to adapt the content to different national and regional requirements. New drivers – road-users – can be taught easily but the main concern is for existing drivers, who have several decades of habits. Advanced technologies shall be included into a type of CPC Driver training, which could be given in the future also at sales location by those who are trained to teach, not just to sell.

The training shall emphasize that advanced systems such as V2V, V2I, V2X, can prevent drivers from taking evasive actions, but it shall mainly focus on the negative aspect that drivers might become overconfident with such advance systems. Beside the road safety aspects, training related to advanced systems should concentrate on efficiency and increased sustainability of transport operations. Furthermore, training shall explain

the standards that have been adopted to ensure that vehicles made by different manufacturers can communicate with each other and as well to deal with more complex use cases. All existing systems should be interoperable as manufacturers use different tools and frequencies in different countries.

By helping and teaching drivers, this technology will play a key role in making the way people get where they need to go safer.

III.6. EACH REGION MAY REQUIRE ITS OWN CONNECTED MOBILITY SOLUTIONS

Indeed, connected solutions that may be useful in some areas of the world could be harmful in others. Several factors determine success: culture, economy, politics, legal system, infrastructure development.

Challenges to adapt these technologies to the needs of developing countries

Low-income and middle-income countries have considerably higher traffic fatality rates than high-income countries. Accor-

ding to the 2013 WHO report on Road Safety, these countries have the highest annual road traffic fatality rate in the world, eighty per cent of road traffic deaths happen in those countries, which represent 72% of the world's population. Rapid urbanisation and population concentration in cities has increased road traffic crashes in developing cities, where the rate of car ownership continues to grow. In fact, according to a PIARC report[63], a survey on people's desire to possess a car shows that China is the most aspiring country closely followed by Indonesia and India. Whereas in developing countries the number of private vehicles is increasing a lot, good quality public transport and infrastructure are neglected. This is in partly due to limited technical, industrial and economic resources according to the World Bank[64]. In PIARC's report the notorious challenge is the lack of investment in road network development and maintenance. Transport infrastructure needs to be improved in quality and coverage.

However, since physical infrastructure is insufficiently developed, it is far more inexpensive to install at the same time both infrastructures (electronic/intelligent infrastructure or "infostructure[65]" and the material infrastructure) than "retrofitting" the existing one. Besides, in these countries the intelligent

Figure 1: Leapfrogging with ITS.
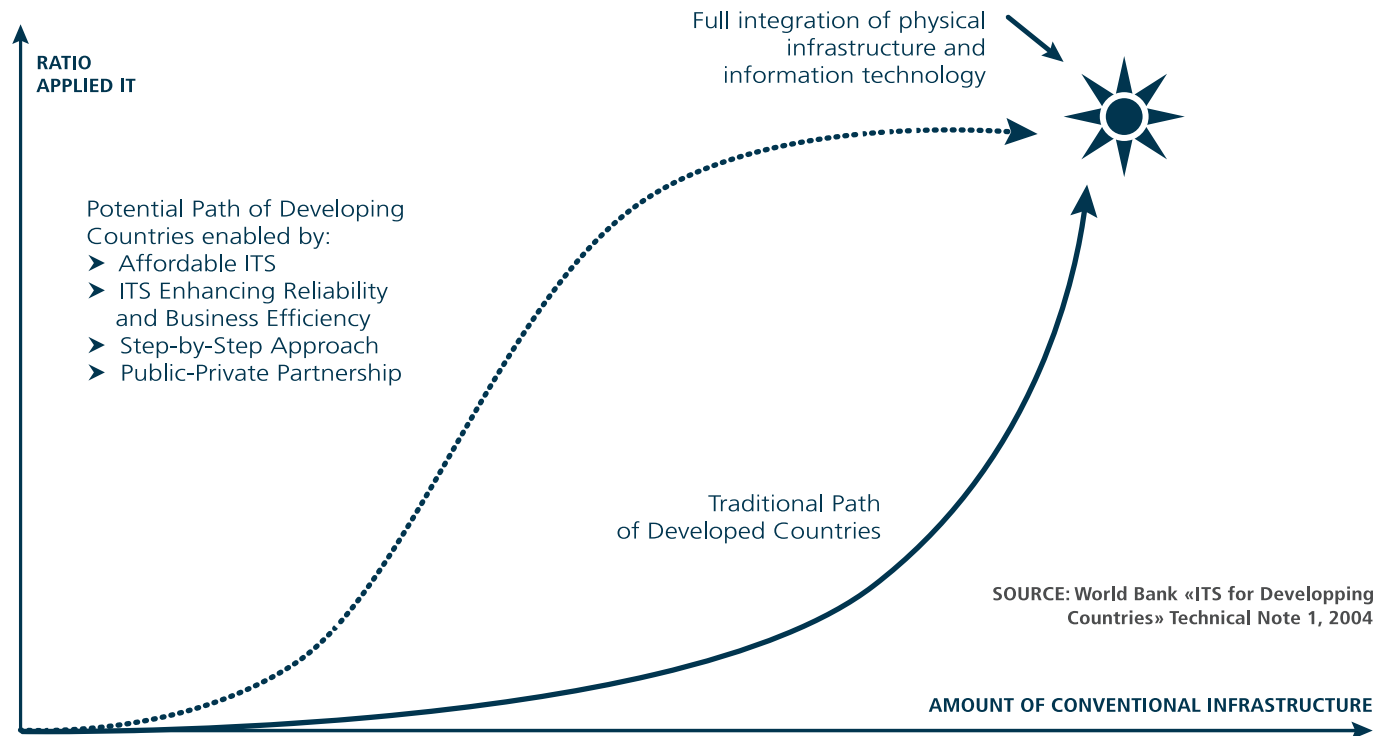
[63] Miles John, Walker Janet, Intelligent Transport Systems make progress around the developing world, n° 328 Systèmes de Transport Intelligents, October 2005
[64] Worvld Bank, ITS for Developing Countries, Technical Note 1, 2004
[65] Infostructure is the information structure required to manage and operate the entire transport system

infrastructure does not need to be updated. Another favou-rable aspect is that developing countries can benefit from high-quality, mature and stable technologies that have already been verified largely installed and renovated. Such technologies are also inexpensive since the cost of IT is continuously decreasing. This helps to avoid costly and environmentally harmful stages undertaken in the past by developed countries according to the PIARC report. That is why these technologies can be deployed easier and faster in the developing world as the figure shows.

Frequently, infrastructure precedes ITS deployment in develo-ping countries for the reason that infrastructure development has immediately perceptible and concrete results. Additionally, politicians do not know all the profits, facilities and availability of such technologies; that is why they need to understand the institutional and technological requirements for deploying such technology. **Also development of local expertise and of monitoring mechanisms becomes crucial in these regions.**

> **An obvious fact needs to be underlined here: there are only low chances that connected technology may save lives if basic road safety measures and devices are not implemented.**

Suggestions on variables of adaption: connectivity and infrastructures

Indeed, connected solutions may be useful in some areas of the world and harmful in others. Several factors determine the success: culture, economy, politics, legal system, infrastructure development.

The following figure compares two factors that seem quite in-fluential: the level of infrastructure and the level of connectivity deployment. This graph brings a few elements to the debate; it doesn't intend to be a complete solution.

Transport Infrastructure (Figure 8)
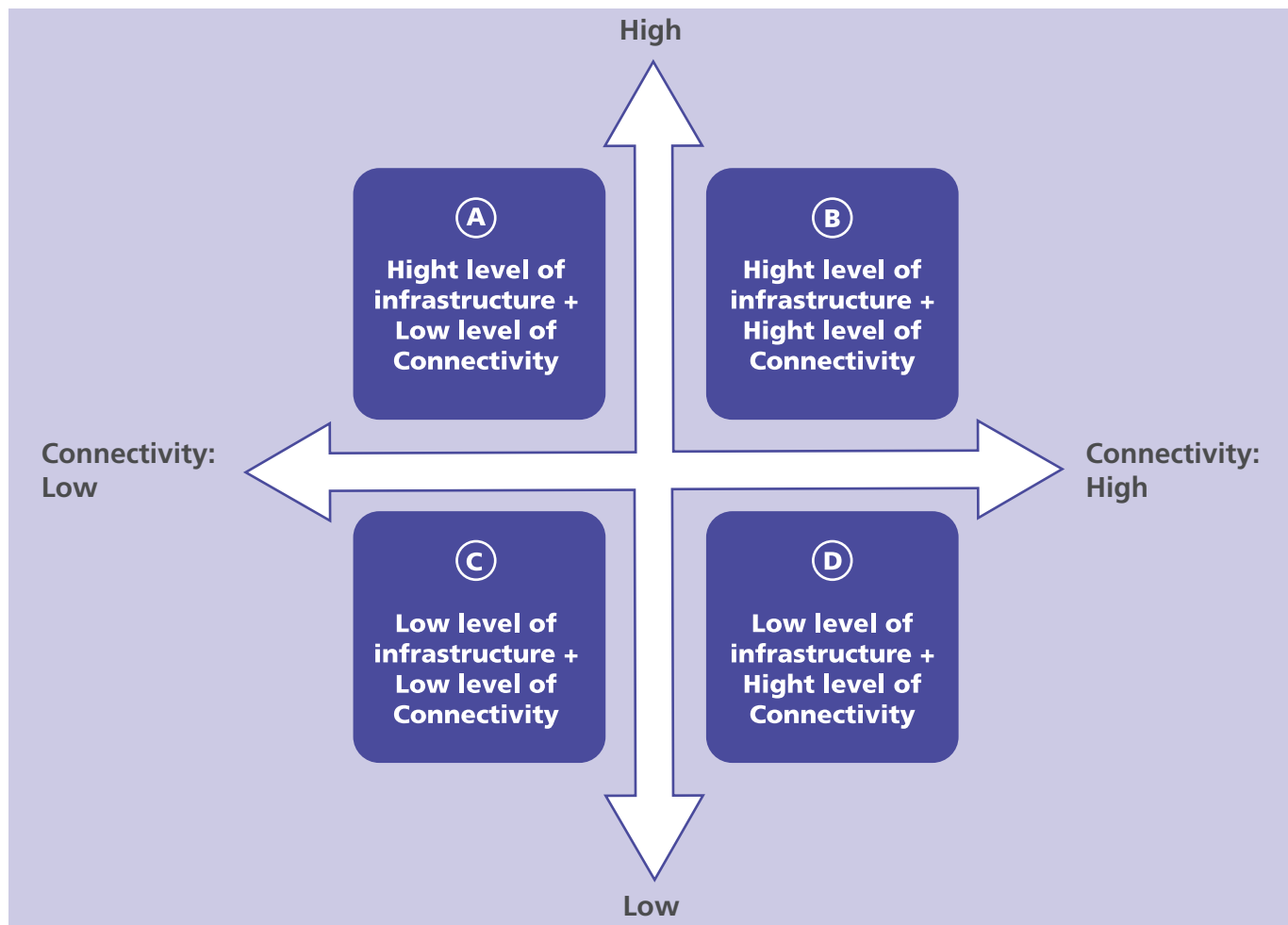
›› **Type A:** Regions with a high level of transport infrastructure development and a low level of connectivity would be characteristic of traditional 20th century patterns of highway development in the industrial world. But this model may also have emerged in the developing world, where roadways may be particularly unsafe, and accidents rate high. Policy solutions may be some ways to improve multi-modal options such as BRT and begin to develop collective ICT solutions for traffic management, and to gradually shift demand for private automobility to other modes.

›› **Type B:** Regions with a high level of infrastructure and high level of connectivity would be indicative of those areas that have made a transition from Type A to new forms of "smart mobility" that can leverage ICT to improve road safety. These areas have been improving road safety and bringing down accident rates, but distracted driving may be a risk. Policy response would be to deploy ICT, especially smart phone apps and digital public displays, more effectively to reduce travel demand, control congestion, and offer alternative public transit and active transport options. These regions have very high potential to develop connected and automated vehicle systems and "intelligent highways", but it may be expensive.

›› **Type C:** Regions with a low level of infrastructure and low level of connectivity are typical of the 20th century developing world prior to the emergence of automobility and the wides-pread growth in ICT connectivity. These areas might have had mixed use roadways with slower traffic speeds and a predominance of pedestrians, and vehicles such as bikes, motorcycles, rickshaws, and hand carts. Because motorized traffic does not dominate, and roadways may not be designed for speed, these areas may have lower accident and fatality rates, but poor levels of emergency response. Policy response would be to create affordable, simple, pedestrian, moto- and bike-oriented ICT solutions that help support non-motorized modes and improve emergency response rates after accidents. Decision makers would need to pay special attention to freight movement, and access to market information.

›› **Type D:** Regions with a low level of infrastructure and high level of connectivity are characteristic of areas where both mobile phones and cars have arrived amidst a Type C setting. While they do not have the full road infrastructure to support a complex mixed system, there is great potential to leverage ICT to "leap frog" to a safer new mobility system. Policy response would be to develop low cost and efficient solutions to emerging challenges of road safety, trying not to replicate the Type A pattern but instead promoting safer multi-modal urban design with mixed infrastructure. The aim would be to leverage the prevalence of connectivity to create new possibilities for car-sharing, local entrepreneurial development, and the emergence of an innovation ecosystem around new mobility concepts.

› ANNEXES

I. EVALUATING THE COSTS OF ROAD CRASHES FROM AN ECONOMIC POINT OF VIEW (REASON WHY WE SHOULD INVEST IN ROAD SAFETY)[66]

Excerpts from White Paper Making the Business Case for Road Safety Investment to Achieve Sustainable Road Mobility, Michelin Challenge Bibendum, 2011

Road crashes have a major negative social and economic impact – in developing countries, the monetary cost is greater than the total aid received from international donors.

It is clearly essential to estimate the cost of crashes to the overall economy at a country level. Such studies highlight the socio-economic burden of road crashes, which are considered to cost annually between 1% and 3% of the national GDP in developing countries. The burden on developing countries is 65 billion US Dollars, representing more than the total aid received from bilateral and multilateral donors. Crashes are not only a massive money drain for countries; they are also a socio-economic issue[67].

A study of Bangladesh and the city of Bangalore showed that more than 50% of the households that were considered poor

after a crash leading to a death or serious injury wouldn't have been classified as such before the crash[68].

As can be seen, beyond reducing deaths and injuries, expenditure in road safety is an investment and not a cost - each US Dollar invested in road safety returns 15 US Dollars on average, which makes the rate of return a stunning 1,500%[69].

The cost of road crashes

At a country level, it is essential to estimate the cost of crashes for the overall economy. Such studies highlight the socio-economic burden of road crashes. In many countries, particularly in the developing world, road safety does not receive due consideration.

Crash costing methods

[…] different methods have been identified to cost road crashes. More details are provided for the first two because they are the most commonly used. All of them are based on a before-hand classification of crashes. Crashes may result in personal injury or in property damage only. Crashes resulting in injury are usually subdivided into the following categories (definitions used by

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[66] Excerpts from White Paper Making the Business Case for Road Safety Investment to Achieve Sustainable Road Mobility, 2011, Michelin

[67] TNT Express has initiated a social fund in India to address this specific issue. This fund is available to support families of any person killed in a road traffic accident involving a contractor vehicle operating on behalf of TNT India.

[68] The Involvement and Impact of Road Crashes on the Poor: Bangladesh and India Case Studies, by Ms A. Aeron-Thomas (TRL), Dr G. D. Jacobs (TRL), Mr B. Sexton (TRL), Dr G. Gururaj (NIMHANS), and Dr F. Rahman (ICMH), July 2004, p. 19.

[69] This calculation has been made on the basis of the Swiss case study (Eckhardt and Seitz, 1998), a case study on the Safer Roads Investment Plan for Serbia (Safer Roads Investment Plans: The iRAP Methodology)and a study by the National Highway Traffic Safety Administration (NHTSA) "What Do Traffic Crashes Cost?"

most Western European countries, as well as by the WHO/UNR-SC Data Manual, UNECE and IRTAD):

›› Fatal crashes: one or more killed due to the crash within 30 days;

›› Serious crashes: there are no deaths but there is one or more seriously injured persons;

›› Slight crashes: there are nor deaths nor serious injuries but at least one person with a minor injury (i.e. cut, sprain or bruise).

The cost of each crash type is hence not the same. In considering costs it is important to take this matter into consideration.

1). The «gross output» or «human capital» approach

In this approach, costs can be divided into two groups, on the one hand those linked to a diversion of current resources and on the other hand, those leading to loss of future output. The first set of costs includes damage to property (mainly vehicles), the cost of medical treatment and police and administrative costs related to crashes (mainly courts and insurance staff).

There is less consensus as to what should be included in the second set of costs and how estimates should be computed. Estimates are not individualized, but are taken from averages. The loss-of-output method takes the average amount of working years lost due to the crash, multiplies it by the average wage and the sum is discounted so as to be in present value. Some variants account for the value of pain, grief and suffering and they do so by multiplying a percentage of the lost output depending on the severity of the crash. This method allows for instance to revert the fact that the death of an elder person would actually be considered as beneficial for society in the previous calculation.

This method has been criticized for several reasons. First on an ethical stand, it would set the economic or statistical value of a person living in a developed country higher than the one of a person living in a developing country. Second, there is debate as to how to account for domestic work, black market or the cost of time lost in traffic (although the NHTSA, 2002 report on the «The economic impact of motor vehicle crashes in 2000», provides a good estimate of those costs). Third, this method requires an important amount of information not always available in developing countries. Finally, it is hard to take into account the social impact of the loss of a family's earner. As it shall be developed further, in developing countries, the impact may be much higher, particularly considering the loss of income for a family, the need to sell productive property to cover for medical expenses or the fact that a child might drop school to take care of the injured family member. Also it is necessary to take into account a lack of social legislation to provide social welfare benefits e.g. unemployment benefit, disability allowance etc.

2). The «implicit public sector valuation» approach

This method estimates the cost implicitly set by state regulation and public policies in road crash and death prevention. The main problem with this approach is that public policies attribute very different values to life depending on the sector. In the UK, studies have shown that using this approach the value of life could range from 50 Pounds Sterling to 20 million15.

Most researchers and organizations (TRL, ADB, iRAP…) prefer to use the «gross output» method in order to estimate the cost of road crashes in developing countries. This method would seem to provide the most balanced approach as it takes into account both the direct and indirect costs of crashes. However, to correct for some of the gross output method's flaws an allowance is added, per type of injury, as a percentage of the cost. In developing countries, the Transport Research Laboratory recommends adding 38% of the total cost for a fatal crash, 100% for a serious injury and 8% for a minor injury to the cost16. In developed countries, another study suggests the sums added should be equal to 20% for a fatal crash, 50% for a serious crash, 30% for a major crash and 1% for a minor crash[70].

3). The «value of risk change» or «willingness to pay» approach

This approach based on the premise that a public sector decision should reflect the preferences of the citizens that it will affect. This method estimates the value given to a road safety risk reduction; it is «defined in terms of the aggregated amount that people are prepared to pay for it», it could also be estimated by the amount people would require in compensation of an increased risk18. This method provides a much higher value for human life but is hard to put in place since there are both a sampling bias and an interview bias. Usually questionnaires put in place for this method assess the amount of money they would be willing to pay for a certain risk reduction. For example a questionnaire indicating that drivers are willing to pay 10 US Dollars for a risk reduction of one chance in 250,000 that they would be killed in a particular journey then the value of an average life would be 2.5 million US Dollars (250 000 x 10).

This method is being used more and more in developed countries, for instance in the UK. Nevertheless, due to the difficulty of obtaining reliable empirical estimates, this approach is hard to apply in developing countries. Furthermore, questionnaires could only be administered to adults and there would be an important bias considering that the proportion of children killed or injured in traffic crashes in developing countries is double that in developed countries.

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[70] Department for International Development, Ross Silcock, TRL Guidelines for Estimating the Cost of Road Crashes in Developing Countries, May 2003, p. 32.

4). The «net output» approach

The difference between this approach and the first is that the discounted value of the victim's future consumption is subtracted from the gross output figure. Once again, it is hard to estimate a person's lifetime consumption.

The «raison d'être» of this method is that the difference between the production of an individual and its consumption can be considered as the society's economic interest in a person's survival. It is so to say his added value to society.

a) The «life-insurance» approach

This approach considers that the cost of a road crash derives from the value at which people are willing to or can insure their lives. This method provides an interesting estimate of the value of the insured person's life to their dependents. Nevertheless, it gives no information on the value of life to the insured person. The insured person may well also be underestimating the value of their life to their dependents. Furthermore, this approach seems to be inapplicable in developing countries where the practice of life insurance is very limited and only the richest get their life insured.

b) The «court-award» approach

This method estimates the value of life or injury by averaging the sums awarded by courts, which result from a crime or a negligence, to the surviving dependants or the injured person. This approach is of limited interest because the sums awarded by courts depend greatly on the degree of responsibility of the culprit. Furthermore, this method only includes private costs.

II. HOW TO CHOOSE COST-EFFECTIVE ROAD SAFETY POLICIES?

Excerpts from White Paper Making the Business Case for Road Safety Investment to Achieve Sustainable Road Mobility, Michelin Challenge Bibendum, 2011

Selection of public policies for road safety should be based on effectiveness and efficiency: effectiveness because there is no value in implementing a policy that does not reduce crashes or injuries, and efficiency because limited resources should be directed toward the activities that yield the highest social return. The two monetary methods used to measure these concepts are cost-benefit analysis (CBA) and cost-efficiency (CEA) analysis[71].

The two methods compare the effect of a public policy in comparison with either the current situation or «business as usual» situation under various criteria. The effects are defined as all the changes resulting from a project. They range from the expected effects on the situation that the policy seeks to solve to side effects which can be positive or negative. For instance in the case or road safety measures, a reduction in the authorized speed limit can have a positive side effect on the environment but also a negative side effect on the time of travel, generating economic costs for travellers. Particular attention must be set on avoiding double counting costs and benefits. Both cost and benefits have to be considered during the entire period studied.

1). The cost-benefit analysis

This approach is based on a balance sheet of costs and benefits, with consideration given to both the direct and indirect effects of the measure. Usually once the economic valuation has been discounted, a **cost-benefit ratio is given to a particular project.** The discount rate used in the economic analysis of investments is a key variable in applying the net present value or benefit-cost criteria for investment decision making. Such a discount rate is equally applicable to the economic evaluation, as distinct from a financial analysis, of both private as well as public investments. If the net present value of either type of project is negative when discounted by the economic cost of capital, the country would be better off if the project were not implemented. Estimates of the value of this variable for a country should be derived from the empirical realities of the country in question. The results of such a discounting effort are only as good as the underlying data and projection made of the benefits and costs for the project.

When various projects are competing for limited resources the one with the biggest benefit-cost ratio should generally be applied. If the question is whether to implement the project or not, the minimum criteria could be a ratio equal to one, i.e. costs equal the benefits.

The main flaws of this method are that it is hard to evaluate precisely the effects or to monetize them, and that the further they are ahead in time the harder it is to link them to the project.

2). The cost-efficiency analysis

This approach can be used in two ways: cost minimization for a determined desired outcome, or effect maximization for a determined amount of resources invested.

Unlike the previous approach, this method does not provide information on the social or economic profitability of a measure. If only one effect is intended then in an effect maximization analysis, the information sought is the cost per

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71 Wesemann for the Dutch delegation at the European Conference of Ministers of Transport in 2000.

unit of the effect; for instance, a road safety policy analysis should seek to estimate the cost per life saved.

The EU funded Thematic Network ROSEBUD (Road Safety and Environmental Benefit-Cost and Cost Effectiveness Analysis for use in decision-making)[72] shows a broad set of examples of measures (user, vehicle and infrastructure related measures) which were assessed on the basis of CBAs and CEAs. Many countries compile programs of road safety measures and targets for improving safety (e.g. percentage of fatalities to be saved in a certain year). The programs are based on a range of strategies and rarely on full ex-ante evaluations of the measures considered. CBAs and CEAs are most often used for setting priorities for safety measures within the framework of a national or local safety program.

The assessment of road safety measures should take place throughout the course of a program, and should be applied across all programs. The application of CBAs and CEAs allows the result of systematic monitoring of road safety activities to be assessed. The evaluation of safety plans or programs requires the systematic recording of the activities and actions and the development of consistent accident and performance indicators with resources dedicated to data collection and analysis.

After comparing road safety plans with the reality, decision makers have the chance to steer the activities in a new direction if necessary, and CBAs and CEAs should be the basis for these decisions.
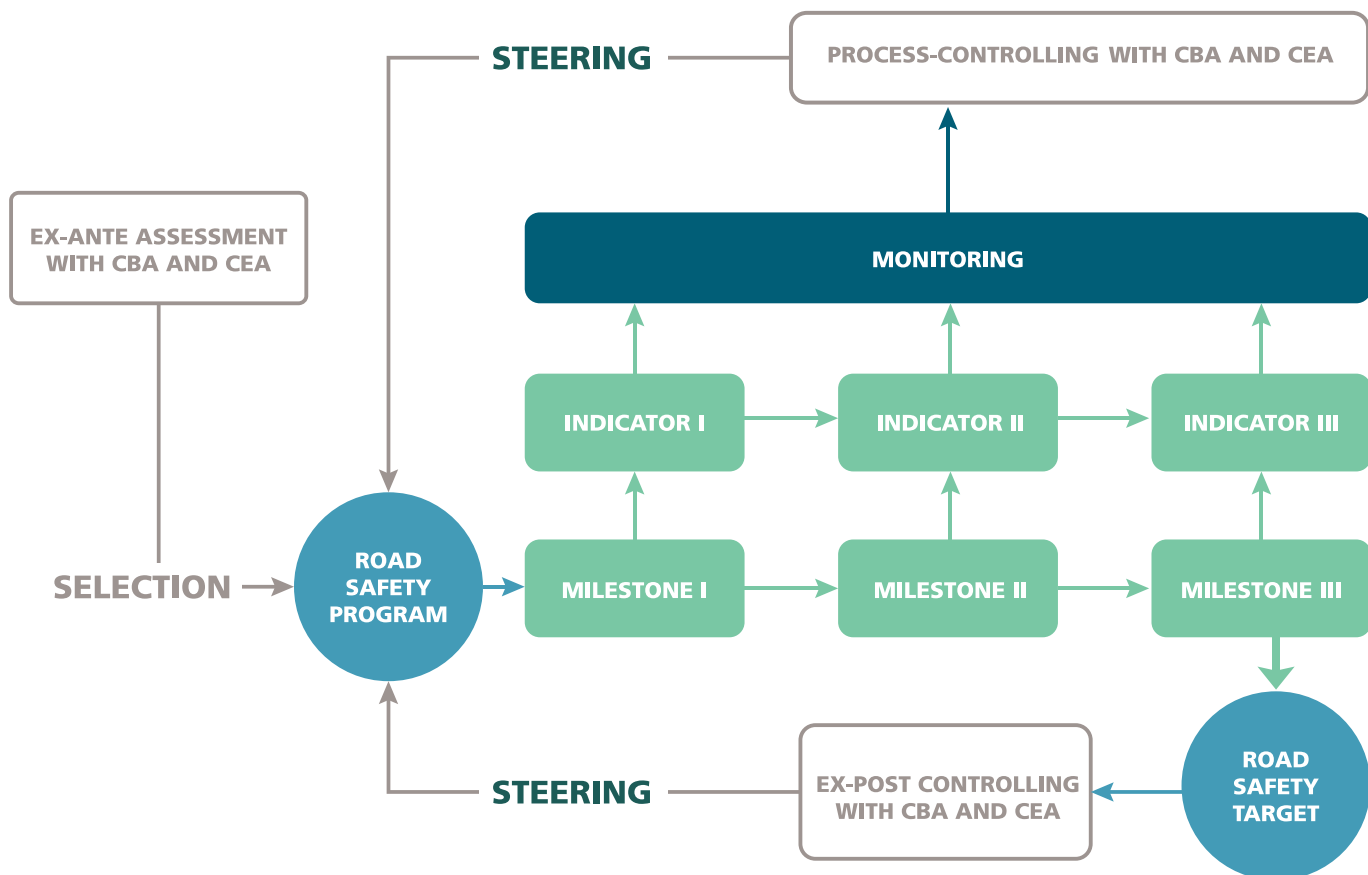

Figure 9: Possible scheme of a systematic evaluation of road safety activities, ROSEBUD

[72] ROSEBUD, Deliverable WP5 Recommendations, 2007.

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