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<tr>
<td>ACEA</td>
<td>European Automobile Manufacturers Association</td>
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<tr>
<td>AD</td>
<td>Autonomous Driving</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance Systems</td>
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<tr>
<td>Algorithm</td>
<td>A mathematical formula or statistical process used to perform an analysis of data. How is ‘Algorithm’ related to Big Data? Even though algorithm is a generic term, Big Data analytics made the term contemporary and more popular.</td>
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<tr>
<td>Analytics</td>
<td>Drawing insights from your raw data which can help you make decisions.</td>
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<td></td>
<td>- Descriptive Analytics - Analytics, which use data aggregation and data mining to provide insight into the past and answer: “What has happened?”</td>
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<td></td>
<td>- Predictive Analytics - Analytics, which use statistical models and forecasting techniques to understand the future and answer: “What could happen?”</td>
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<tr>
<td></td>
<td>- Prescriptive Analytics - Analytics, which use optimization and simulation algorithms to advise on possible outcomes and answer: “What should we do?”</td>
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<tr>
<td>APN</td>
<td>Access Point Name – The gateway between GSM network and Internet.</td>
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<tr>
<td>ASFINAG</td>
<td>Autobahn- und Schnellstraßen-Finanzierungs-Aktiengesellschaft” which is German for &quot;Autobahn and high way financing stock corporation.</td>
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<tr>
<td>Big Data</td>
<td>Big data is high volume, high velocity, high variety and high veracity (reliability) information assets that require new forms of processing to enable enhanced decision.</td>
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<td>CAGR</td>
<td>The Compound Annual Growth Rate (CAGR) is the mean annual growth rate of an investment over a specified period of time longer than one year.</td>
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<tr>
<td>Cloud</td>
<td>Software and/or data hosted and running on remote servers and accessible from anywhere on the Internet.</td>
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<tr>
<td>Computing</td>
<td></td>
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<tr>
<td>Cybersecurity</td>
<td>The protection of information systems from theft or damage to the hardware, the software, and to the information on them, as well as from disruption or misdirection of the services they provide.</td>
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<tr>
<td>Data Lake</td>
<td>A large repository of enterprise-wide data in raw format.</td>
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<tr>
<td>Data Mining</td>
<td>Finding meaningful patterns and deriving insights in large sets of data using sophisticated pattern recognition techniques. It is closely related to the term Analytics.</td>
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<tr>
<td>DTC</td>
<td>Diagnostic Trouble Code – The standardized codes received from the OBD-II port.</td>
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<tr>
<td>ECU</td>
<td>Electronic Control Unit - is a generic term for any embedded system that controls one or more of the electrical systems or subsystems in a motor vehicle. The ECU involves both hardware and software required to perform the functions expected from the unit.</td>
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<tr>
<td>Edge</td>
<td>Edge computing is a distributed information technology (IT) architecture in which client data is processed at the periphery of the network, as close to the originating</td>
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<td>Computing</td>
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source as possible. The move toward Edge computing is driven by mobile computing, the decreasing cost of computer components and the sheer number of networked devices in the internet of things (IoT).

<table>
<thead>
<tr>
<th>EC Type Approval</th>
<th>Means the procedure whereby an authority of an EU member state certifies that a type of vehicle, system, component or separate technical unit satisfies relevant technical requirements and administrative provisions listed in the Directive.</th>
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<tbody>
<tr>
<td>FCD</td>
<td>Floating Car Data</td>
</tr>
<tr>
<td>FMS</td>
<td>Fleet Management Services</td>
</tr>
<tr>
<td>Hadoop</td>
<td>Apache Hadoop ( /həˈduːp/) is a collection of open-source software utilities that facilitate using a network of many computers to solve problems involving massive amounts of data and computation. It provides a software framework for distributed storage and processing of big data using the MapReduce programming model. Originally designed for computer clusters built from commodity hardware—it has also found use on clusters of higher-end hardware. All the modules in Hadoop are designed with a fundamental assumption that hardware failures are common occurrences and should be automatically handled by the framework.</td>
</tr>
<tr>
<td>Head Unit</td>
<td>The control centre and user interface for an automobile’s entertainment centre, which typically resides in the centre of the dashboard. It provides the main controls for the radios (any combination of AM, FM, XM, Sirius, HD Radio) as well as a CD/DVD player, GPS navigation, Bluetooth cell phone integration, hard disk storage for music and iPod connector. There may be auxiliary controls on the steering wheel.</td>
</tr>
<tr>
<td>IoT</td>
<td>Internet of Things - IOT is the interconnection of computing devices in embedded objects (sensors, wearables, cars, fridges etc.) via internet and they enable sending or receiving data. IOT generates huge amounts of data presenting many big data analytics opportunities.</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
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<tr>
<td>Machine Learning</td>
<td>A method of designing systems that can learn, adjust, and improve based on the data fed to them. Using predictive and statistical algorithms that are fed to these machines, they learn and continually zero in on “correct” behavior and insights and they keep improving as more data flows through the system.</td>
</tr>
<tr>
<td>MapReduce</td>
<td>MapReduce is a programming model and the best way to understand this is to note that Map and Reduce are two separate items. In this, the programming model first breaks up the big data dataset into pieces (in technical terms into ‘tuples’ but let’s not get too technical here) so it can be distributed across different computers in different locations (i.e. cluster computing described earlier) which is essentially the Map part. Then the model collects the results and ‘reduces’ them into one report. MapReduce’s data processing model goes hand-in-hand with hadoop’s distributed file system.</td>
</tr>
<tr>
<td>MNO</td>
<td>Mobile Network Operator</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Network Slicing</td>
<td>Network slicing allows a network operator to provide dedicated virtual networks with functionality specific to the service or customer over a common network infrastructure. Thus it will be able to support the numerous and varied services envisaged in 5G.</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology is an organisation run by US trade department.</td>
</tr>
<tr>
<td>NSC</td>
<td>National Sales Company</td>
</tr>
<tr>
<td>OBD-II</td>
<td>On-board Diagnostics, version two. A vehicle’s self-diagnostic and reporting system which uses a standardized digital communications port to provide real-time data and a standardized series of diagnostic trouble codes.</td>
</tr>
<tr>
<td>ODPI</td>
<td>Open Data Platform Initiative, ODPI will accelerate the delivery of Big Data solutions by driving interoperability.</td>
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<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer (often used for the Vehicle Manufacturers)</td>
</tr>
<tr>
<td>OTA</td>
<td>Over-the-Air</td>
</tr>
<tr>
<td>PSAP</td>
<td>Public-Safety Answering point</td>
</tr>
<tr>
<td>SIM</td>
<td>Subscriber Identity Module – unique identity for a unit in a mobile network</td>
</tr>
<tr>
<td>STA</td>
<td>Swedish Transport Administration (Trafikverket)</td>
</tr>
<tr>
<td>Structured versus Unstructured Data</td>
<td>This is one of the ‘V’s of Big Data (i.e.Variety). Structured data is basically anything than can be put into relational databases and organized in such a way that it relates to other data via tables. Unstructured data is everything that can’t – email messages, social media posts and recorded human speech etc.</td>
</tr>
<tr>
<td>TMC</td>
<td>Traffic Management Center</td>
</tr>
<tr>
<td>TPSP</td>
<td>Third Party Service Provider (for eCall)</td>
</tr>
<tr>
<td>TSP</td>
<td>Telematics Service Provider</td>
</tr>
<tr>
<td>Type</td>
<td>Vehicles of a particular category, which do not differ in certain essential respects set out in Annex II of the framework Directive 2007/46/EC, as amended.</td>
</tr>
<tr>
<td>VMS</td>
<td>Variable Message Sign</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>The standard wireless local area network (WLAN) technology for connecting computers and electronic devices to each other and to the Internet. Every laptop, tablet and smartphone comes with Wi-Fi. Wi-Fi is an IEEE standard with the official designation of 802.11. In the early 2000s, 802.11b was the first popular version, followed by 11a, 11g and 11n. The latest is 11ac (see 802.11ac).</td>
</tr>
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1 Abstract and Executive Summary

1.1 Abstract

The aim of this work package, Big Automotive Data Analytics (BADA) Business Models, is to identify how Big Data can reinforce the current business models, or perhaps lead to modifications in the current business models, that will result in better performance of the entire land transport infrastructure. When all land transport vehicles, irrespective of how they are powered, act as multiple sensors in the road network, massive amounts of data can be collected on how these vehicles are using the network. This data, combined with other types of data, such as weather, temperatures, events and historical statistics, will enable more effective, safer and more environmentally responsible transport. The great challenge for society in general and both public authorities and private enterprises is to find effective ways to contribute to the new possibilities that big data analytics offer and to benefit from these possibilities by delivering better products and services. This report attempts to identify the principal consequences of employing big data analytics in the land transport context and to provide recommendations on how the BADA partners can do so most effectively.

1.2 Executive Summary

The land transport infrastructure of the future will be much more heterogeneous than today, comprising an ecosystem of different types and combinations of transport alternatives and transport-related services. In this ecosystem, it will be decisive to have the ability to understand the interactions of all components of the infrastructure and the vehicles using it, and to manage the massive amounts of data that are being generated. Collecting and processing this data require new techniques that are referred to as Big Data Analytics. For purposes of our work, we have chosen to use the following definition of Big Data: Big data is high volume, high velocity, high variety and high veracity (reliability) information assets that require new forms of processing to enable enhanced decision.

In order to arrive at the consequences of Big Data for road transport operators and users, and to provide recommendations for adaptations and modifications to current business models of those who are engaged in road transport-related operations, we have:

- Investigated the issues, problems and opportunities for future mobility;
- Elaborated on the ecosystem of data exchange, its principal actors and their roles;
- Analysed the implications of Big Data on a number of key transport services; and,
- Reviewed the legal implications of processing data obtained from public and private vehicles.

Work in the BADA Project has been focused on the following three major goals: improve traffic flow, lower harmful emissions and improve traffic safety. The aim of the study is to provide the basic building blocks that are necessary to take the next
step in the development of Big Data Analytics in the automotive and transport sector, including exploring and designing new business models and service concepts that could be made possible by the ability to handle Big Data.

We have identified the following consequences and recommendations that apply to all of the BADA partners:

- Data have the potential to drive your organization. Prioritize accordingly!

It has been often said of late that ‘data is the new oil’, that it is fueling the massive growth of the technology companies, both large and small, and supplanting petroleum as the world’s most valuable commodity. Data, like oil, is valuable only if it is refined. Data must be broken down and analyzed in order for it to have value. The companies that are doing this best today are the technology giants that have supplanted the oil concerns as the world’s most valuable. Compared to oil, data is relatively free, which is why the largest companies by market value today have small numbers of employees. However, they are focusing increasing amounts of their resources in mining data to increase their competitive advantages.

In our report, we have provided numerous examples of how all of the BADA partners can obtain and use Big Data in order to increase competitiveness and operational effectiveness while meeting our three major goals (improving traffic flow, lowering harmful emissions and improving traffic safety). In order to accomplish this, the organizations must prioritize the collection, analysis and use of data. The need to do so will only increase as artificial intelligence plays an increasingly larger role in all aspects of society.

- It is highly recommended to raise Big Data analysis at executive level to benefit from it at all levels and in all businesses.

Swedish companies and governmental agencies are well-known for bottom up and consensus-based decision-making. This approach has proven to be an effective way to ensure that everyone in an organization is working toward common goals. In the case of applying Big Data Analytics, it is neither obvious nor self-evident that there is a strongly felt need at the individual level to initiate activities for collecting or analysing Big Data. Deciding to implement the processes necessary for benefitting from Big Data needs to be taken at an executive level and then reviewed with staff to determine the best ways of approaching the entire process.

- For all actors it is important to find their desired role in the ecosystem of data exchange and work hard to achieve that role.

Big Automotive Data is predicated on vehicle connectivity. The business related to the connected vehicles in the entire data exchange ecosystem is expected to grow quickly in the coming years, and all actors have to identify their roles and take their respective positions. In addition to the governmental road transport administrations, actors include vehicle OEMs, mobile network operators, content providers, on-board and off-board system providers, platform service providers, traffic management centres, road...
operators, mobility service providers and new roles as Big Data analyzers. Some of these overlap, and more of them will do so in the future as actors attempt to increase their influence in the value chain and take on multiple roles. The key will be to make the effort to identify which role or roles will result in the highest overall benefit, to invest in acquiring the personnel and systems needed to achieve a high level of competence in role, and then following through with high quality execution. The role taken by government, as an active participant or as a financial supporter and enabler, will need to be defined in conjunction with the legal and regulatory policies.

- Using Big Data processes for transport requires much more cooperation among many parties in order for the desired results to be achieved. That cooperation extends to both the public and private sectors.

As communication increases between vehicles and other vehicles and between vehicles and the road transport infrastructure (e.g., floating car speed data, incident reporting, road condition warning, emergency telematics) the need for cooperation among all actors intensifies. This was clearly highlighted in our future scenario modelling exercise. This work provided a perspective on future developments in the transport sector. Scenarios are not forecasts describing what the future will be; they provide a plausible, consistent picture of alternatives of what the future could be. In all scenarios that model higher levels of connectivity, interdependence between decisions that are taken by governments and those taken by companies will only increase. Private and public sectors need to find ways to use existing forums and, when necessary, create new forums, where developments can be discussed and solutions found that best meet the agreed goals.

- Public authorities at all levels of government need to integrate their data assembly and integration processes. Private companies must be willing to integrate data which they collect with other companies’ data and with data from the public authorities.

In the case of Big Data, the more data that is available for processing, the more likely it will be that data analytics results will be useful for the largest number of actors. There will, of course, be datasets that both the public and private actors will not wish to share or may not be allowed to share due to privacy or security concerns. However, even if data may today be viewed as superfluous and unnecessary to share, in a Big Data context it could prove very useful and could assist in gaining new insights that would be otherwise impossible. Sharing as much data as possible among all actors is the only way to obtain the benefits of Big Data Analytics. In order to do so, all necessary cybersecurity measures must be taken to protect the privacy of individuals and institutions.

- Standards are more important because data exchange among many parties is essential.

Until now, car OEMs have had individualized ecosystems for data collection and interchange with their selected partners. This has allowed for secure connectivity and allowed each OEM to move at a pace that suited its particular business. In order to
realize the full benefits of Big Data, standardized vehicle-to-vehicle, vehicle-to-infrastructure, vehicle-to-cloud and cloud-to-third-party methods will be needed to complete the data exchange among all parties, including car manufacturers, service providers, road owners and public authorities. Major steps have been taken by regional standardization bodies in Europe, North America and Asia to standardize communication methods and message sets, and while there is as yet no agreement on how best to move forward, there is agreement that it is essential for all parties to support the standardization efforts through active participation in these efforts and the allocation of resources for testing and validation of the alternative solutions.

- In order to obtain the full benefits of Big Data, all vehicles should be connected in order to deliver and receive data and information.

Government and the auto industry fully agree that when vehicles can communicate with other vehicles in their vicinity, either directly or via roadside units, many types of accidents will be avoided and lives will be saved. Added benefits of improved traffic flow will be reduced emissions and increased road capacity.

The Swedish vehicle OEMs have been among the most advanced in the entire global industry in implementing vehicle communications technology, both in terms of doing so at a very early stage and using the most robust techniques. Solutions that were first developed by the Swedish OEMs, such as a centralized telematics service provider for data management, have been adopted as a standard by all OEMs. The Swedish members of BADA should be leading efforts to consolidate the opinion of Sweden’s road transport industry and work toward building a consensus among their equivalents in the other countries of the EU to influence the direction of connectivity developments within the EU and the rest of the world.

- Access to vehicle data will be extremely important and it can be executed in different ways. It is important to work towards a common agreed concept that takes into account the interests of all major stakeholders.

In 2014, the European Commission Directorate-General for Mobility and Transport (DG-MOVE) established a Cooperative Intelligent Transport Systems (C-ITS) multi-stakeholder platform, with an aim toward “cooperative, connected and automated mobility”. Its primary purpose was to work toward identifying remaining obstacles to C-ITS deployment in Europe. C-ITS is based on a 2010 EU directive intended to facilitate the deployment of EU-wide interoperable smart transport systems. The directive has a broad scope, covering eCall emergency calling and communication of dangerous road conditions, traffic conditions, and truck parking spaces.

On 30 November 2016, the EC released a Communication providing detailed priorities in its strategy. The objective of the strategy is to allow for a wide-scale commercial deployment of C-ITS—a network of vehicles that can “talk” to each other and to EU transport infrastructure—by 2019. The Communication focuses on vehicle data relevant for transport safety and the environment.
DG-MOVE commissioned a study in 2016 by the UK-based TRL, the title of which is *Access to In-vehicle Data and Resources*. The Report reviews the results of the EC-run C-ITS Deployment Platform WG6. This working group was established to examine potential ways to “give access to in-vehicle data and resources in order that service providers could propose services based on data to their customers.” Giving access means either encouraging or requiring through regulation OEMs to share any or all data that is collected by the vehicle from systems installed by the OEM and communicated from the vehicle using systems also installed by the OEM. The 250-page TRL Report evaluates the three technical solutions WG6 devised for providing unfettered access to in-vehicle data. They identified three basic solutions.

1. In-vehicle Interface
2. On-board Application Platform
3. Data Server Platform (DSP)

Three sub-options were included by WG6 for the DSP.
- Extended Vehicle
- Neutral Party Shared Server
- B2B Marketplace Platform

The European Commission through C-ITS will be recommending a connectivity solution that should be implemented by the road transport industry. It is vital that the members of the BADA team take the lead in advocating the adoption of the Data Server Platform, Extended Vehicle option.

- Security and data privacy become more important because of the potential for cyberattacks on the connected vehicles.

The way that data privacy is interpreted in the EU General Data Protection Regulation (GDPR) can make it difficult to achieve both data security and data privacy while maximizing the potential use of vehicle data for Big Data applications. GDPR replaces the Data Protection Directive 95/46/EC and is designed to “harmonize data privacy laws across Europe, to protect and empower all EU citizens’ data privacy and to reshape the way organizations across the region approach data privacy.” Privacy is not defined in the document nor is it related specifically to any of the terms used in the document. The surrogate for ‘privacy’ is ‘personal data’, which is defined as “any information relating to an identified or identifiable natural person”.

There are currently no precedents for making decisions on how vehicle data will be interpreted, either as the personal data of the owner/driver/passenger of the vehicle or as non-personal data that falls outside the jurisdiction of the GDPR. Without access to vehicle data, it will be very difficult to realize the benefits of Big Data to achieve the goals of improving traffic flow, lowering harmful emissions and improving traffic safety. BADA partners should work together to devise policies for guiding the developments in this important area and also for recommending ways that security against cyberattacks can be maximized.

- Big data and the use of artificial intelligence (AI), neural networks and deep learning will make it possible to find patterns and new ideas that haven’t been
possible with earlier technologies. Practical methods need to be developed in order to utilize the potential of Big Data in business development.

It has only been during the last five years that the fifty-year-old idea of artificial intelligence has begun to gain traction. It is through predictive applications that data can be turned into decisions and these decisions can be put into action as part of an automated process. In the past, many of the most complex and interesting applications of AI in business have been held back by either a lack of available training data or a lack of computing power. Now, both are available in abundance. As an added bonus, the increasing computing power needed for Big Data, and the resulting infrastructure, especially in the cloud, are agnostic to the use case. This means, the same hardware that is used for simple number crunching can also be put to use for complex optimization problems.

- We recommend the establishment of a multidisciplinary forum/group within each BADA project organization that can discuss issues regarding data exchange and how Big Data and AI can be used in support the organization’s activities. Each organization needs to develop policies, strategies, roadmaps, action plans, etc. and allocate relevant competence to implement them.
- To promote the interests of the Swedish actors on a European and global market, we also recommend the establishment of a group/forum with representation from the project partners to continue to jointly drive issues regarding the use of Big Data, access to data and how we interact for efficient data exchange and policies and strategies regarding these this issues.
2 Introduction

2.1 Prerequisites and background

The automotive industry is facing a revolution, and today's standalone vehicle can potentially be replaced by an ecosystem of co-existing transport units. In this ecosystem, it is decisive to have the ability to control the system and manage data, not to focus on individual vehicles. At the same time all vehicles will act as multiple sensors in the road network, collecting huge amounts of data that can be combined with other types of data and used for a wide variety of purposes. The great challenge for society and the automotive industry is to benefit from these new possibilities and meet the trends of Big Data Analytics.

As input to this report on business models future scenarios, a state-of-the-art report was prepared. It begins with a brief history of the evolving market of Telematics and the Connected Car and explains how and why the Connected Car Ecosystem is an enabler of large amounts of data and business development built on data and data analytics. There are multiple ways to view the Connected Car Ecosystem, including the actors involved and services enabled, and these are explained in the state-of-the-art report. The business related to the Connected Car Ecosystem is expected to grow quickly in the coming years and actors have to identify their role and take positions. Actors include Vehicle OEMs, Mobile Network Operators, Content Providers, On-board System Providers, Telematics Service Providers, Traffic Management Centres, Road Operators and new roles as Big Data Analyzers and Mobility Providers.

The integration platform is the heart of the ecosystem, and it is important to understand the level of integration necessary for enabling business opportunities. Big Data Analytics will definitely grow with the increasing amount of data collected from all kind of connected devices including vehicles. Services for mobility is one area that will benefit from connected vehicles and big data analytics. Crowdsourcing, Mobility-as-a-Service and the development of sharing economy are new areas that will influence the development of new business models.

2.2 Overall goal and purpose with Big Data Analytics in the transport sector

The overall goals of BADA in the transport sector are to improve traffic flow, lower harmful emissions and improve traffic safety. The goal of the main study is to provide the basic building blocks that are necessary to take the next step in the development of Big Data Analytics in the automotive and transport sector. This includes implementation of an information sharing platform and an analytics platform and exploring and designing new business models and service concepts that could be made possible by the ability to handle Big Data.

2.3 The objective of the work package BADA Business models

Each of the partners in the BADA project, including the Swedish Transport Administration, has its own business model which is representative of the business
area it represents (i.e. automobile OEMs for Volvo Cars, truck/bus OEMs for Volvo Technology and Scania, national road administrations for Swedish Transport Administration). At present, none of the project team members is in a business directly related to Big Data. There is, however, the possibility that as a result of this project work, one or more members of the team will realize there is a business which it can enter that is based on Big Data. Whether this is an implicit or explicit goal of participation is up to each of the members, but it is not the goal of this work package to identify business opportunities.

The objective of this work package is to identify how Big Data can reinforce the current business models, or perhaps lead to modifications in the current business models, that will result in better performance on the important indicators of success. In the case of the vehicle OEMs, success results in higher revenue and higher profit margins. In the case of Swedish Transport Administration, success results in fewer vehicle-related deaths and injuries, lower harmful emissions from vehicular transport and improved traffic flow.

2.4 Scope and delimitations

For the automotive industry Big Data Analytics can be used in a number of different areas. Computer Sciences Corporation has identified the following areas: Conceptual Design, Drawing Board, Procurement, Manufacturing, Marketing, Finance, Performance, Service and Aftermarket. Most of these areas are out of scope for BADA as the focus in BADA is business models for exchange and use of data and Big Data Analytics within road transport and traffic, i.e. when the car has left the factory. Our focus is therefore part of the three areas Performance, Service and aftermarket listed above.

Out of scope is also:

- Transportation on rail, on sea and in air
- The use of data in public transport
- The use of data for optimization of freight

Data from all kinds of sources can be of interest when optimizing road transport and traffic. All roles, actors and business models that currently are involved in businesses around this, are of interest in this study. This means that data from a broad spectrum of sources are of interest, e.g. vehicle sensors, mobile phones and networks, road side equipment, social media, etc.

Big Data can be used directly in real time in support safe, smooth and environmental friendly traffic, which is the focus in this report. Another way of using Big Data with the same goals is by analysing historical data to find trends, dependencies, optimizing

1 http://www.csc.com/big_data/insights
the infrastructure, etc. This second way of using Big Data with the same goals was covered in the pre-study and will be more covered in future project.

2.5 Outline of this report

The main focus of this report is to analyze the following issues for each category of actors in the ecosystem of connected vehicles:

- Role to be played
- Pre-conditions for participating in big data analytics
- Interaction with other participants
- Business model adaptations required to take advantage of big data analytics
- Probability of adapting the business model

Six definitive services were defined by the BADA Project team prior to the initiation of this report. Some of the services are general and some very detailed. Description of the services can be found in chapter 6.

In this report we describe the needed interactions between all of the actors in order to enable the implementation and operation of these services.

The result of the report is a set of consequences for BADA-partners and recommendations for further action.
3 Elaboration of the Goals

There are three goals which the BADA Project addresses:

- Less environmental impact e.g. reduce transport-related harmful emissions
- Increase road safety
- Improve traffic flow

3.1 Less environmental impact and reduced emissions

The Paris Agreement, adopted on 22 April 2016, shall enter into force on the 30th day after the date on which at least 55 Parties to the Convention accounting in total for at least an estimated 55% of the total global greenhouse gas emissions have deposited their instruments of ratification, acceptance, approval or accession with the Depositary. As of September 23rd, 60 of 197 have ratified the Paris Agreement, including Sweden, representing 47.76% of global GHG emissions.

In order to achieve the long-term temperature goal set out in Article 2 of the Paris Agreement, Parties aim to reach global peaking of greenhouse gas (GHG) emissions as soon as possible. It is recognized that peaking will take longer for developing countries. Following the peaking, Parties will undertake rapid reductions in accordance with best available science so as to achieve a balance between anthropogenic (i.e., caused or produced by humans) emissions by sources and removals by sinks of greenhouse gases. This should be accomplished in the second half of this century, and it should be done on the basis of equity and in the context of sustainable development and efforts to eradicate poverty.

3.1.1 Government

EU headline environmental target

- To reduce greenhouse gas emissions by 20 per cent compared with 1990 levels.
- To increase the share of renewable energy sources in final energy consumption to 20 per cent and try to increase energy efficiency by 20 per cent.
- Achieve the 20-20-20 energy and climate targets.

Sweden’s national targets

- Sweden has undertaken to reduce greenhouse gas emissions by 17 per cent by 2020, compared with 2005.
- Sweden’s national climate target is that its emissions should be 40 per cent lower in 2020 than emissions in 1990. This target applies to the activities not covered by the EU Emissions Trading System (EU-ETS).
- Sweden has also undertaken to increase the share of renewable energy to 49 per cent by 2020.
- The national target is set to at least 50 per cent of the total energy use by 2020. Riksdagen has also adopted a target on energy efficiency, expressed as a 20 per cent reduction in energy intensity by 2020, compared with 2008.
3.1.2 Vehicle manufacturers

Monitoring CO₂ emissions from passenger cars and vans


The regulation for passenger cars sets a CO₂ ‘specific emission’ (1) target of 130 g CO₂ /km by 2015 whilst the regulation for light commercial vehicles sets a CO₂ ‘specific emission’ target of 175 g CO₂ /km by 2017, defined as the average value for each manufacturer’s fleet of newly registered vehicles in the EU that year.

3.1.3 Vehicle owners

Cars

Development and deployment of clean and energy efficient vehicles have been regarded as one of the tools to lower the environmental impact of transport as well as to strengthen the European automotive industry striving towards increased innovativeness and global competitive advantage. To this end, in the 2010 Communication: *A European strategy on clean and energy efficient vehicles*, the European Commission outlined a strategy for encouraging the development and uptake of vehicles with low environmental impact.

Among over 40 concrete measures to be implemented by the Commission, the Communication contained a commitment to present a set of rules which should be taken into consideration while preparing financial schemes for incentivising the deployment of the clean and fuel efficient vehicles.

Trucks

Scania provides an example of a heavy vehicle OEM offering for fleet management. Scania has been offering telematics services since early 2000. Initially, the focus was on transport management and improving customer operations. With products such as Scania Order Support and Driver Log, it was possible to tailor make an efficient logistics operations. Approximately 5000 trucks were connected, but larger volume was difficult to achieve due to the need of tailoring for each specific customer need. In 2008, Scania shifted strategy and focused on telematics for everyone, offering basic, easy-to-use solutions, and the possibility to sell and support the offering by the local Scania salesforce.

3.1.4 General Requirements

Cost effective GHG sampling mechanism

For estimating CO₂ emissions from passenger vehicles today, empirical models are used to predict in-use fuel consumption of passenger cars based upon linear
combinations of key variables including the vehicle mass, engine capacity, rated power, and power to mass ratio.

- Develop a method for delivering actual CO₂ emissions from a moving vehicle.

**Verifiable on-the-road testing methods**

Current testing methods are based on fuel consumption per unit of distance driven for a specific engine and vehicle type.

- A method is required that delivers actual CO₂ emissions emitted during a driving cycle.

**Consistent, long-term regulations**

Consistent guidance that applies for the life cycle of new vehicles would mean that the data generated from any pre-programmed systems built into the vehicles would be usable during that life cycle. Unfortunately, many factors affect regulatory guidance, and one of those factors is the change of government and new priorities set by the political parties running the government.

- A method is required to modify the methods of delivering the CO₂ emissions data.

### 3.2 Increase road safety

Both society and individual drivers have a strong interest in improving safety on the roads to reduce the chances of accidents that result in injuries and deaths.

#### 3.2.1 Society

**International and EU**

Between 2001 and 2010, Europe cut the number of road deaths by 43% in spite of the increased traffic volumes. Europe reduced the number of road deaths by another 17% since 2010. With 51.5 road fatalities per one million inhabitants, Europe has the lowest fatality rate for any region in the world. This ratio amounts to 106 in the United States and to 174 globally.

*Figure 1: European Parliament with quite a number of empty seats*

The progress rate has lately clearly slowed down: change in fatality figures was close to zero from 2013 to 2014, and 2015 repeated the same pattern. The current slowdown means that efforts must be stepped up, especially at national level, if the
strategic target of approximately halving the number of road deaths by 2020, set by the European Parliament, is to be reached.²

**EU headline vehicular traffic fatalities reduction target**

The EU Parliament has defined quantitative targets to be met by 2020. These figures are to be established according to a uniform EU definition to be devised as soon as possible:

- A 60% drop in the number of children under 14 killed on the roads
- A 50% drop in deaths of pedestrians and cyclists
- A 40% drop in the number of people seriously injured

Furthermore, in its resolution on a sustainable future for transport (P7_TA(2010)0260), Parliament asked the Commission to present a brief study on the best practices in Member States concerning the impact of speed limiters and expressed its concerns over the safety of workers in the transport sector.

**Sweden**

Principles were added to Vision Zero: Traffic Safety by Sweden³ in order to ensure that motorists would comprehend the full extent of the movement’s purpose:

- Traffic deaths and injuries are preventable; therefore, none are acceptable.
- People will make mistakes; the transportation system should be designed so those mistakes aren’t fatal.
- Safety is the primary consideration in transportation decision-making.
- Traffic safety solutions must be addressed holistically.

**Sweden’s national targets**

The current interim target for road safety is to halve the number of fatalities between 2007 and 2020. That translates into a maximum of 220 road deaths in 2020. The number of seriously injured on the roads is to be reduced by a quarter. In addition to the current national target, there is an interim target at the EU level, for halving the number of road deaths between 2010 and 2020. This corresponds to a more stringent interim target of a maximum of 133 road deaths in 2020. No decision has yet been made to adjust the Swedish target to this level, and so the interim target of no more than 220 road deaths remains.

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² In September 2015, The European Parliament reiterated calls for a pan-European target to cut serious road injuries. In a vote on September 9th, on a review of European transport policy since 2011, MEPs called for, “the swift adoption of a 2020 target of a 40% reduction in the number of people seriously injured, accompanied by a fully fledged EU strategy.”

³ The Vision Zero Initiative is a platform for the collected knowledge about and technology around traffic safety in Sweden. Founded by the Swedish Government and Swedish Industry, it summarises the Swedish approach to traffic safety. The Vision Zero Initiative is administered by Business Sweden – The Swedish Trade and Invest Council, with offices in more than 60 countries. Our headquarters is located in Stockholm, Sweden.
3.2.2 Drivers

Peace of mind is the absence of mental stress or anxiety. One major cause of stress is driving on roads that are unfamiliar. The U.S. Department of Transportation has found that nearly 22% of large commercial vehicle crashes are due in part to this very issue. Recommendations for reducing stress in unfamiliar places include:

Research the Traffic Laws: Knowing the laws of your destination will help you anticipate the type of traffic you might encounter. The more you know about town features such as roundabouts, strange road signs, and more, the easier it will be to prepare for them.

- Provide a tool that informs drivers of traffic and parking regulations, interprets road signs and explains the rules of yielding at intersections and roundabouts.

Be Aware of Your Environment: Understanding your surroundings will make it easier to anticipate the types of situations you might encounter. For example, if you are in the countryside, you may encounter a cow in the middle of the road. Or if you are in a big city, you probably should watch out for bikers. It is also a good idea to look at the local weather report before leaving home.

- Provide a tool that informs drivers of special conditions that may be expected and the most likely times of day that these conditions will be experienced.

Watch Out for Landmarks: Build confidence with the unfamiliar place you are traveling to by looking for prominent landmarks. This will make it easier for you to pinpoint your location and recognize important destinations in case you get lost.

- Provide a tool that identifies major visible landmarks and reference these landmarks to the principle routes to negotiate through or around built-up areas.

Drive Cautiously: Reduce your speeds and be careful on unfamiliar roadways. Driving slower will give you more time to respond to unexpected obstacles, especially at night.

- Provide a tool that displays recommended speeds by time of day, day of week and season.

3.3 Improve traffic flow

Improving traffic flow provides direct benefits to society and to drivers, both private and commercial. Congestion costs money in time and fuel wasted. Congestion also causes irritation and stress that can result in dangerous driving and accidents.

3.3.1 Society

International and EU

The aim of the European Union’s land transport policy is to promote mobility that is efficient, safe, secure and environmentally friendly. The EU’s policy objectives for road transport are therefore to promote efficient road freight and passenger
transport services, to create fair conditions for competition, to promote and harmonise safer and more environmentally friendly technical standards, to ensure a degree of fiscal and social harmonisation, and to guarantee that road transport rules are applied effectively and without discrimination.

The potential of intelligent transport systems (ITS) can only be achieved if their deployment in Europe evolves from the limited and fragmented scenario of today into an EU-wide one. Trans-national deployment of continuous cross-border services for travel information and traffic management cannot be done by Member States if they work independently from each other.

Coordinated action at EU level will have a greater effect (e.g. common rules on liability) leading to large-scale economies that can push the markets.

Intelligent transport systems can contribute to the main transport policy objectives. The links between modes, e.g. public transport, become increasingly important.

**Sweden**

Trafikverket, The Swedish Transport Administration, is responsible for long-term planning of the transport system for all types of traffic, as well as for building, operating and maintaining public roads and railways. Trafikverket’s vision statement expresses the desired long-term direction: "Everybody arrives smoothly, the green and safe way."

In a report prepared by TomTom in 2013, as Stockholm was preparing to introduce congestion charging, it was estimated that during peak periods, drivers in the Stockholm region are delayed by 48 minutes per every hour of travel. This means that a person with a 30-minute commute who travels during the peak period will spend over 100 hours during the year idling in traffic. This results in a substantial cost to society.

### 3.3.2 Drivers

Improving traffic flow provides direct benefits to society and to drivers, both private and commercial. Congestion costs money in time and fuel wasted. Congestion also causes irritation and stress that can result in dangerous driving and accidents.
4 Issues, Problems and Opportunities for Future Mobility

4.1 Introduction

What happens when the vehicle turns into a source of data, rather than as a medium for delivering services? A model for this is shown below. One outcome is that the customer can convert his or her vehicle’s data into currency by delivering useful data to service providers via the OEM and receiving payment in the form of services in return. Examples of a data users include the traffic authority for providing up-to-date information to motorists as a public service, OEMs for gaining a better understanding of how their vehicles perform in all types of situation, and companies that process all types of data in order to deliver commercial services.

Figure 2: The Connected Car Money Flow adding data flow from the vehicle (Source M.L. Sena Consulting AB)

Vehicle OEMs have multiple reasons for using data in addition to achieving environmental and safety objectives. These include increasing differentiation compared to competitors, lowering costs, reducing costs of ownership for their customers, gaining competitive advantage or reducing company risk.

The questions listed below originate from a workshop with the BADA Project Team. They were considered as important topics to be addressed. Most of the questions are therefore handled later in this report in one way or another.

4.2 General questions

The following issues have been investigated as part of the BADA Business Models State-of-the-Art Report.
• What can be learned from other areas?
• Is it possible to reach the objectives in the context of the transport system or will we require much more cooperation with other industries?
• Can we draw parallels with other industries?
• Are there location dependencies. What scenarios relevant in urban areas, suburban areas or rural areas?

4.3 Actors and Roles in the future ecosystem

The following issues are addressed in Section 5 of this report as well as in the description of services in Section 6.

• Which actors must work together to be able to manage traffic with a better traffic flow than today?
• Which actors may dominate the business of traffic and transport data in the future? Which particular companies are in the front line to be able to assume a dominant business position in the future?
• What will the global market for traffic, transport and vehicle data look like in the future? Will there be a few large actors or many small actors?
• Will one company be dominant and be the owner of data and become the de facto service provider for services based on processed and analysed data?
• What will be the roles of Service Providers vs OEMs vs Authorities when processing and analysing data.
• What will the value chains look like?
• What use cases are relevant in different future scenarios, and how do they affect different business models.
  o What are the key factors for defining scenarios?
  o What are the relevant business models?
  o How can innovation in SME be supported in these business models?
• What traffic should be managed: cars, trucks, buses, bikes, cable cars, pedestrians?
• For whom are we improving mobility?

4.4 Factors driving the future in a desired direction

These issues are addressed in the service descriptions in Section 6 and in Section 7.

• How should incentive models be created so that they support the three main objectives of this study while at the same time being attractive for large commercial actors?
• What transaction costs exist in the ecosystem, and how do these affect the business models.

4.5 Technical configuration of data chains

These issues are addressed in the BADA Business Models State-of-the-Art Report.

• On-board vs Off-board solutions. To what extent do technical solutions, such as whether systems are on-board or off-board, affect business models? What are the driving factors for systems being on-board or off-board?
• Will road sensors be obsolete in the future when vehicles produce large amounts of data in a less expensive way?
4.6 Value of Data

Each of the service descriptions in Section 6 address the issue of paying for data, including whether it is likely that actors will pay for particular types of data and what the data would potentially be worth.

- What are the advantages and disadvantages of free exchange of data versus paying for data?
- Will it be possible to charge for data in the future and who will be willing to pay?
- How should the value of data be established?
- What are the options for how data is paid for?
- Who pays what to whom for data?

4.7 Data Exchange

Section 5 addresses this issue in the descriptions of each of the members of the ecosystem.

- What are the barriers and limitations for successful exchange and use of big data?
- Which actors will establish rules and exchange formats and determine which networks of platforms and ecosystems are used?
- What kinds of motivation are required to convince an actor to operate an integration hub?

4.8 Big Data Analytics

There is a sub-section of Section 5 that is specifically devoted to Big Data Analytics.

- When a service requires Big Data Analytics, where will the analytics be done: locally, centrally, distributed or a combination of two or all three?
- How will big data analysis be paid for?

4.9 Legal aspects

As part of each of the service descriptions in Section 6 there is an analysis of legal aspects. There is also a specific section, Section 8, that is devoted to legal questions.

- What permissions are needed?
- What are the implications of the Delegated Act regarding the provision of safety-related data?
- What are the effects of legal requirements and regulations, and have they been clearly identified?

4.10 Cybersecurity

Data security for vehicles must cover all of the following conditions:

- Protection of the vehicle’s systems to perform in a safe manner by ensuring that no unauthorized messages are received from roadside units or telematics service providers. All data received by the vehicle must be sent from an authorized source in an authorized format for an authorized application.
- Protection of the owner’s, driver’s or passengers’ data privacy. All data sent from the vehicle must be protected from redirection to an authorized receiver, and all
data stored on the vehicle must be protected from access and theft by unauthorized parties.

- Protection of the systems of other vehicles to which the vehicle communicates (V2V).
- Protection of the data integrity of off-board systems to which the vehicle communicates (V2I).
- Data exchanged between public applications (e.g., social media services, e-mail, web search), with one of the access points being in the vehicle, must be physically separated from all vehicle systems.
5 Ecosystem, Actors and Roles

5.1 Introduction

A complex ecosystem starts to become visible when the services described above are combined. This chapter describes the likely future ecosystem that will evolve along with the different roles each of the actors will play and how they will interact with each other.

5.2 Overview (From BADA Integration Platform_V3)

BIG AUTOMOTIVE DATA ANALYTICS will involve a large number of participants in an extensive global ecosystem. Higher data transfer speeds and lower latency rates will be enabled by 5G, the next generation of telecommunications, compared to the current 3G and 4G technologies. 5G coupled with ITS-G5 (802.11p/WAVE/DSRC/Wi-Fi), means that many more sources of data—and applications that can use this data—will be available for use compared with the data that can be processed with today’s wireless technologies. The diagram below prepared by the BADA Project Team shows the various data sources that will feed into integration platforms for further processing by big data analytics applications. Artificial Intelligence (AI), known also as expert systems and neural networks, will have an increasingly larger role in processing all of this data on Big Data Analytics platforms and attempting to convert it to useful information for improving traffic flow, improving safety on the roads and reducing harmful emissions.

![Diagram of BADA Integration and Analytics Platform](image)

Figure 3: Roles and data flow in the future BADA Ecosystem

The diagram above shows how data flows through the different processes. Multiple sources are integrated and passed to the Big Data Analytic processors where the data are readied for delivery as traffic information and automation services. Vehicles,
drivers, operators and authorities receive the results and begin the process anew by feeding data back to the various sources.

5.3 Data Sources

5.3.1 Vehicle data

One of the largest new sources of road data will be the vehicles. According to a 2015 study from automotive technology research firm SBD, by 2020 there will be some 33 million vehicles sold annually with built-in connectivity, generating more than 163 million terabytes (1.63 petabytes or \(1.63 \times 10^{15}\)) of data each year via their on-board cameras and sensors (gyroscopes, accelerometers, lasers, ultrasonic sound systems, ambient light systems, radar, LiDAR, GPS, ). Google claims that its self-driving cars process 750 Mbytes of live data per second to allow the cars to drive themselves. Some of this data could be useful to other cars in order to allow them all to drive more safely and efficiently.

5.3.1.1 Vehicle Manufacturers

**Role to be played:** Deliver to the Data Integration Platform data obtained from the vehicle which relate to the vehicle’s operation and the conditions sensed by the vehicle within an area surrounding the vehicle. This data should contain no references to the identity of the vehicle or owner of the vehicle, and contain no information that could be used to judge either the performance of the specific vehicle or the actions of the driver—whether the driver is human or a robot.

**Actors:** Audi, BMW and Mercedes-Benz are already sending sensor data from their vehicles to their TSPs and then to HERE for integration and Big Data processing. Tesla is collecting data in real time from all of the vehicles it has sold in order to identify anomalies and provide over-the-air updates to affected vehicles. All passenger vehicle OEMs are potential actors. Volvo, Scania and Daimler-Benz are among the truck manufacturers that have been the most active in connecting their vehicles.

**Pre-conditions:** Regulations must allow for the use of a vehicle’s operational data. The question is whether the processing of such data requires the specific authorization of the owner and/or the driver of the vehicle. While this may be possible with a first owner, it may be very difficult with second or following owner, especially if the vehicle is sold directly by the owner. Regulations must be designed to both protect individual privacy and promote the public interest by allowing sensor data to be collected from vehicles.

**Interaction with other participants:** Each OEM will have its own wireless interface built into the vehicles it manufactures and sells, and this interface will pass through the OEM’s designated telematics service provider (TSP). Nevertheless, the format of the data sent from the vehicle must be agreed with other vehicle manufacturers and

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4 A Petabyte could hold about 3.6 billion 300 Kilobyte images or maybe about 300,000 hours of good quality video. A Petabyte could hold 1 million copies of the Encyclopedia Britannica. \(1/100^{th}\) of a Petabyte could hold the printed collection of the Library of Congress.
with the Integration Platform operators in order for the process to be quick, efficient and with a minimum risk of error. This is most clearly shown with two examples:

- SENSORIS - Initiated by HERE in June 2015 when the company published the first open specification for how vehicle sensor data gathered by connected cars could be sent to the cloud for processing and analysis. Currently, vehicle sensor data exists in multiple different formats across automakers.

- Extended Vehicle\(^5\) - An extended vehicle is understood as a physical road vehicle with external software and hardware extensions for some of its features. These extensions are developed, implemented and managed by the vehicle manufacturer. The vehicle manufacturer is fully responsible for the communication among the various parts of the extended vehicle, especially between the internal and external software and hardware components.

In addition, there must also be co-operation between the vehicle manufacturers and the other data providers to ensure that if there are overlaps in the data types they are reported consistently so the Integration Platform can effectively use the multiple sources.

**Business model adaptations required:** There are precedents for vehicle manufacturers or fleet operators offering their cars or trucks as traffic probes and delivering time-stamped speed data. In some cases, the manufacturers or operators are paid for the data, while in others, their drivers receive processed traffic information in return for delivering data. With Big Data, there will be much more than simply time-stamped speed data, and the result will not necessarily be usable by an individual driver at a specific time and place. Vehicle manufacturers will need to develop more complex cost-benefit analysis calculations to justify the cost of delivering and administering data provision.

**Probability of adapting:** Many of the vehicle manufacturers, including Volvo Cars, Volvo Trucks and Scania, are actively involved in testing autonomous driving systems and intelligent processing of massive amounts of data, and the delivery of real-time information to their vehicles will be essential for safe driving. The probability is very high that the vehicle manufacturers will actively engage in developing the capabilities of Big Data processing.

### 5.3.1.2 Fleet Operators

**Role to be played:** At present, fleet operators collect data from their vehicles, and both the data format and the methods to retrieve it vary greatly according to the vehicle manufacturer, fleet management system used and data applications. For Big Data applications, data would be deliver to the Data Integration Platform, either directly using an agreed standard, such as SENSORIS, or via the TSP. This data should contain no references to the identity of the vehicle or owner of the vehicle, and

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\(^5\) The Extended Vehicle (ExVe) – New Standardization Project ISO 20078
contain no information that could be used to judge either the performance of the specific vehicle or the actions of the driver—whether the driver is human or a robot.

**Actors:** Fleet operators of all sizes from the largest, such as DHL, to the smallest single-vehicle owner, are included. Fleet management software and hardware developers are also part of this group within the ecosystem.

**Pre-conditions:** Regulations must allow for the use of a vehicle’s operational data. The question is whether the processing of such data requires the specific authorization of the owner and/or the driver of the vehicle. While this may be possible with a first owner, it may be very difficult with second or following owner, especially if the vehicle is sold directly by the owner. Regulations must be designed to both protect individual privacy and promote the public interest by allowing sensor data to be collected from vehicles.

**Interaction with other participants:** The format of the data sent from the vehicle must be agreed with other vehicle manufacturers and with the Integration Platform operators. There must also be cooperation between the vehicle manufacturers and the other data providers to ensure that if there are overlaps in the data types they are reported consistently so the Integration Platform can effectively use the multiple sources. Today, the Fleet Management System Interface (FMS) is used to transfer a set of pre-defined data elements from commercial vehicles. The standard was defined by the principal European commercial vehicle manufacturers in 2002 and is used to make possible manufacturer-independent applications for telematics. rFMS is a HTTP- and REST-based API for retrieval of vehicle data from a specific customer’s fleet of trucks or buses.

**Business model adaptations required:** Fleet operators routinely offer time-stamped speed data from their vehicles to traffic data aggregators. In most cases, the fleet operators are paid for the data, while in others, their drivers receive processed traffic information in return for delivering data. With Big Data, there will be much more than simply time-stamped speed data, and the result will not necessarily be usable by an individual driver at a specific time and place. Fleet operators will need to develop more complex cost-benefit analysis calculations to justify the cost of delivering and administering data provision.

**Probability of adapting:** Very high since both the fleet operators and their customers will benefit from much more reliable information.

### 5.3.2 Infrastructure data from road owners

Smart infrastructure, including sensor devices in and along the roads as well as transmitters for delivering data to vehicles, will be a critical source of transport data. Smart infrastructure responds intelligently to changes in the surrounding environment, including user demands and other infrastructure, to achieve an improved performance (*Smart infrastructure: the future. The Royal Academy of Engineering. 2012*). Smart Infrastructure uses feedback loops of data that provide evidence for informed decision-making, both by humans and by automated systems.
In addition to the dynamic data, national, regional and local information on planned projects involving roadways and their surroundings that will have an effect on traffic flow can be fed into the Integration Platform.

5.3.2.1 Public Road Organisations

**Role to be played:** Data collected by the road organisations from its various types of road sensors will be delivered to the integration platform. In addition to the dynamic data, national, regional and local information on planned projects involving roadways and their surroundings that will have an effect on traffic flow can be fed into the Integration Platform.

**Actors:** Trafikverket, other public road operators in Europe.

**Pre-conditions:** The regulatory structure is in place to allow data collected by the road organisations to use this data for management and planning purposes.

**Interaction with other participants:** The format of the data sent to the Integration Platform must be agreed with the Integration Platform provider and with other data sources.

**Business model adaptations required:** Today, infrastructure data that is provided to commercial entities or to governmental agencies is done so with commercial agreements. These agreements cover the eventual use and resale of the data. There should not be any need to change the current business model to adapt to Big Data-based applications.

**Probability of adapting:** High.

5.3.2.2 Private road operators

**Role to be played:** Data collected by the road organisations from its various types of road sensors will be delivered to the integration platform. In addition to the dynamic data, national, regional and local information on planned projects involving roadways and their surroundings that will have an effect on traffic flow can be fed into the Integration Platform.

**Actors:** Autoroutes Paris-Rhin, Rhone, Autoroutes et tunnels du Mont-Blanc, Autostrade per l’Italia, Concessioni Autostradali Venete and other private operators in Europe.

**Pre-conditions:** The regulatory structure is in place to allow data collected by the road organisations to use this data for management and planning purposes.

**Interaction with other participants:** The format of the data sent to the Integration Platform must be agreed with the Integration Platform provider and with other data sources.

**Business model adaptations required:** Today, data on road usage that is provided to commercial entities or to governmental agencies is done so with commercial agreements.
agreements. These agreements cover the eventual use and resale of the data. There should not be any need to change the current business model to adapt to Big Data-based applications.

**Probability of adapting:** High.

### 5.3.3 Map data

The collection of digital map data moved from digitizing the centerlines of paper topographic maps in the 1980s to collecting data visually using 360° camera vehicles and post-processing the images in the 2000s.

*Figure 4: Navteq data collection vehicle*

The NAVTEQ vehicle illustrated to the right from 2009, which was prior to the name change in 2011 to HERE, is fitted with cameras, assisted GPS equipment and other sensors. Map data collection is now moving to the next phase. According to HERE, today, the data generated from sensors on board modern vehicles can be used for both map updates and for dynamic traffic messages (e.g., to warn others of possible dangers, including icy roads or a spill, sudden braking or traffic build up, an accident, or an animal or object on the road, provide warnings of poor road infrastructure like potholes as well as construction). Dynamic map updates are essential for advanced driver assistance systems, in which accurate, up-to-date road data is critical for safe and effective operation of the ADAS applications.

#### 5.3.3.1 Commercial map data suppliers

**Role to be played:** There are multiple map data suppliers today, and they are delivering different types of data compared to the digital map data supplied by the former duopoly, HERE (NAVTEQ) and TOMTOM (TELE ATLAS). HERE and TOMTOM are still the primary suppliers of digital map data for navigation and route guidance, as well as for ADAS systems, but they have been joined by Google Maps, WAZE (wholly-owned by Google but operating separately), AND and possibly even APPLE. A number of hardware suppliers, such as NVIDIA, CONTINENTAL and VELODYNE, are developing methods to collect and process images seen by vehicles using high-resolution flash LiDAR, and using deep learning techniques with on-board super computers, continually teach the automated driving system to react in an appropriate way in every driving situation.

**Actors:** HERE and TOMTOM have evolved from analogue-to-digital map producers to heavy users of sensor-equipped vehicles to collect all types of data about roads and their surroundings. AND is similar to HERE and TOMTOM, but operates on a much smaller scale and in areas that are not covered in detail by HERE and TOMTOM. Google and APPLE are doing much the same, but unlike HERE and TOMTOM, they do not license their data but provide an end-user route guidance application for in-vehicle use.
NVIDIA, CONTINENTAL and VELODYNE are new entries to the map producer group. They have entered this arena for the same reasons Navteq and Tele Atlas became navigation map producers thirty years ago: there was nothing on the market that satisfied the map data requirements of the navigation systems that were being built at the time. Some driverless vehicles need a different type of map to supplement the navigation maps that guide the robot-driven vehicles to the destination that is desired by the human being in the vehicle—or to the destination that has been programmed for the vehicle to either pick up a human being or to deliver something to him or her. These new types of maps include 3D images of everything in the vicinity of the road that need to be continuously updated with new information. This is a massive big data analytics task that is being attacked with massive computer processing power, both on board in the case of NVIDIA, and off board in the case of CONTINENTAL.

WAZE is a commercial version of Open Street Maps (see next section). It started life in 2006 as an Israeli company (originally called FreeMap Israel) but was acquired by Google in 2013 for $1.2 billion. (An interesting note is that all 100 employees of WAZE received a bonus of $1.2 million when the purchase was consummated.) As part of providing free routing and traffic services (and in their own words, “all kinds of cool social and geo-gaming elements that actually make commuting fun”), users agree to keep their smartphones connected to the WAZE platform. According to the WAZE description of its services, the data that is sent from the application allows WAZE to ‘calculate average speed, check for errors, improve road layout and learn road and turn direction.’ In other words, in addition to providing traffic information it is crowdsourcing updates to its map data. Note that users are paying for the data transfer in both directions through their mobile phone subscription, and WAZE warns that the cost of this data transfer can be substantial. Since it was acquired by Google, the base map geometry data and street names should be the same as in Google Maps, but, if it is, it is very much simplified.

**Pre-conditions:** There are two types of pre-conditions: commercial and technical. On the commercial side, for companies that are in the business of providing map data, such as HERE and TOMTOM, and for traffic information suppliers like INRIX and MEDIAMOBILE, they will require support for delivering their data for Big Data integration from customers who would agree to use and pay for the eventual use of the processed data in their applications. Companies like Google will require some type of financial incentive or market advantage. System suppliers like Continental, NVIDIA and VELODYNE appear to be focusing on processing the data on-board and will need to be convinced of the advantages of up-loading the data for integrated processing. On the technical side, there will need to be agreed data formats, either using pre-existing standards from groups such as OGC (Open Geospatial Consortium), or new standards (e.g. SENSORIS).

**Interaction with other participants:** It is highly unlikely that HERE and TOMTOM will agree to mix their data in a single integration platform. It is even more unlikely that Google will agree to a merging of its data with other data suppliers since it does not even license its data for use on external servers. What is most likely is that there are
multiple integration platforms that feed their respective datasets to Big Data Analytics platforms operated by third parties or themselves.

**Business model adaptations required**: The best map data comes from organisations that are in the business of delivering map data, not from organisations that are in a completely different business and use map data to support that other business. Google is in the advertising brokering business and map data is an enabler of geographic searches for places that pay money to Google. Companies pay Google to reference its map data, but it these fees are a pittance compared to its income from advertisers. HERE and TomTom are in the map data business, and if they do not produce data that it can sell at a price acceptable to its customers, they are out of business.

**Probability of adapting**: Companies will not want to be left out of the Big Data Analytics process, and most of them will not be able to match the quality of the processed data if they attempt to do the entire process on their own.

### 5.3.3.2 Public map data suppliers

**Role to be played**: Public map data suppliers will provide supplementary data to that obtained from private and open source map data providers to be used as a base for various types of applications.

**Actors**: Public map data suppliers include the national land surveys, municipal governments, transport planning and management agencies and other authorities that use road data and associated attributes to fulfil their operational requirements.

**Pre-conditions**: The principal pre-condition is that the data collected by the public source can be used for private purposes, with or without a fee for usage. Another pre-condition is that the data can be delivered to the data integrators in a format that is usable or one that can be converted to a usable format.

**Interaction with other participants**: Since the data collected by the public agencies is principally used by the agencies in their own internal applications, there would not be major interactions with other participants outside of the current areas of interaction, although a dialogue with other actors is necessary to be able to support private actors when appropriate.

**Business model adaptations required**: Public agencies have delivered their data to navigation and fleet management application developers and data integrators for many years, and they have adapted their processes to the business models that apply to the industry. There should be little or no adaption of current models for Big Data applications.

**Probability of adapting**: Very high.

### 5.3.3.3 Open source map data suppliers

**Role to be played**: Deliver free map data with no license or usage fees.
**Actors:** OpenStreetMap Foundation (OSMF)

**Pre-conditions:** OpenStreetMap is open data: users are free to use it for any purpose as long as they credit OpenStreetMap and its contributors. If a user alters or builds upon the data in certain ways, the user may distribute the result only under the same licence. (See the Copyright and License page for details.) Use of all OSMF operated services is subject to OSMF’s Acceptable Use Policies and its Privacy Policy.

**Interaction with other participants:** OpenStreetMap Foundation describes itself as follows: “OpenStreetMap’s community is diverse, passionate, and growing every day. Our contributors include enthusiast mappers, GIS professionals, engineers running the OSM servers, humanitarians mapping disaster-affected areas, and many more. To learn more about the community, see the user diaries, community blogs, and the OSM Foundation website.”

**Business model adaptations required:** None.

**Probability of adapting:** No adaptation is required since the use of OSM is regulated by the terms and conditions.

### 5.3.4 Other data sources

Mobile phone probe data has been a very important source of street flow data for traffic information suppliers for the past decade because most vehicles were not connected. Mobile network operators, such as Vodafone, provide anonymized data from mobile phone users that are georeferenced to a street network. Time stamps on the signals make it possible to calculate the speed of travel. Algorithms for filtering the data from mobile phones that are not moving in cars have improved, and the data has provided a relatively reliable surrogate source for data from the actual vehicles. This source for traffic flow is becoming less important because smartphones are delivering positions directly, as described below, and more vehicles are becoming connected. In the near future, new sources of data, such as unmanned aerial vehicles, will monitor traffic flow for entire regions in a much more comprehensive way.

![Figure 5: Google crowd-sourced data on traffic flow](image)

As the smartphone application Waze has shown, crowd-sourced data is proving to be an excellent means to obtain real-time information on traffic disruptions, and Open Street Map has, to a much more limited extent, verified that street map data can be collected from independent individual sources.⁶ Probably the best crowd-sourced traffic data comes from the Google Maps application. Without most of the

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⁶ The majority of Open Street Map data has been collected from public data sources, not from traces delivered by private individuals. Public authorities and some private data suppliers (e.g. AND
users of the map display and route planning application even realizing it, they are
delivering their location data with a timestamp to Google’s server. The application
uploads this georeferenced data at regular intervals to the server, and Google
processes it into traffic flow map data.

Figure 6: Google traffic map showing actual speeds.

Google goes one step further and
geocodes the vehicles on its Google
Earth images for LIVE traffic flow.
Clicking on a dot on the map, the
application returns actual speed of
travel! Although many users of
Google Earth believe they are looking at real-time aerial photo images, most of the
imagery is between one and three years old. Collecting real-time aerial imagery has
been an expensive endeavor—until recently. Unmanned aerial vehicles, also known
as ‘drones’, are changing the economic equation.

5.3.4.1 Mobile Application Developers

Role to be played: Mobile phone applications will feed a combination of key words
and phrases (e.g., congestion, jam, stuck in traffic) and location to the application
servers. This data will be parsed by the application servers and sent to the integration
platforms.

Actors: Waze (owned by Google), CoPilot (Trimble), Navigon (Garmin)

Pre-conditions: Application users will need to authorize the use of their data, and
there will need to be some benefit to the application developers for delivering the
data. Today, Waze makes it a condition of receiving traffic information and route
guidance that the user shares his or her data with Waze at no cost to Waze.

Interaction with other participants: There will need to be a geospatial database upon
which to reference locations, and there will have to be an agreed location referencing
system that is used to place any time of location on this map for visual or analysis
purposes.

Business model adaptations required: The business model used for most mobile apps
is either a download fee or a share of advertising revenue paid by ad brokers like
Google and Microsoft. If the application included traffic warnings as an add-on for
those users who agreed to deliver their data it would enhance the value of the
application for the user and make it more attractive as an advertising channel.

Probability of adapting: Since it a relatively easy adaptation to make, and the benefits
seem to outweigh any processing costs, the probability is high that mobile app
developers would adapt to the big data model.
5.3.4.2 Unmanned Aircraft Systems (UAS)

According to the International Civil Aviation Organization, an Unmanned Aircraft System (UAS) is “an aircraft and its associated elements which are operated with no pilot on board.” The United States Federal Aviation Administration (FAA) defines an Unmanned Aircraft Vehicle (UAV) as a “powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload.” A UAV is the aircraft in the definition of a UAS. The official FAA definition of a Drone is that it is a UAV with the addition of autopilot artificial intelligence allowing it to be pre-programmed.

Figure 7: U.S. FAA depiction of Unmanned Aircraft Systems (UAS)

Role to be played: Unmanned Aircraft Systems comprise an ecosystem that includes multiple technologies, application developers and service providers. UASs will deliver different types of data to supplement the data collected from all the various land transport actors.

Actors: The U.S. National Aeronautics and Space Administration (NASA) along with Google, Amazon and a number of other companies that have been active in UAS developments, are working together to create a standardized approach to data collection and processing using unmanned aerial systems. The illustration shows how different types of UAVs could be used to monitor road and rail transport management while sharing the air with safety, logistics and agricultural applications. Research on this topic began in earnest in the second half of the 2000s. Methods have been proposed for transmitting and analyzing traffic data acquired from UAVs, and research has focused on the type of data that should be collected and the information that should be extracted to design appropriate traffic simulation models. A major advantage of UAVs is their ability to hover at just the right altitude to deliver both wide coverage and high resolution, and to do this in real time.

Pre-conditions: Regulations for using UAVs vary from region to region. Only private hobby uses are officially allowed in the U.S. Commercial regulations have finally been drafted by the Federal Aviation Administration, but they are not yet approved. They are being reviewed and tested before a final regulation is submitted to the legislature for enacting into law. In other regions of the world, including Europe, guidelines have been prepared in some countries, but there is no consistent set of policies for cross-border usage. Issues of privacy, safety and protection of both physical and intellectual

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property rights are still in the formative stage of clarification. Standard data formats will be essential. Sweden has determined that UAVs equipped with video cameras infringe on the privacy of individuals and have therefore placed a ban on their use.

**Interaction with other participants:** Data will need to be georeferenced, so there will have to be interaction with spatial data providers.

**Business model adaptations required:** This is a new business area and business strategies are evolving quickly. A single UAV can have multiple uses, from taking photos for an insurance company of a roof that has been damaged in a storm to spraying insecticide on an apple orchard. The devices are relatively inexpensive, compared to manned aerial vehicles and satellites, so it is possible to start a business with a small amount of capital. This means there can be many small companies offering services using different business models, such as pay-per-use, short- or long-term rental, pay for services delivered. At the same time, large companies, especially Google and Amazon, have shown a strong interest in both developing the UAVs and applying them to multiple applications.

**Probability of adapting:** The market for unmanned aerial systems of all types is in the very early stages of development.

### 5.4 Integration

It is on the Integration Platform where all of the various data sources, dynamic and static, are merged into a single geospatial database. There are a number of geospatial integration platforms in operation today. **HERE, TomTom, Google and many other companies** collect data from multiple sources and combine them for performing spatial search functions, for delivering route guidance services, traffic information and aiding advanced driver assistance systems. A public sector example of a spatial data integration platform is the **U.S. Federal Geospatial Platform (FGP)**, an initiative of the Federal Committee on Geomatics and Earth Observations (FCGEO). This committee comprises senior executives from twenty-one departments and agencies in the U.S. government that are producers and/or consumers of geospatial data, or have an interest in activities, requirements and infrastructure related to geomatics. The FCGEO community recognized an opportunity for federal departments and agencies to manage geospatial information assets in a more efficient and coordinated way by using a common “platform” of technical infrastructure, policies, standards and governance. The FGP is a ‘collaborative online environment consisting of authoritative geospatial data, services, and applications, built on a shared infrastructure that will enable the government’s most relevant information to be managed spatially, analyzed, and displayed in a visual context to enhance decision-making support of government priorities’.

#### 5.4.1 Platform operators.

##### 5.4.1.1 Spatial data

**Role to be played:** Processing of data delivered from multiple sources, including,
among others, sensors on board vehicles and integrated into the infrastructure, from mobile devices, from the telecommunications network and from unmanned aerial vehicles.

**Actors:** Here, TomTom, Google, Zenrin, Toyota Mapmaster

**Pre-conditions:** As more vehicles become connected, a vast ocean of sensor data will be generated. This data has the ability to transform journey routing and driver safety but only if relevant information can be aggregated and shared. Making the huge volume of data manageable enough to be ingested easily into the cloud and then fed quickly to all relevant vehicles on a wide range demands industry collaboration. Although the diagram below shows data passing directly from vehicles to the HERE Locations Cloud, currently, the OEMs delivering data to HERE (BMW, Audi and Daimler) collect the data at their individual TSPs and then pass it to the HERE Location Cloud.

![Image](image.png)

**Figure 8: SENSORIS proposed standard for Sensor Ingestion Interface Specification**

The HERE Open Location Platform applies data fusion and crowdsourcing for the extremely challenging task of deriving useful information from a huge volume of vehicle sensor data. The platform ensures the robustness of data it sources to enable a car to effectively 'see around the corner' and avoid an accident. Achieving the highest possible confidence level requires continuous near real-time processing of large streams of very diverse data which are then fused with map, traffic, incident, weather and other data. For information to become actionable and made known to other vehicles on the road, it would typically have to evolve through multiple layers of information extraction hierarchy. Here has already implemented a next generation engine for real-time traffic and in doing so has gained significant expertise to apply similar technology for road events relevant to highly automated driving. To achieve this, HERE has published SENSORIS, a sensor interface specification to define consistent parameters for data gathered by vehicles on the road. The result should be fewer accidents and more efficient journeys, as well as moving the industry closer to its aspiration for cars that can fully understand their environment and drive themselves.

**TomTom’s Real-Time Maps** is an example of how a geospatial integration platform can
work. TomTom calls it a transactional-based mapmaking platform. It serves as the data processing resource for TomTom’s staff to enter new geographies and update features and attributes. It also allows crowd-sourced data to enter from TomTom’s navigation devices, mobile phone probes and end-user direct input with mobile apps provided by TomTom.

The map suppliers already delivering data to the vehicle industry would seem to have the largest incentive for operating an integration platform that would feed a Big Data Analytics component. The problem with mixing their data with competitors’ or even partners’ data one of economics. Today, every data supplier licenses and is paid for the data it delivers. Mixing the data and taking it one further step away from the eventual users of the data by adding the Big Data Analytics component can create a difficult challenge for all parties, especially if the BDA component is operated by another, independent party that has the aim of being the end supplier to the service providers.

Interaction with other participants: HERE has initiated discussions with car manufacturers to outfit some of their cars with the full range of sensors used in HERE’s own data collection vehicles. TomTom collects data from the vehicle manufacturers that have installed its software in their vehicles.

Business model adaptations required: The car manufacturers would obtain financial rebates for map data, and have access to the latest research and test results for HERE’s High Definition maps that can be used in autonomous driving. TomTom has similar agreements.

Probability of adapting: The companies thus far who have signed up to participate in SENSORIS are: Aisin Aw, Continental, Daimler, Elektrobit, Harman, HERE, LG Electronics, NavInfo Co. Ltd, Nng, Pioneer Europe, Qualcomm, TomTom and ZENRIN. Daimler is the only vehicle manufacturer, but both Audi and BMW are owners of HERE along with Daimler, so it is assumed that they are also participating. Nevertheless, this effort will need to gain support from other European vehicle manufacturers as well as from the U.S. and Asian vehicle industry.

5.4.1.2 ADASIS Hardware Providers

Role to be played: Processing of data delivered from multiple sources, including, among others, sensors on board vehicles and integrated into the infrastructure, from mobile devices, from the telecommunications network and from unmanned aerial vehicles. In November, 2015, Continental presented its first set of driving test results for the connected, dynamic electronic horizon (eHorizon). It stated: “For vehicles it is becoming increasingly important to know what lies ahead, and today’s traffic reports and digital road maps are no longer enough. What is needed is much more precise information about road characteristics such as gradients, curve radii, temporary speed limits and other traffic signs, lane changes due to construction work, and other important information.”
Continental states further: “Road Database supplies vehicles with highly accurate route information by compiling data from different vehicle sensors in a machine-readable image of the road, which, in addition to conventional information, also contains data on variable speed limits, mobile roadworks etc. Road Database uses the sensors already found in modern vehicles, such as cameras, radar, and increasingly lidar, which continuously record a vast amount of the information required. The route data obtained in this way is first checked by the on-board computer for plausibility and compared with information about the route already saved on board. The result of this analysis is a vector-based image of the road and its attributes, which is anonymously transmitted to the backend operated by Continental. The data volumes that are generated are comparatively small. The data from all Road Database vehicles are consolidated and refined in the cloud. As part of this process, all the information, whether road geometry or "street furniture" (road signs, traffic lights, etc.), is assigned to a reliability index. If several vehicles confirm modified lane guidance, for example, or a new road sign, recognition errors can be quickly ruled out. The highly accurate route information can then be fed back wirelessly to the vehicles connected to the system. The data can then be used locally by the advanced driver assistance systems and as a basis for further refinement and updates using the on-board sensors. The Continental Road Database maps can be used as a supplement or an alternative to traditional digital road maps.”

**Actors:** Continental, Bosch, Denso

**Pre-conditions:** The ADASIS protocol was developed in order to prevent companies delivering map data or companies developing the actual ADAS applications from bundling the map in a proprietary format so that it only worked with the application. To be ADASIS-compliant, a map provider must ensure that it can deliver data to the ADASIS Horizon Provider and an ADASIS application developer must ensure that its software can receive data from the ADASIS Horizon Reconstructor. This applies to data that is resident on-board as well as data that is delivered from an off-board server, such as the Continental Dynamic eHorizon. The data delivered from Continental must be usable by non-Conti systems if it to be used with the ADASIS protocol.

**Interaction with other participants:** It appears from its own press statements that
Continental Automotive has decided to compete with HERE and TomTom by producing its own Road Database. In some statements it states that its Road Database is not intended to be used for navigation and way finding, but in other it claims that the “Continental Road Database maps can be used as a supplement or an alternative to traditional digital road maps”.

Business model adaptations required: The hardware suppliers make money selling hardware and related services. Continental charges for the data it delivers from its Road Database, and, presumably, it is at a lower price than the prices charged by either HERE or TomTom (since it states that these databases are ‘expensive’). If integrating spatial data helps the hardware suppliers sell more hardware, then the investments made in assembling, processing and delivering the data will be justified within their current business models. However, if there is no direct link between the data they deliver, even if they charge for it, and the eventual systems used on-board by the customers for this data, it is difficult to see a model that will support their position as a competitor to companies that are already in the business of licensing spatial data.

Probability of adapting: As long as there is a direct link between the on-board systems and the data that is being integrated, it is unlikely that an ADAS hardware supplier could be a reliable partner for delivering data to a Big Data Analytics component.

5.4.1.3 Navigation Hardware Providers

Role to be played: Processing of data delivered from multiple sources, including, among others, sensors on board vehicles and integrated into the infrastructure, from mobile devices, from the telecommunications network and from unmanned aerial vehicles.

Actors: Continental, Harman, Bosch, Denso, Aisin

Pre-conditions: Until very recently, all navigation hardware providers processed spatial data obtained from map data suppliers and other sources and compiled this data into their own proprietary formats for use on their systems. The proprietary formats were viewed by the navigation system providers as a competitive advantage when marketing their systems to OEMs and to consumers. The principal variables that they attempted to optimize were storage capacity required, volume of point-of-interest, landmark and topographic reference data, speed of generating a route and ease of updating. For the same reasons that vehicle OEMs wanted to have a standard for extracting spatial data for use on ADAS applications, they wanted to separate map data storage from the eventual navigation and map display application. With the Navigation Data Standard (NDS), developed during the past sixteen years, the industry has achieved this standard. Most of the navigation hardware suppliers and map data suppliers participate in NDS and can deliver data using the standard.

Continental: Road Database enables route information to be generated, made available, and updated almost in real time. And at low cost too.
Interaction with other participants: Navigation hardware suppliers will interact with map data suppliers, ADASIS system suppliers, and Integration Platform providers. CONTINENTAL, HARMAN and DENSO are functioning as data integrators as well. HARMAN announced at CES 2016 that the first new service provider for the SDP is HERE. Automakers can now deploy HERE Real Time Transport Protocol Experts Group (TPEG) Traffic through the HARMAN SDP. HERE Real Time TPEG Traffic delivers up to the minute information about traffic conditions and incidents that could cause delays, including slower than normal traffic flow, road works and accidents – improving the accuracy of arrival times.

Figure 10: Harman navigation display

Business model adaptations required: The hardware suppliers make money selling hardware and related services. If integrating spatial data helps the hardware suppliers sell more hardware, then the investments made in assembling, processing and delivering the data will be justified within their current business models. However, if there is no direct link between the data they deliver, even if they charge for it, and the eventual systems used on-board by the customers for this data, it is difficult to see a model that will support their position as a competitor to companies that are already in the business of licensing spatial data.

Probability of adapting: As long as there is a direct link between the on-board systems and the data that is being integrated, it is unlikely that a navigation hardware supplier could be a reliable partner for delivering data to a Big Data Analytics component.

5.4.2 Platform software suppliers

DeCarta

A San Jose company called DeCarta\(^9\) has been one of the only companies that developed and licensed a geospatial platform that could be used by enterprises to offer all types of services. It has been used by many companies, like Google and Yahoo, to get them started with their geospatial activities. ONSTAR is a current user.

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\(^9\) In 2015, deCarta was acquired by Uber who plan to use its software to improve all aspects of its taxi services.
Before its demise in 2001, FRAMFAB had licensed the platform with the aim of providing location-based services via the Internet. This is how DECARTA describes its Geospatial Platform:

*At the core of any geospatial service is data. Poor data, or poorly integrated data sets will kill any platform, no matter how advanced the functionality. DECARTA processes and integrates a wide range of geo-data allowing it to work seamlessly across data sets and geographic areas. We normalize all data into DECARTA’s Rich Map Format (RMF), ensuring that disparate features are well aligned and indistinguishable at the application level.*

*RMF also allows our customers to choose from many data suppliers...or integrate their own data to the best use of their application. Applications can access a wide variety of DECARTA partners for geospatial and non-geospatial data. They can also integrate proprietary content to build customized applications for local search and social media websites, real estate portals, travel and concierge services, navigation solutions, fleet-tracking and telematics solutions, and call center/dispatch applications.*

Combining datasets from multiple suppliers is the main advantage of DECARTA’s platform, and this must be the motive for UBER acquiring the company. UBER is not intending to sell its data but will use the DECARTA platform to create a dataset that will provide a competitive advantage compared to the data that it is using now from Google and compared to the data that is used by its competitors. Using Google data for China, which is considerably less accurate that local databases from NAVINFO and AUTOAVI, was said to be one of the reasons why DIDI KUAIDI, the local competitor to UBER that did use local data, quickly outpaced its American rival. DIDI KUAIDI purchased UBER CHINA’s company assets in early August, 2016. UBER is now determined not to make a similar mistake, neither in its major home market nor in other global markets and will build its own databases, integrating spatial data and attributes from the best available sources.

An integration platform that was able to assemble data from multiple suppliers, rather than being restricted to a closed set of data sources, would provide more useful input to Big Data Analytics processes. The main questions that need to be answered are:

- Who has an interest in operating such a platform; and,
- How will it be financed?

**Ericsson**

Founded in 1876, Ericsson has its headquarters in Stockholm, Sweden. Net sales in 2015 were SEK 246.9 billion (USD 29.4 billion). Ericsson is listed on NASDAQ OMX stock exchange in Stockholm and the NASDAQ in New York. Ericsson Connected Vehicle (ECV) is an independent business unit within the Ericsson Concern. ECV began its TSP services with Volvo Cars in 2012, offering the Connected Vehicle Cloud solution in conjunction with the Volvo Sensus Connect system. ECV announced development relationships with Scania and Geely in 2016, and began a service contract with Geely’s
LynkandCo brand in the same year.

Ericsson Connected Vehicle (ECV) uses the Ericsson horizontal IoT products that ECV then optimize for automotive to produce the TSP services. Therefore ECV can use R&D investment on a higher level as it builds products and capabilities for all industries. ECV’s products are built for global operations and scale as we have approximately 2.5 billion mobile devices based on our capabilities, and operate around 1 billion mobile devices directly. Ericsson in total has 60,000 people in operations in 180 countries that we can use to build and operate TSP programs.

Ericsson does not provide a full range of telematics services solution, such as for safety and security, stolen vehicle tracking, but focuses on data management, Internet connectivity, network management.

It has a market leading data analytics installation in the telecom world with millions of users for over 10 years. ECV has tailored its DA product offering for automotive with some industry-specific use cases. Uses 70% of standard components (e.g. Hadoop, Mapar distribution, spark, among others) and have ~30% IPT on top focused on: real time, automatic activation, user perceptions, and others.

Veridict

Veridict is a three-year-old Stockholm-based company with five employees. It describes itself an artificial intelligence company that enables its enterprise customers to ‘access, process, analyze and visualize their business-critical data on a massive scale in real-time. Its technologies range from AI to predictive analytics, cloud computing, speech technology, machine learning and natural language understanding. It claims to provide highly optimized solutions for mission-critical applications.

5.5 Big Data Analytics

5.5.1 Big Data Analytics as a Business Enabler

The timing of the emergence of Big Data Analytics is related to Moore’s Law. Intel’s Senior Fellow, Mark Bohr said: “Big Data would not be here without Moore’s Law. It gave us bigger memory, more intensive computing and the power, efficiency and reliability that large server farms require to handle all that processing power.” As memory drives and processors became more powerful and cheaper, businesses began to create huge server farms with racks of drives and processors from floor the ceiling. But it took Google to be able to make these server farms truly effective. Google was the first to solve two related problems:

1. To link thousands of computers together so that they all work in a coordinated fashion to store massive amounts of data and run computations across all of the stored data with all of the processors running in parallel. The major invention was to make these computers act as one so that if there were any failures they would not be noticed. This was called GFS or Google File System.
FFI – Big Automotive Data Analytics

2. To make the massive amounts of data searchable for patterns and insights. This was called MapReduce.

These advancements allowed Google to advance quickly and become totally dominant in the field of search as well as in identifying patterns and insights from huge amounts of data. However, perhaps as a way to ensure that it would not be brought down as a monopolist, or because it felt that competition would be good for its own business, it decided to publish the outlines of how both inventions worked. In the autumn of 2003, Google published a general description of GFS, and in late 2004 it published a description of MapReduce, describing it as “a programming model and an associated implementation for processing and generating large data sets...Programs written in this functional style are automatically parallelized and executed on a large cluster of commodity machines. The system takes care of the details of partitioning the input data, scheduling the program’s execution across a set of machines, handling machine failures and managing the required inter-machine communication.”

A group led by Doug Cutting took these two papers and created an open source version of Google’s proprietary closed system which they called HADOOP (the name of Cutting’s two-year-old son’s toy elephant). Cutting had worked at Xerox PARC research center and was part of a team investigating how to move the company from paper to a digital world. He wrote an open-source search program in his spare time that he hoped would compete with Google’s proprietary system. When Google published their papers, he took the opportunity to build on the outline, and the result was HADOOP.

It was not a magical alignment of the stars that enabled the emergence of companies like Twitter and Facebook around the same time, in the mid-2000s. It was the availability of a tool, (i.e., HADOOP) that such companies would have struggled to create themselves, to connect together commodity computers as they grew. Another advancement that HADOOP incorporated was the ability to process unstructured data. Before Hadoop was available, the principal way that data was queried was using Oracle Structured Query Language (SQL, which was originally developed by IBM in the 1970s). Unstructured data, if it was gathered, was usually discarded because there were no means to analyze it and it was too costly to store. HADOOP and Moore’s Law changed this. Cutting said that Hadoop enabled data analysts to sift through mountains of unstructured data, without necessarily knowing what they were looking at, and be able to query it and get answers back and identify patterns. This was a profound breakthrough.

5.5.2 BADA Platform

The addition of the Big Data Analytics component is what makes the BADA Platform different from current traffic and transport data services platforms. The ultimate objective for the BADA Platform is to assist drivers or on-board autonomous systems to make decisions using data that is being fed into the Integration component from multiple sources. These decisions could be in real time or post processed. As the diagram below shows, Big Data allows decision-making to move from Sense and
Respond to Predict and Act. SAP created this diagram to illustrate why developing predictive insights is a critical element in Big Data scenarios. The goal is optimization of traffic flow which should result from optimizing the safe movement of every vehicle on the road.

IBM, in describing the power of Big Data and Analytics for smarter transportation, says that by the time real-time data in the current traffic information systems arrives, it is too late to make useful responses to the conditions that existed when the information was generated. The information is no longer representative of the actual traffic. It claims that by using its Big Data Traffic prediction algorithms, relevant insights are generated for immediate use using a combination of historical data related to the time of day, day of week and month, weather and road conditions, events as well as split-second data about conditions in the vicinity of each vehicle.

As part of HERE’s efforts around the HERE HD LIVE MAP, the company invested in data analytics and automated data processing capabilities to process and analyze sensed data in real-time, enabling the map to be self-maintaining. HERE has also invested in the capabilities to return high quality, actionable activity data back to vehicles to close the data loop, allowing vehicles to make better, safer and more comfortable driving decisions. HERE’s HD LIVE MAP product is intended to offer a sustainable future path for automakers developing ADAS and autonomous driving capabilities.
5.5.3 Big Data Analytics Companies

5.5.3.1 Big Data Analytics software providers

**Role to be played:** Provider of business analytics software. SAS claims to offer three key technologies for extracting business value from Big Data:

- **Information management for Big Data** – Manage data as a strategic, core asset with ongoing process control for big data analytics.

- **High-performance analytics for Big Data** – Accelerated processing of huge data sets uses the following four SAS primary technologies:
  - Grid Computing
  - In-database processing
  - In-memory analytics
  - Support for Hadoop

- **Flexible deployment options for Big Data** – Options are offered for on-premises or hosted computing and software-as-a-service.

**Actors:** SAS Institute Inc., SAP

**Pre-conditions:** Companies that are in the business of licensing Big Data Analytics software or providing Big Data Analytics as a service will require compensation. The amount of compensation will depend on whether they process the data for delivery directly to end users, by-passing service providers, or deliver unprocessed data to service providers who package it for delivery to end users.

**Interaction with other participants:** Companies that are in the BDA business will have to work closely with the data integrators that will feed data to their BDA platforms, with the eventual service providers or possibly direct to end customers, functioning as service providers.

**Business model adaptations required:** Companies that are in the BDA business have developed two strategies: selling software and service support related to the software; and, selling BDA as a service, usually cloud-based. These companies are in a position to develop service provider capabilities, either growing them internally or acquiring existing service providers.

**Probability of adapting:** High.

5.5.3.2 Big Data Analytics service providers

**Role to be played:** Provider of business analytics services. Amazon says of its Amazon Elastic MapReduce (Amazon EMR) that it “simplifies big data processing, providing a managed Hadoop framework that makes it easy, fast, and cost-effective for you to distribute and process vast amounts of your data across dynamically scalable Amazon EC2 instances. You can also run other popular distributed frameworks such as Apache Spark and Presto in Amazon EMR, and interact with data in other AWS data stores.
such as Amazon S3 and Amazon DynamoDB.”

**Actors:** IBM, Microsoft, Amazon Web Services, Google

**Pre-conditions:** Companies that are in the business of providing Big Data Analytics as a cloud-based service offer pay-for-time usage or pay-per-data amount processed service agreements.

**Interaction with other participants:** Companies that are in the BDA business are used to taking data from various sources, so it will be up to the integrators to determine how best to feed data to the analytics platform.

**Business model adaptations required:** Big Data Analytics service providers will either have commercial agreements directly with Service Providers, combining the results of their analyses with integrated map data, or they will deliver their results back to the Integration Providers who will perform a new integration and then deliver the results to the Service Providers.

**Probability of adapting:** A new role is defined for a virtual BDA Provider.

### 5.6 Service Providers

#### 5.6.1 Content service providers

Traffic information and automation service providers are today principally continental or regional in their coverage. The main markets are Western and Central Europe, North America (U.S., Canada and Mexico) Russia, China, South Korea and Taiwan, Japan, Australia and New Zealand, Brazil and Argentina, South Africa, Israel and Middle East. Certain service providers, like HERE, TOMTOM, Google/WAZE and BOSCH, attempt to cover all regions, while others, like MEDIAMOBILE, VODAFONE and ATANDT, restrict themselves to specific regions due to legal or business reasons. Some regions, like China and Russia, are difficult to enter because of protective legal restrictions, and others, like Japan, create technical challenges because its in-vehicle systems, map data format and mobile network systems are country-specific.

The principal services that are offered which could be expanded with Big Data are:

- Traffic and traveler information;
- Traffic automation;
- Route guidance and map data update information; and,
- Fleet management

#### 5.6.1.1 Traffic information service providers

**Role to be played:** These service providers today are the channel for traffic information data to the vehicles or to smart phones. They deliver the data in standard formats, such as RDS-TMC and TPEG, as well as in their own proprietary formats. They will continue to be primary suppliers of traffic information in the future.

**Actors:** Inrix, Mediamobile, Here, TomTom, Waze, Apple
**Pre-conditions:** Apple delivers traffic information to its map application loaded on iPhones for free. Waze is also free. Its data is crowd-sourced from the users of its app. In order to benefit from the application the user needs to be connected and interacting with the server both actively (i.e., sending messages from the app) and passively (i.e., allowing the app to track the vehicle in real time). Traffic data suppliers usually have an agreement with OEMs for their integrated navigation applications for supplying traffic information to the buyers of the systems.

**Interaction with other participants:** Interaction varies by company and is becoming less rather than more important as the companies vertically integrate. Apple started out by using map data from Google and then it created its own map application using TomTom maps. It is now sourcing its own map data using its own map data gathering vehicles. Crowd-sourcing means that the most important interaction is with the users of the application.

**Business model adaptations required:** With Big Data that is integrated from multiple sources and then processed through an analytics engine that does not necessarily belong to the service provider delivering the results to customers, there will need to be business model adaptations. If Waze or Apple choose to become part of the Big Data ecosystem, and if there were payments attached to using the results, they would either have to charge users a subscription fee—which they do not at present—or they would have to find other ways of generating income.

![Google Free Navigation and Traffic Information Money Flow](image)

**Figure 11: Google/Waze Free Navigation and Traffic Information Money Flow**

**Probability of adapting:** Medium-to-low.

### 5.6.1.2 Traffic automation services

**Role to be played:** These are principally mobile apps on smart phones or integrated in
the vehicle head unit that provide useful mobility-related information, such as parking location and payment, public transport connection times, fueling and electric charging station location and booking information among others.

**Actors:** BestParking, PlugShare, Parkopedia

**Pre-conditions:** The business model of the parking app companies is built around obtaining data from parking facility operators about the number of spaces they have in their garages and lots, the cost of parking and the live feed of availability. The parking app companies then license this data to automotive OEMs, map and traffic data providers, like HERE and INRIX. Secondary revenue streams are the selling of their apps and running advertising on their apps. The parking industry is finally upgrading their information management systems, and this means that there is more data available. NL and DE are very advanced in installing technology. Southern Europe and North America is not as advanced, but catching up. Now, on-street parking is being added.

**Interaction with other participants:** Digital payment is a new phenomenon and this is helping to make traffic automation services more interesting for consumers. OEMs view this as a positive development because customers put more value on the service and this helps to sell the concept of connected vehicles.

**Business model adaptations required:** These service providers earn money by providing a platform that connects information from the originators of the content (e.g., car park owners) and the customers who want to have the information. They are brokers. When they add a payment component, they earn additional money by charging a service fee to complete the transaction. If there is additional data that can be produced as a result of big data analytics, and there is a provider of this data that wants to reach end users, these companies could extend their platforms to include the additional data. There does not seem to be any business model change required to do so.

**Probability of adapting:** The probability is high that these companies would adapt to the use of data that has been processed by a big data analytics platform.

### 5.6.1.3 Route guidance service suppliers

**Role to be played:** There are two basic types of Route Guidance service providers:

- **Embedded solutions** that are integrated in the vehicle by the OEM and work with on-board data and/or data that is supplied to the on-board system from an off-board server and/or route guidance instructions that are delivered from an off-board server and delivered using the on-board audio and display functions of the vehicle.

- **Nomadic solutions** that function outside or inside a vehicle but are not integrated in the vehicle. These solutions may use the audio or display functions of the vehicle but can operate fully autonomously of any input from the vehicle’s systems.
**Actors:** Here, TomTom, Google, Waze, Apple, Continental, Bosch

**Pre-conditions:** In the case of the embedded solutions, the vehicle OEM must source the route guidance software and, if external connectivity is required, provide the communications module. The costs for communication can either be included in a subscription service paid for by the customer on a tethered device, or it can be part of a mobile communications service provided by the vehicle OEM. In the case of a nomadic solution, the device must be compatible with software provided by the OEM for pairing the mobile device with the audio and display functions.

**Interaction with other participants:** Route Guidance Service Suppliers cooperate actively with many content providers and this will intensify when Big Data services become available.

**Business model adaptations required:** This service has been free; customers pay for the device on which the service is delivered (i.e., smart phone, PC, on-board navigation system). There has never been a model in which the customer pays for each route requested. This is not likely to change when Big Data is used to enhance the route guidance function. However, when the vehicle is part of the data delivery chain, there will be opportunities for car owners to negotiate higher levels of data or higher rates of receiving updates by delivering more data from their vehicles.

**Probability of adapting:** Very high.

### 5.6.1.4 Fleet Management

**Figure 12:** Fleet Management within the Car and Truck Telematics Ecosystem (Source: Michael L. Sena Consulting AB)
Role to be played: Fleet management systems add a dimension that is not present in most private car telematics. As the diagram above shows, the customers for and users of the systems are actively involved in both accessing information and providing data to the back-end systems, while in most private telematics applications the users are principally seeking information or requesting assistance.

Fleet management suppliers must be able to adapt their systems and services to a wide range of business applications, and users need to invest both time and money in integrating the solutions into their business processes in order to obtain maximum value for money. There are a large number of companies offering various types of fleet management solutions, and this number is growing quickly with mobile apps providing single-service functionality. Not all of these companies are interested in or able to offer their solutions to other companies who wish to offer fleet management services, and most of them are small, local niche players. Some companies focus on specific market segments, such as local fleet or HCV, some specialize in particular functions, such as tracking or energy savings, while others attempt to satisfy the full range of requirements for all segments.

Actors: Scania, Volvo Trucks, TomTom, Danaher

Pre-conditions: According to studies performed by the American Transportation Research Institute, in the US, 31% of operational costs in trucking are fuel. The percentage is even higher in Europe because of significantly higher fuel costs due to higher taxes. In a low margin business like trucking, the effect of lowering fuel consumption by 5% can lead to an increase of 18% in company profitability. The biggest factors affecting fuel consumption:

- Vehicle specification and configuration
- Aerodynamics
- Weather, road, and traffic conditions
- Vehicle maintenance
- Driver behavior

Figure 13: Operational Costs of Trucking

Truck manufacturing companies have devoted a considerable amount of their research budgets to developing both systems and services to address both the maintenance and driver behavior issues as they affect fuel consumption. They have also focused on finding ways to lower driver costs by automating more driver tasks so that less-experienced (i.e. lower cost) drivers can be put behind the wheel.

Interaction with other participants: The European Automobile Manufacturers Association (ACEA), founded in 1991, represents the interests of the fifteen European...
car, truck and bus manufacturers at EU level. It is an Economic Interest Group with its headquarters in Brussels. In 1995 and 2004, ACEA opened additional offices in Tokyo and Beijing respectively. ACEA has taken the initiative as a neutral party in order to improve fleet management solutions by opening a dialogue between the truck OEMs and third party fleet management solutions (FMS) suppliers. The intention is to find a way for both truck and FMS suppliers to identify both technical and commercial business models that deliver more useful solutions for their common customers. One possible roadblock is the EU’s view on industry cooperation that can be interpreted as non-competitive collusion.

**Business model adaptations required:** There should be no business model adaptations necessary.

**Probability of adapting:** Very high

### 5.6.2 Traffic Management, planning and maintenance

**Role to be played:** Traffic Management Centres (TMCs) need data in real time to be able to manage traffic and to provide traffic information to vehicles and travellers. Traditionally, a TMC monitors traffic and identifies problems with the help of data obtained from fixed roadside equipment, such as cameras and radar, and with verbal reports from private car drivers, commercial truck drivers, the police and others who witness traffic events.

**Actors:** Traffic Management Centers (TMCs), national public road authorities (e.g. Trafikverket), private road operators, municipal traffic and road authorities

**Pre-conditions:** Today, a TMC is mostly reactive, informing drivers and travellers about the current traffic situation. Information channels are primarily radio, web, apps and variable message signs on the roads. The Connected Car Ecosystem will enable a cooperative traffic management where road owners and service providers cooperate to enable harmonized and more individually adapted traffic information to be directed towards the vehicle/driver/traveller. Individualization of traffic information will probably be done via service providers. Using Connected Cars acting as real-time probes in the road network will provide totally new opportunities for

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**Figure 14: Proposed ACEA/HDEI Web service Standard**
TMCs to become more pro-active traffic management centres by using large amounts of data, predicting traffic and steering traffic in space and time to a much larger extent than today.

**Interaction with other participants:** Rules that are established for how roads in a jurisdiction are used must be clear to all actors in the ecosystem. There must be an open and transparent framework for how the rules are arrived at and how they are to be enforced.

**Business model adaptations required:** There should be no business model adaptations necessary.

**Probability of adapting:** Very high

### 5.7 Customers

Customers are the final users of the information that has been processed and delivered as services to drivers of all types of vehicles and to the on-board systems that use the information for improving safety, reducing emissions and improving traffic flow. Customers also include the owners and operators of public authority, private and commercial fleets of vehicles as well as owners and operators of traffic management, planning and maintenance infrastructure.

#### 5.7.1 Travelers

**Role to be played:** User of all the information that has been processed.

**Actors:** Drivers of vehicles, suppliers of on-board units, suppliers and operators of roadside units.

**Pre-conditions:** For most of the services, the driver will need to have a commercial agreement with a Service Provider, or have some form of subscription (paid or free) with the OEM for the vehicle or the on-board unit.

*Figure 15: HoloActive Touch shown by BMW AG at CES 2017*

**Interaction with other participants:** Drivers will not interact directly with other participants, including other drivers. Data will be processed and delivered as information to the vehicle drivers.

**Business model adaptations required:** Pre-paid subscription, pre-paid debit card, pay-per-use, free warranty period service and any other model can be adapted for traveler services.

**Probability of adapting:** High as long as the services are of a high quality and the customers feel that they provide good value for the money paid for them.
5.7.2 On-board vehicle systems

**Role to be played:** Data receptor of all the information that has been processed.

**Actors:** Drivers of vehicles, suppliers of on-board units, suppliers and operators of roadside units.

*Figure 16: Continental AG – Augmented Reality Head-up Display*

**Pre-conditions:** The units must be capable of receiving and sending data in standardized formats.

**Interaction with other participants:** Systems will support vehicle-to-vehicle, vehicle-to-infrastructure, vehicle-to-pedestrian and vehicle-to-network functions as well as operating in autonomous (i.e., without any connection to other systems) mode.

**Business model adaptations required:** The main issues are whether on-board systems are mandated by law or if they are voluntary, and if public bodies provide roadside units to receive and transmit information or if the infrastructure consists of the telecommunications networks.

**Probability of adapting:**

5.7.3 Authorities

**Role to be played:** Users of large amounts of the data that has been processed.

**Actors:** National public road authorities, private road operators, municipal traffic management authorities

**Pre-conditions:** In order for authorities to be able to benefit from large amounts of data, data integrators or brokers will be needed, that collects and processes data from a large number of sources. Then the data must be available in formats that can be readily processed by the authorities and used in their traffic management, planning and maintenance systems.

**Interaction with other participants:** Authorities are interacting with public regulators in order to obtain both the mandates and funding to carry out their missions. They are interacting with the public through traffic management systems (e.g. V2I roadside units, variable message signs, radio broadcasts).

**Business model adaptations required:** There should not be any need to change the current business model to adapt to Big Data-based applications.

**Probability of adapting:** High.
6 Services

6.1 Introduction

An important objective of this Business Models Future Scenarios analysis is to determine what data is required for achieving the desired goals of reducing emissions, improving traffic safety and improving traffic flow. We have attempted to accomplish this by working from the goal to the value proposition (Who gains what?), identifying the requirement needed to realize the value proposition and then postulating what data are needed to meet the requirement. While this may appear to be a linear process it is actually iterative. Data that is assumed to be necessary may not be available, or it may be obtainable with other data that enhance the value proposition.

The working group identified a number of current and possible future services as examples of the different value propositions. By using these services as examples we found it easier to gain a deeper understanding of the entire eco-system and the relationships among the various actors. The diagram below represents the synthesis of our work on describing the relationships. All of the service examples can be mapped to the diagram below.

The requirements and data described in the examples below are not intended to be exhaustive. The intention is to provide a method for analyzing services and determining whether they have the potential to either generate or use big automotive data analytics and the extent to which they help to achieve the stated goals.

![Figure 17: BADA Integration and Analytics Platform](image)

6.2 Urban autonomous transport system

6.2.1 Goal of Service

The scope of this “service” is indeed vast, combining the megatrends of mobility service integration and vehicle automation. There is great potential in mining vast amounts of data on travel patterns of citizens to optimize the complex web of
modalities and service offerings in the combined public and private personal mobility industries. Knowing in detail the service availabilities of all forms of transportation and travel patterns and preferences of all citizens would enable unprecedented system wide optimization opportunities. Today, such data is located in many places and system wide optimization beyond any single operator and/or modality is therefore difficult. But things are changing.

The development of true vehicle automation will render the current traffic system obsolete. Once automated vehicles become affordable, services now provided by drivers of ships, planes, trains, buses and taxis will become a thing of the past. Instead, automated vehicles will cater for mobility needs. This development in turn will lead to the diminishing importance of customer choice and, indeed ownership, of cars, further accelerating the trend towards complete ‘servitization’ of personal mobility already apparent in the emerging Mobility-as-a-Service (MaaS) concept.

**Mobility As A Service**

- From the user’s perspective MaaS offers an attractive value proposition by providing a better customer experience in terms of:
  - **Journey Planning**: real-time journey planning allows a user to plan their journey, choosing from multiple modes that are ‘intelligently’ suggested based on their personal preferences (like for example, cost, comfort, time).
  - **Ease of Transaction**: The user can access mobility using a range of payment channels for example a phone, watch, smartcard or bank card regardless of which modes of transport they use.
  - **Flexible Payment terms**: The user can pay for their mobility choice via pre-pay, post-pay or pay-as-you-go.
  - **User Experience**: Data analytics will enhance the overall user experience. This feature may be seen as a virtual “concierge service” that provides the user with the best possible whole journey experience by managing the choices they make.
  - **Personalized Service**: A fully personalized service that builds a relationship between the user and the MaaS provider by allowing two-way communication. The MaaS ‘service’ will be highly customer relevant and focused and will react to user feedback.

MaaS is a recently coined concept describing a fully integrated multimodal transport service. In theory, this includes various forms of payment, although monthly subscription fees are often seen as a possibility. MaaS was tested in the 2014 research project GoSmart(UbiGo) in Gothenburg and the concept has gained much interest from policy makers recently. In Sweden, Västrafik is currently seeking to invest in a combined mobility service in the region. In Stockholm, SL is experimenting with allowing third party sales through their apps. The big automotive OEMs have invested in car rentals, car sharing and increasingly mobility services (e.g. Uber, Lyft, Car2Go, DriveNow). Thus, the fragmentation hurdles needed to enable a first step of system wide Big Data analysis of optimization of services and resources seem to be diminishing.

OEMs will face challenging strategic decisions of what role to occupy in this future landscape of competition. Operator/owners of full MaaS services (the recent statements of Ford allude to this), mere automated taxi/carsharing providers, or continue the current business model by merely providing other actors with the
necessary hardware (cars and busses). This volatile future vision contains a number of challenges and opportunities coupled to data analytics. The production of cars consumes a vast amount of resources and a car is typically used 5% of the time with a low seat occupancy. By increasing the usage rate to 20-40% and seat occupancy, there are huge opportunities for making today's transport system more efficient whilst focusing on uptime and encouraging circular economy business models (more durable cars are more profitable in operation). Furthermore, automation in itself will not necessarily lead to a lower consumption per kilometre travelled, but it enables system wide optimization, through which the total carbon footprint and usage of natural resources will be lower due to efficient routing and less vehicles needed to fulfil the transport needs of the inhabitants in a city or region.

6.2.2 Service Description

The service will offer the inhabitants in a city a transport service with high availability and flexibility, substituting the need for owning their own car.

- A central system manages all the users' transport needs including spontaneous and recurring trips and with the possibility to ride alone or sharing the ride with another traveller to reduce the cost of mobility and the amount of vehicles needed.

- The central system gathers data from various data sources such as the vehicles themselves, the users and external data, such as weather data to optimise the traffic flow.

6.2.3 Service Levels and Timeframe

SAE International’s standard provides and defines the six levels of driving automation, from no automation to full automation. Consistent with industry practices, the standard helps to eliminate confusion by providing clarity and is frequently cited and referred to by industry and media. The following summary of SAE J3016 levels of driving automation is an updated version published in September 2016, superseding the previous version published in January 2014. While the update has not materially changed the taxonomy, it provides more granular technical description.

Glossary of SAE J3016 technical terms

- **ADS** (Automated Driving System): The hardware and software that are collectively capable of performing the entire Dynamic Driving Task on a sustained basis, regardless of whether it is limited to a specific Operational Design Domain. This term is used specifically to describe a Level 3, 4 or 5 driving automation system.

- **DDT** (Dynamic Driving Task): All of the real-time operational and tactical functions required to operate a vehicle in on road traffic. These exclude the strategic functions such as trip scheduling and selection of destinations and waypoints. However, these include, without limitation, lateral vehicle motion control via steering; longitudinal vehicle motion control via acceleration and deceleration; monitoring the driving environment via object and event detection, recognition, classification, and response preparation and execution; manoeuvre planning; and enhancing conspicuousness via lighting, signalling and gesturing. Dynamic Driving
Task fallback is the response by the user or by an Automated Driving System to either perform the Dynamic Driving Task or achieve a minimal risk condition after occurrence of a Dynamic Driving Task performance-relevant system failure or upon Operational Design Domain exit.

- **ODD (Operational Design Domain):** The specific conditions under which a given driving automation system, or feature thereof, is designed to function, including but not limited to driving modes. These may include geographic, roadway, environmental, traffic, speed and/or temporal limitations.

- **OEDR (Object and Event Detection and Response):** The subtasks of the Dynamic Driving Task that include monitoring the driving environment (detecting, recognising and classifying objects and events, and preparing to respond as needed) and executing an appropriate response to such objects and events as needed to complete the Dynamic Driving Task and/or Dynamic Driving Task fallback.

### Table 1 - Summary of levels of driving automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>Driver performs part or all of the DDT</th>
<th>DDT</th>
<th>OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
<td></td>
</tr>
</tbody>
</table>

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<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>Fallback-ready user becomes the driver during fallback</td>
<td>Limited</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
<td></td>
</tr>
</tbody>
</table>

- Fully autonomous Level 4+ vehicles available in the different transport segments, but little or low impact on the products themselves and will have the current car design features. The role of today’s fleet managers and drivers will be reduced to a minimum.
- New vehicles will appear to better match the users’ travel patterns and the cities need for space. Some segmentation will likely still be retained. Thus exclusive vehicles with few seats will exist while the amount of fully autonomous “minivans” will probably grow. The vehicles will still have to be operated, but it is unclear whether this task will be managed by the OEMs, fleet managers or even individuals owning the cars. Private vehicles, i.e. not part of pools, will become increasingly rare.

- The mobility market will have settled into a few dominating patterns of multimodal MaaS. The increasing integration of modalities will entail increasing availability of massive amounts of data to analyze the mobility patterns of entire regions with comparative ease.

6.2.4 Actors and Roles
There are several actors with varied incentives to occupy available niches in the MaaS ecology. First, each actor is organizing according to their strategy within their modality. Will the OEMs move to integrate the fleet manager role? Or will they stay as an equipment provider? If they choose to move towards servitization, will they continue and aspire to control the service front end too? Once there, the opportunity to engage other modalities is apparent and they could indeed opt to control all or part of an integrated MaaS service. The more thorough the integration of all actors, the higher the potential of service optimization by data analytics.

![Modal view of strategic options for automated MaaS](image)

**Figure 18: Model view of strategic options for automated MaaS**

**City**

Cities are already engaging in collaborations with (non-automated) MaaS platform providers to further develop the local public transport system. As a key activity, they will strive to utilize massive data on transportation patterns to optimize vehicle service allocation.
Cities have a desire to reduce the number of cars from three different perspectives:

- **Space** - as cars are using up a lot of space while travelling on the roads and while they are parked. There is a huge potential to develop the space that cars are using. Peak hours are still a problem.
- **Safety** – Today’s cars might be a hazard to the drivers themselves but also to cyclists and pedestrians in the close environment. Autonomous cars will reduce this risk to a minimum.
- **Pollution** – Smart routing algorithms that makes ride sharing attractive could reduce the amount of cars, vans and buses necessary, but the total distance travelled will probably not diminish with an autonomous MaaS service. New power trains with alternative fuels will have larger impact from an environmental perspective.

**Fleet manager**

Today’s fleet managers can have several tasks: to own, sometimes drive and in some cases repair and maintain. The optimization of the fleet is their main priority. The interface with OEMs and e.g. transport authorities varies. With autonomous driving, the role of many fleet managers will diminish and their position could be threatened.

**Vehicle manufacturer**

The probability of turning OEMs into mobility providers in the short-term (i.e., five-to-ten years) is estimated to be low due to business risks, conflict of interest towards today’s customers and the organisational structure of production focused companies. Car manufacturers and their authorised dealers will probably adapt their business model and will expand their duties and perform some of the tasks of the fleet manager and selling service contracts instead of physical products. Over time, the products coming from the manufacturers will change to provide a more efficient transport system. Manufacturers of buses will focus on smaller vehicles and car manufacturers will probably be looking at smaller and larger vehicles than today.

**Traveller**

The traveller can buy rides from a MaaS Platform instead of owning their own car. In an urban environment, the service should aim to provide the same or better degree of mobility compared to owning own car, but at a lower cost. As new pricing mechanisms will emerge, they will probably merge into subscriptions based on the distance travelled and service level.

**6.2.5 Value Proposition**

The future mobility market will probably emerge from today’s public transport systems, the car sharing market and different kinds of ride-hailing services, where these services will be integrated into one front end facing the traveller.

Today’s car sharing business is focusing on enabling the customer (users) to pay when they use a product or service. With driverless cars, the users will be buying transport instead of renting a vehicle during a short time, just like buying a trip with taxi or public transport.
The value added by driverless e-hailing compared to today’s car sharing will provide several benefits:

### 6.2.6 Data Requirements

The following parameters will be managed by the MaaS system.

<table>
<thead>
<tr>
<th>Traveller</th>
<th>MaaS</th>
<th>City</th>
<th>Fleet manager / Vehicle owner</th>
<th>Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduled and real time trip needs (R)</td>
<td>Traffic information, actual and predictions on all roads within service area, (R)</td>
<td>Road condition information</td>
<td>Vehicle speed, detected anomalies in traffic flow (R)</td>
<td></td>
</tr>
<tr>
<td>Personal settings and service level</td>
<td>Detailed longitudinal multimodal travel patterns</td>
<td>Map data</td>
<td>Diagnostic vehicle info (R)</td>
<td></td>
</tr>
<tr>
<td>Payments</td>
<td>Planned road works</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected time to pick-up/arrival (R)</td>
<td>Vehicle speed, position, routing(R)</td>
<td></td>
<td>Vehicle speed (R)</td>
<td></td>
</tr>
<tr>
<td>Planned road works</td>
<td>Diagnostic vehicle info</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realtime trip needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal settings and service level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Green: what each actor provides, Red: what each actor consumes, (R) = real time data
6.2.7 Business Models and Governance

Just like today’s public transport system, the travellers should pay for their personal transport need. New ways of pricing will be possible, some travellers will be willing to pay an extra fee for personal needs such as:

- Travelling during peak hours
- Be able to ride by themselves
- Pre-planned or ad-hoc travels
- More comfortable vehicle.

The MaaS platform will manage all the payments and pay the fleet managers based on the total amount of vehicles needed for the overall service level which in turn will pay the OEM for the vehicles and parts necessary.

In some cases, the city will be a co-sponsor. Local and governmental authorities will probably set the rules concerning the availability and performance of the mobility providers and gradually make sure that less and less conventional cars are used in a certain area.

6.2.8 Big Data Challenges

- Elasticitic compute resources
- Edge computing
- Anomaly detection
- Pattern recognition
- Real time processing
- ...

Developing the planning and routing algorithms to match the customers’ needs whilst simultaneously ensuring high utilization of resources is at the heart of analytics challenges in this area. The algorithms will need to consider many data types in their calculations and some calculations will have to be made in the vehicle and in real time. The data will have to be collected, in some cases centrally processed and redistributed to the users, the infrastructure and the vehicles.

6.2.9 Consequences for BADA-partners

Introducing a fully autonomous transport system will render a radical shift of OEM’s business models. Depending on the available strategic options pursued, an OEM could occupy a role similar to that of today, or as a powerhouse driving the complete integration of the multimodal automated transportation system of tomorrow.

Considering current responsibilities of Trafikverket, the impact of this service will likely not be as significant, they will still administrating road maintenance and development. Besides from direct effects to the road building practice (it is a widely held belief that more efficient driving will utilize less space on roads), Trafikverket will benefit from superior data analysis in their long term planning.
6.2.10 External Stakeholders

The mobility planning of cities and regions is potentially radically transformed. The public transport authority within them is a likely contender for the role of MaaS operator. The project has had initial discussions with representatives from the City of Gothenburg, but more input is needed to understand how the city can contribute to and benefit from the superior service optimization, and prerequisite data analysis of a fully integrated automated MaaS.

6.3 Maintenance of Road Infrastructure

6.3.1 Goal of Service

The goal of this service is to enable more effective and efficient road maintenance. Currently, specially equipped vehicles are operated by Trafikverket as well as contractors for the sole purpose of gathering information about the current road conditions. While this generates good diagnostic data, there are new opportunities for gathering novel vehicle sensor data. Utilizing generic automotive sensor data, the goal of a Road Maintenance service is to reduce the cost of road maintenance whilst simultaneously increasing quality by providing more accurate information in real time from a great number of private vehicles about the wear and tear on the roads. By using this new set of information, it will be easier to prioritise work and manage contractors which will in turn lead to a better flow of traffic and fewer fatalities.

Figure 19: Mobile sensor rigs from WSP

6.3.2 Service Description

The prerequisite for the realization of the service is that vehicles collect data suitable for informing road maintenance practice. This data can it be of two types:

- Incident occurrence, such as a slippery road, pot holes detection or lidar detection on broken side-protection, miss-placed sign (compared to digital map data)
- Statistical data collected per way-node and containing information on road friction, vibration and other relevant data for each way-node.
6.3.3 Service Levels and Timeframe

Initially, the service will most likely be designed using a centralized architecture. Distributed service designs based on e.g. Edge computing and local intelligence is an option in the future and might be necessary to enable an even better performance.

Initially, few cars will have the necessary infrastructure to become suppliers of data. This will mean that coverage and reporting frequency will not reach their full potential. However, even a fraction of the total car population will provide a wealth of data on which to perform analyses.

Additionally, the initial set of data types collected will be limited to a small selection of readily available sensor data types, subject to the design of the onboard systems, connectivity suite and back office capabilities of the initial supplying OEM.

At the initial inception, bilateral contracts will likely be signed between data supplying OEMs and benefiting authorities and/or contractors. As the capabilities required of vehicles and OEMs become more widespread, contracting and architecture will likely become institutionalized. As contracting and integration maintenance becomes more complex due to the growing number of partaking entities, a specialized actor will likely emerge to take responsibility of the data collection architecture. The existence of an intermediary, catering for data collection and validation, will likely lead to such an actor developing analytics capabilities matching the needs of e.g. authorities and contractors.

Late services level entails fully automated vehicles. As projected by a majority of OEMs, such vehicles will need to have a more advanced detection system employing far more sensors than available or near future vehicles. This will enable far more detailed and reliable analyses.

6.3.4 Actors and Roles

Use case 1: Road Authority

The most likely use case for the road authority would be to have continuously updated status of the road infrastructure condition. This can then be used to make sure that the resources for road maintenance are accurately allocated according to actual needs. There is likely a beneficial case for the service considering the costs involved in current alternatives utilizing specially made vehicles. The service can be used to follow up on contractor service levels, making sure that the commitments made in road maintenance contracts are adhered to.

Use case 2 Maintenance Contractor

A road maintenance contractor could use the service much in the same way as the road authority, to ensure that maintenance leads to well functioning road infrastructure in an efficient manner. Contractors with access to the service could create superior bids to government maintenance contracts based on big data analysis of maintenance needs.
It could ultimately open for new business models where road maintenance contractor would deliver infrastructure as a service, agreeing on a certain level of minimum road condition, rather than a per repair payment. This would require the gathering and analysis of historical data and ensuring proper calibration between the vehicles’ reporting about the road conditions.

**Use case 2 Driver**

Getting more detailed information on current road conditions would help inform drivers of optimal routing choices.

### 6.3.5 Value Proposition

<table>
<thead>
<tr>
<th>GOAL</th>
<th>VALUE PROPOSITION</th>
<th>REQUIREMENT</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fewer fatalities</td>
<td>1.1 Improved data on road conditions lead to fewer fatalities</td>
<td>Analysis of current road condition</td>
<td>Close to realtime detailed data with full road system coverage round the clock</td>
</tr>
<tr>
<td>2. Improve traffic flow</td>
<td>2.1 Less time wasted in e.g. weather induced traffic queues drivers</td>
<td>Visualization of analysis to inform road maintenance practice</td>
<td>Driver origin and destination, time of departure, historical data</td>
</tr>
<tr>
<td></td>
<td>2.1.1 Calculate drivetime based on historical and real time data and inform relevant actors</td>
<td>2.1.2 Coordinate vehicle speed of vehicles to ensure optimal throughput</td>
<td>speed, road works and other events, historical data, road friction, rain sensor, temperature, roadsign and road</td>
</tr>
<tr>
<td></td>
<td>2.1.3 Inform purchasing and follow up of maintenance services</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6.3.6 Data Requirements

The list shall be seen as a first draft of ideas to be investigated, it need to be more analysed and an important features will be adding new data captures as new needs is required.

**Vehicle sensors**

- Time stamped position data from vehicle
- Vehicle speed
- Vehicle type
- Incident related data (e.g. hazard alert, stationary vehicle).
- Suspension sensors, detecting problems in road surface such potholes, cracks etc.
• Road slippage (traction control) and together with traction control system or Lane keeping system activated – indicating a curve with faulty sloping.
• Braking sensors and quick reduction of speed together with radars can identify the reason for breaking or lane change e.g. car, elk or other big objects can be detected. Changing lanes without any vehicle in front, reason could be a dead animal on the road, person walking at the side, rubbish or other material, a hole in the road.
• Brake sensors and radars to identify new driving patterns on the road.
• Air quality information and noise levels to seek opportunities for the improvement of environmental quality in areas adjacent to roads.

Road data condition

• Sensor data recording road surface conditions
• Sensor data from radars and cameras indicating roads-side condition (i.e. need for re-fill of roadside filling)
• Average speed
• Temperature
• Air quality

6.3.7 Business Models and Governance

The value proposition for road authorities (national and local) could be to provide them with:

• A measurement of the quality of winter road maintenance conducted.
• More accurate information about the work required to maintain a road segment for sourcing purposes.
• Automatic real time reporting tool of anomalies to quickly mitigate congestions.

Value Proposition for maintenance contractors:

• Provision of key information to optimize road maintenance processes.
• Using superior knowledge gained from analytics to compete for contracts effectively

Road Maintenance Data Chain

![Figure 20: Needed data chain for road maintenance](image-url)
There are several possible governance structures available. The road authority could integrate and analyse the data by themselves to provide for the services sought. This would enable effective strategic planning of maintenance service procurement, planning and follow up from a purchasing perspective. The contractors could perform advanced analytics in-house to be able to profitably compete for tenders. The integration and/or analytics processes could be outsourced to a third party provider that develops services. The affected parties could form a consortium to govern part of or all of the functions.

6.3.8 Big Data Challenges

Limited at the beginning, but progressively pronounced as the complexity grows with more sources, providers and consumers. The following are identified at this stage:

- Ensure drivers’ privacy
- Calibration between different vehicle types
- Interpretation of certain driving patterns and relating to a certain type of incident/problem and find the appropriate solution
- Closing the feedback loop to the right recipients

6.3.9 Consequences for BADA-partners

Volvo Cars

Volvo Cars already has access to the prerequisite digital features. Volvo Cars primarily views this function as a means to sell cars and increase the up-selling of necessary options. Road sign data and road marking data is possible in the near future, but remains to be developed. Function for in car data collection and redistribution exists between Volvo Cars but a third party interface function needs to be developed to initiate the data exchange with third parties such as other car manufacturers, infrastructure and contractors. Costs associated with added development need and running maintenance costs will have to be compensated.

Volvo AB and Scania

Scania primarily views this function as a means to sell vehicles. Scania currently does not have key prerequisite digital features, but many components already exist, e.g. capturing and collecting data. Remaining development would cover development of cost effective processes for this.

Volvo will offer this type of service to strive for a reduced number of traffic accidents, reduced emissions and satisfy their customers by predicting the overall transportation time which in the end means satisfied customers and an increase in sold transportation solutions.

Trafikverket

Dual uses are apparent, both direct and indirect. First, Trafikverket will be able to follow up on road maintenance more efficiently. Second, those services will likely be
more efficient and less costly if the contractors utilize the service by using the information generated about the road segment that they are responsible to maintain.

6.3.10 External stakeholders

Contractors

Based on the assumption that the urban environment is improved and that the data provided is increasing the quality or decreasing the cost of the contractors’ work.

Existing Data providers

Weather services e.g. SMHI and Foreca. Data collected from vehicles can be used to increase the accuracy of existing forecasting models.

Road condition data services e.g. WSP, ÅF, Sweco. These actors are potential third party providers of the aggregation, analytics, and service processes.

Other road keepers

National, local, public and private. These would have much the same incentives as the national road authority and differ only in terms of capabilities. Local road authorities are likely interested in joining any initiative on the same grounds. As the national grid authority. In major Swedish cities, the traffic is increasingly managed in close cooperation between Trafikverket and the local Trafikkontoret.

Data aggregators and analysts

There are several actors in this segment that will probably play a part in this scenario. Likely there will be many competing initiatives and services comprising divergent data sources and analyses. If the cost of establishing contextualized analytics competence is not insurmountable, new actors could initiate or buy aggregation or analytics capabilities and provide services to existing actors.

6.4 Identify places with frequent accidents and the cause of these accidents

6.4.1 Goal of Service

- Fewer fatalities: by monitoring patterns in vehicle behaviour and road condition, the cause of the anomaly is identified and warning messages is sent out to vehicles prior to the incident spot thereby avoiding incidents/accidents.
- Improved traffic flow: by using the service it will result in a better traffic flow in general as known trouble spots are detected through the traffic management monitoring centres, the reason for the incidents can be identified and resources can be allocated to remove/avoid that new incidents occur.
6.4.2 Service Description

The services will be operated by a services provider that will offer the services towards the road authority, Trafikverket and its traffic management centre. The services will provide:

1) A tool to identify incidents as they occur, improving the speed of recovery from incidents and accidents as they can be handled faster.
2) An Incident statistics tool with root-cause identification.
3) An incident warning tool that communicates with vehicles on the road to alert or re-route.

The traffic management Centre is monitoring the incident patterns on the roads. The monitoring system looks for frequent and/or continuous abnormal behaviour and is correlated to search for patterns and causes of the incident. When a probable cause of incident is identified, the Traffic Management Centre will send out a message to all vehicles on the road. If the incident cause is related to the road, resources will be allocated to remove the problem (i.e. wild animal, waste on the road, damaged road etc.). The Traffic Management Centre can send out different messages to the vehicles on the road, such as incident warning or re-routing to other road.

For the services to start functioning, data needs to be collected and analysed in order to find algorithms that can correlate the incident events with associated vehicle data. Vehicle data can be combined with data from other sources, such as weather from traffic information or weather sites. Through analyses which use big data approaches to detect anomalies in the traffic pattern, areas with recurring incidents can be pinpointed and plausible root-causes of the incidents can be identified. This will then form statistics with time and space dimension, and it should be possible to use the results for two main purposes.

1. General road incidents with high granularity in the road network. This information can then be used in order to allocate resources to road maintenance and improvement where best needed.
2. It can also be used as an early warning system by real-time processing of data to give indications to the road keeper on arising conditions in the road network needing immediate attention.

In order to make sure that the incidents’ root causes are identified, it is critical that a solution is needed that enables humans to ‘educate’ the system in detecting the root cause of incidents and making the correction classification.

For incident warning, there will need to be a means to communicate to the vehicles and even between vehicles. Vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2l), vehicle-to-network (V2N) and vehicle-to-pedestrian (V2P) technologies—collectively called V2X for Vehicle-to-Everything—are systems that are designed to transmit and receive messages from and to vehicles in order to improve driving safety and traffic efficiency, reduce negative environmental impacts and provide information or entertainment to the driver. Also called Cooperative ITS, V2X communicates and shares information between ITS Stations to give advice or facilitate actions and
decisions with the objectives of improving safety, sustainability, efficiency and comfort beyond that achievable by stand-alone systems.

Figure 21: V2X Technologies (Source: SAFESPOT Integrated Project – EU co-funded FP6)

6.4.3 Service Levels and Timeframe

Initial level of service will be directed toward manually driven vehicles. The current text describes a service designed for a centralized architecture. Service designs based on, for example, Edge computing and local intelligence is an option and might improve the data recording of the incident with the vehicle taking larger part of the decision on the type of relevant data to be used/recorded and the type of sensor data to capture in order to detect incidents.

In order to be able to start this service, authorities need to require that vehicles provide the data, the methods of collecting the data from the vehicles are developed and the tools for analysing the data are tested and approved. Preparing a useful service will require some time because intelligent algorithms that will identify the incident patterns and associate the possible reason for the incident will need to be developed. Nevertheless, with a relatively small penetration in the vehicle park, a reasonably good picture will start to emerge.

The next level of service will be for ADAS and autonomous driving. This will provide incentives to the OEMs to develop new sensors, thereby having a richer set of sensors to record incident data. This will lead to better and more accurate real-time incident warning.

When the service is developed to its full potential, it will improve the quality and accuracy of the probability of the cause of the incidents and their locations, thereby preventing incidents and accidents.

6.4.4 Actors and Roles

Actors:

- Road keepers
- Road authorities
- Analytics service provider
- Vehicle makers
- Owners of vehicles
**Use case: Incident and accident analytics as decision material for road maintenance resource allocation.**

When the data have been collected and processed it will be possible to identify accident- and incident-prone sections in the road network. This data can then be used to quantify and allocate spending on road maintenance in order to optimise resources utilisation based on facts.

Furthermore the material can be used to suggest root-causes for incidents. This information can be used to determine the correct action for improving traffic flow or reduce accidents by warning drivers of dangers.

**Use case: Incident and change traffic pattern in near real-time,**

With anomaly detection in place, it should be possible in near real-time to detect changed behaviour on the roads. In addition, based on trained algorithms analysing the vehicle data and other relevant data sources, plausible root-causes can be identified. This can form the basis of alerting the staff in a Traffic Management Center to take action and also indicate the possible cause of the anomaly.

**Use case: Incident warning and re-route instructions to vehicles on the road**

The Traffic Management Centre collects data, either directly from sensors on the vehicles or from the vehicle OEMs’ telematics service providers to identify abnormal vehicle behaviour and incident events. With the identified vehicle anomaly data combined with other associated data (e.g., road sensors, GPS, weather data, private traffic data), the cause of the incident can be analysed. Frequent and/or continuously abnormal behaviour is analysed and correlated to search for patterns and cause of the incident. When a probable cause of incident is identified, the Traffic Management Centre will send out a message to all vehicles on the road. If the incident cause is related to the road, a service vehicle will be sent out to remove the problem (i.e. wild animal, waste on the road, damaged road).

**6.4.5 Value Proposition**

Traffic Authority:

1) A tool to identifies incidents as they occur, improving the speed of recovery from incidents and accidents as they can be handled faster.

2) A tool that prevents new incidents to occur as it can identify risk areas as they appear, locate the place and communicate warnings or re-route instructions to vehicles on road, thereby avoiding accidents and improving traffic flow.

3) An Incident statistics tool with root-cause identification, thereby helping to plan actions and allocate resources.

Vehicle owners:

1) Reduced incidents and better traffic flow through warning and re-routing instructions in the vehicle cluster.
In relationship towards the overall social goals as defined by Trafikverket.

6.4.6 Data Requirements

Incident detection:

- Suspension sensors, detecting problems on road surface such as pot holes, cracks etc. Road slippery (traction control) together with traction control system or Lane keeping system activated – indicating a wrong sloped curve
- Braking sensors and quick reduction of speed together with radars can identify the reason for breaking or lane change (e.g. car, elk or other big objects can be detected.) Changing lanes without any vehicle in front, reason could be a dead animal on the road, person walking at the side, rubbish or other material, a hole in the road.
- Brake sensors and radars to identify new driving patterns on the road
- Data generated from cameras, lidars, radars, sonic sensors, etc.
- A vehicle that slowed down to turn, this might then cause incidents.
- The incidents also need to be geo-located.
- In order to perform the analysis and find the root-cause, sensor data created prior to and during the incident also need to be included in the incident reports
- Use of other type of external data, such as waze, weather information.

6.4.7 Business Models and Governance

The service is operated by a services provider that will offer the services to the road authority, Trafikverket, and its Traffic Management Centres (TMCs).
The road authority pays a fee for the service, which is included in the budgets of the TMCs. The road authority holds the relationship with the vehicle owners and promotes subscriptions to the service by downloading an app. For vehicle users there would no fee for the subscription.

**BADA Value Flow for Passenger Cars**

Fleet management companies should be very interested in this type of information for scheduling commercial transport. Commercial services would not be covered by free services delivered by a Traffic Management Centre. In order for commercial companies to purchase information beyond the free services offered by the public authorities, the paid services must offer more than the free services.

*Figure 22: DADA Value Flow for Passenger Cars*
6.4.8 Big Data Challenges

Application of machine learning: Anomaly detecting and machine learning could be used to find patterns in incident reports that could lead to defining more accurately where and when incidents are most likely to occur. It is also possible to find plausible root causes for incidents based on machine learning.

Data privacy: It will be necessary to ensure that the GDPR specifications are followed when implementing solutions that transfer data from the vehicle to a collection point.

Where the analysis occurs: The location of the analysis of data received from the vehicle is important because it will be there that the data will be combined with other data sources to generate useful information. All data sources must meet the specifications of the GDPR concerning privacy, and there must be a method built into the collection of data that ensures proper permission for use has been obtained.

6.4.9 Consequences for BADA-partners

Big Data Analytics Company - SICS

In general in order to achieve a highly reliable incident recording a standardised method to define incidents triggers need to be defined, as well format for passing relevant vehicle sensor data that can be used to identify root-cause of the incident.

Volvo Cars
An infrastructure to collect slippery road (*halka*) will be in place during 2016. Solution to expose the information to a services analytics centre need to be develop.

**Scania and Volvo AB**

A basic infrastructure to collect data exist, but not developed for the purpose of this type of data.

**Trafikverket**

The customer of the analytics result will be road authorities, as described above, so figuring out how to make or buy is a question to be considered in this case. In favour of buy would be the potential to share the gains with other road authorities on other markets.

**6.4.10 External Stakeholders**

External data providers would enable a better understanding of root-causes.

**6.5 Road Hazard Warning**

**6.5.1 Goal of Service**

- Fewer fatalities: By monitoring hazard warnings from vehicles and vehicle positions, a warning message will be sent out to vehicles on the road so that vehicles can chose another route to avoid traffic stops and incidents.
- Improved traffic flow: Using the monitoring service will result in better traffic flow in general as vehicles “in trouble” are detected through the traffic management monitoring centres.

**6.5.2 Service Description**

The services will be operated by a services provider that offer the services for the following stakeholders:

1) The road authority, Trafikverket and its traffic management centres
2) Drivers of cars, buses and trucks
3) Rescue cars: Ambulance, Police

The services will provide:

- A tool to identify incidents that have triggered a hazard warning in the vehicles, improving the speed of recovery from incidents and accidents as they can be handled faster.
- An Incident statistics tool with root-cause identification.
- An incident warning tool that communicates with the vehicles on the road to alert or re-route.

1) The Traffic Management Centre is monitoring the incidents on the roads. The monitoring system is triggered by an activated hazard warning.
At the same time, it looks for frequent and/or continuous abnormal behaviour and correlates it with external data such as weather, searching for patterns and causes of the incident. When a probable cause of the incident is identified, the Traffic Management Centre will send a message to all vehicles on the road. If the incident cause is related to the road, a service vehicle is sent to remove the problem (e.g., wild animal, waste on the road, accidents, damaged road, etc.).

For the services to start functioning, a solution needs to be set-up so that the vehicles’ data can be sent to a data platform, and the data platform where it can be processed into useful information to be sent data back to those vehicles that are are in the vicinity of the road incident. This applies for vehicle-to-vehicle communication regarding data communication and vehicle to traffic authorities.

**BADA – Road hazard warning**

![Diagram of BADA Road Hazard Warning Service]

*Figure 24: Configuration of the implemented Road Hazard Warning Service*

### 6.5.3 Service Levels and Timeframe

Initial level of service involves manually driven vehicles, as opposed to autonomous, ADAS-assisted or self-driven vehicles. In order to start up the first basic level of the service, authorities need to require that vehicles provide the data and that they can send hazard warning signals and other positioning data to a centralized data processing system as well as to other vehicles. Other vehicles on road need to be able to receive the active hazard warnings from vehicles that are in their vicinity or from a Traffic Management Center. In order to be able to start up next level of the service that would address autonomous, ADAS-assisted and self-driving vehicles, algorithms need to be developed in order to identify the incident patterns and to associate the reason for the incident. Also, more advanced sensors may be needed to record...
incident data that will lead to better and more accurate incident warning on a continuous basis.

When the service is developed to its full potential it will improve the quality and accuracy of the probability of the cause of the incidents and where it is located, thereby preventing incidents and accidents to occur.

6.5.4 Actors and Roles

Actors:

- Road keepers
- Road Authorities
- Analytics service provider
- Vehicle makers
- Owners of vehicles
- Rescue cars

Use case: Incident warning and re-route instructions to vehicles on the road

The Traffic Management Centre is collecting data from sensors on the vehicles to identify hazard warning incidents. Together with the identified hazard warning, other associated data such as road sensors, GPS, weather data and other relevant external data (e.g., Waze), the cause of the incident is analysed. Frequent and/or continuous abnormal behaviour is analysed and correlated to search for patterns and cause of the incident. When a probable cause of an incident is identified, the Traffic Management Centre will send out a message to all vehicles on the road. If the incident cause is related to the road, an emergency vehicle will be sent out to remove the problem (e.g., wild animal, waste on the road, damaged road, etc.). The Traffic Management Centre can send out different messages to the vehicles on the road, such as incident warnings and re-routing to other roads.

Use case: Incident warning and alerts sent out to rescue vehicles

The Traffic Management Centre collects data from sensors in the vehicles to identify hazard warning incidents. Together with the identified hazard warning and other associated data, such as road sensors, GPS, weather data and other relevant external data (e.g., Waze), the cause of the incident is analysed. Frequent and/or continuous abnormal behaviour is analysed and correlated to search for patterns and cause of the incident. When a probable cause of incident is identified, the Traffic Management Centre will send out a message to all vehicles on road and if the incident cause is related to traffic accidents with people and cars involved, the traffic management can send out a message to the rescue cars for immediate action.

6.5.5 Value Proposition

General

- A tool to identify incidents as they occur, improving the speed of recovery from incidents and accidents as they can be handled faster.
• A tool that prevents new incidents from occurring as it can identify risk areas as they appear, locate the place and communicate warnings or re-route instructions to vehicles on the road, thereby avoiding accidents and improving traffic flow
• An Incident statistics tool helping to plan actions and allocate resources.

Vehicle owners

• Reduced incidents and better traffic flow through warnings and re-route instructions.

Rescue cars

• Quicker response time when an accident has occurred, can save lives.

In relationship to overall social goals defined by Trafikverket.

<table>
<thead>
<tr>
<th>GOAL</th>
<th>VALUE PROPOSITION</th>
<th>REQUIREMENT</th>
<th>DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fewer Fatalities</td>
<td>1.1 Better statistics give better decision material for fact based action</td>
<td>1.1.1 Well defined incident reporting that can be adjusted over time</td>
<td>Vehicle type position</td>
</tr>
<tr>
<td></td>
<td>1.3 Near real-time of incident avoids accidents</td>
<td>1.2.1 Fast anomaly detection and forwarding to appropriate stakeholders for action.</td>
<td></td>
</tr>
<tr>
<td>2. Improve traffic</td>
<td>2.1 Rebuild incident prone road sections improves traffic flow</td>
<td>2.2.1 Fast anomaly detection and forwarding to appropriate stakeholders for action.</td>
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</tr>
<tr>
<td></td>
<td>2.2 Near real-time anomaly detection make traffic centres more efficient</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.5.6 Data Requirements

Incident detection

• Hazard warning signals
• Positioning data (GPS)
• Time stamp
6.5.7 Business Models and Governance

The service is operated by the vehicle OEM or a third-party service provider. The business models are similar to 6.4.

The value for the user is to receive immediate assistance and guidance on what to do without causing traffic accidents. The value for the commercial industry is to avoid traffic queues and congestions. For vehicle users there is no fee.

6.5.8 Big Data Challenges

Application of machine learning: Anomaly detecting and machine learning could be used to find patterns in incident reports that could lead to defining more accurately where and when incidents are most likely to occur. It is also possible to find plausible root causes for incidents based on machine learning.

Data privacy: It will be necessary to ensure that the GDPR specifications are followed when implementing solutions that transfer data from the vehicle to a collection point.

Where the analysis occurs: The location of the analysis of data received from the vehicle is important because it will be there that the data will be combined with other data sources to generate useful information. All data sources must meet the specifications of the GDPR concerning privacy, and there must be a method built into the collection of data that ensures proper permission for use has been obtained.

6.5.9 Consequences for BADA-partners

Big Data Analytics Company - SICS

In general, in order to achieve a highly reliable incident recording, a standardised method to define incident triggers needs to be defined. A second step could be to include a format for passing relevant vehicle sensor data that can be used to identify root-cause of the incident.

Volvo Cars

An infrastructure to collect road hazard warning will be tested during late 2016. Solutions to expose the information to a services analytics centre needs to be developed.

Scania and Volvo AB

A basic infrastructure to collect data exists, but it is not developed for the purpose of this type of data.

Trafikverket

Trafikverket will incorporate the data in its Traffic Management Center.

Rescue vehicles (ambulance, police)
The traffic authorities need to set-up a system solution for communicating with rescue vehicles. In order to quickly send out to expose the information a services analytics centre need to be develop.

6.5.10 External Stakeholders
External data providers would enable a better understanding of root-causes.

6.6 Improved Traffic Information

6.6.1 Goals of Service
Improved traffic information is a very general service, which means that the goal with the service essentially is the same as the overall goal for the society and for public authorities:

- Improved Traffic Safety
- Improved Traffic Flow
- Reduced Emissions – although this might not be the primarily goal for a traffic information service

Car manufacturer and service providers providing traffic information services do have other goals as well, such as to give the driver or the traveller a safe, predictable and comfortable journey.

6.6.2 Service Description
The Traveller, the driver and/or the vehicle receive information about the traffic situation along with timely safety warnings. This information is delivered to the traveller, driver and/or the vehicle using all available types of delivery methods. Data delivered to the vehicle’s on-board systems is processed by these systems and used in advanced and automated driver assistance systems.

6.6.3 Service Levels and Timeframe
There are three service levels that will be implemented over a yet-to-be-determined period of time:

Level 1: Independent services from each kind of actor, such as incident messages or speed flow information from OEM or traffic information service providers, or hazard warnings from OEM-specific car-to-car communication.

Level 2: Common service via standardized vehicle-to-vehicle and vehicle-to-infrastructure communication.

Level 3: Common Service based on big data analysis.

6.6.4 Actors and Roles
The service, Improved Traffic Information, involves many actors in many different ways. The most important actors that might be involved include:

- Public authorities responsible for regulations and policies
• Road operators operating Traffic Management Centres. Usually a Traffic Authority (Local, Regional or National) but private road operators exist.
• Service providers (providing services that include traffic information)
• Integration and/or big data analytics providers (as of today operated by larger service providers)
• Vehicle OEMs operating telematics services and cloud services for collection of VPD and distribution of traffic information services. Telematics services and cloud services can be hosted in-house or by third-parties.
• End user traveller, driver, vehicle (as a user of data)
• Data supplier:
  o Vehicle as a generator of data (ownership of data might be transferred to fleet owner or OEM)
    ▪ Automatic internal sensor-compiled data
    ▪ Automatic external sensor-compiled data
    ▪ Manual driver-initiated data
  o Infrastructure (road owner or road-side service provider)
  o Map data (in reality HERE, TomTom or Google)
  o Other data sources

Figure 25: Level 1 Traffic Information Service

The example above is based on BADA total data flow: Data from TomTom map data + infrastructure based data --> TomTom integration --> TomTom traffic service --> Web/Mobile App/Device in vehicle.
Figure 26: Level 2 Traffic Information Service

The example above is based on BADA total data flow: Data from all kind of sources (vehicle data is main source) -> standardized interface (V2I) -> HERE integration (open location platform) -> HERE traffic service -> Web/App/Device In vehicle.

Figure 27: Level 3 Traffic Information Service

The example above is the complete Ecosystem: Data from all kind of sources (vehicle data is main source) -> standardized interfaces (V2I and V2V) -> HERE/Amazon integration and big data analytics platform + (directly to InVehicle) platform -> Use of Traffic Management Plans, etc. from Traffic Control Centres -> HERE traffic service -> Web/App/Device/In vehicle.
FFI – Big Automotive Data Analytics

Level 2 and 3 can be configured with an extended role for public authorities where a Public Information, Integrating and Sharing Platform is established as an alternative to the HERE OLP platform in the examples.

6.6.5 Value Propositions

Figure 28: Value Proposition for Improved Traffic Information

A Traffic Information Service provides the following value proposition for the driver/traveller:

- Less time wasted in traffic queues by drivers
- More dependable surface transport journey times
- Customer who feels safer and more comfortable when driving
- More efficient use of the road network, which means more value for money
- Smoother and less congested traffic, which means reduced emissions

A Traffic Information Service provides the following value proposition for the car manufacturer:

- Customers who feel safer and more comfortable when driving

A Traffic Information Service provides the following value proposition for the public authorities:

- Fewer traffic-related deaths and injuries
- More efficient use of the road network, which means more value for money
- Smoother and less congested traffic, which means reduced emissions

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Requirements in order to fulfil the value propositions

- Recommendation to drivers on when to start journey
- Recommendation to drivers/vehicles on route to take
- Recommendation on currently best multimodal travel option to traveller
- Provision of information regarding deviations in time schedule and suggestions for alternative to chosen multimodal journey
- Provision of traffic flow situation on chosen route
- Provision of road works information to drivers/vehicles
- Provision of road and weather conditions to drivers/vehicles
- Provision of current and upcoming events influencing chosen route
- Provision of temporary closed road segments and lanes
- Provision of information regarding incidents, accidents, stationary/slow vehicles, wrong way driving, etc. to drivers/vehicles
- Provision of hazardous locations to drivers/vehicles

6.6.6 Data Requirements

Static data

- Road network description in three dimensions including detailed lane information
- Traffic regulations including:
  - Parking regulations
  - Standing regulations
  - Passing regulation
  - Turning restrictions
  - Speed limits by time of day
  - Pedestrian crossing regulations
  - Yield regulations at intersections, roundabouts, parking lots and garages
- Attributes describing the road network including VMS, traffic lights
- Pre-defined Traffic Management Plans including alternative and recommended routes
- Parking areas and multimodal exchange points

Historical data

- Accident and incident statistics
- Historical weather and road conditions
- Traffic flow statistics
- OD-statistics
- CO₂ emission value data summarized by vehicle type

Real-time data

- Vehicle location and destination
- Traffic flow
- Incidents
- Road conditions
- Road works
- Events
- Temporary closed bridges, tunnels, road segments, lanes
FFI – Big Automotive Data Analytics

- VMS - actual message and intention
- Traffic light status and schema
- Current valid Traffic Management Plan when a specific TMP is in use for a certain area
- OD for vehicles and people
- Current air quality per road segment

Real-time emissions data received and processed

A vehicle transmits greenhouse gas (GHG) emissions data along with type of vehicle (car, truck, van, etc.) date, time, exterior temperature, geographic position of the vehicle, vehicle speed. The GHG data is processed for each road segment by type of vehicle, day of year, time of day. The data is sent in real time.

Real-time emissions data sent while driving

A sample list of data that could be sent in real time during a driving cycle includes the following:

- Vehicle type
- Position (X, Y, Z)
- Date
- Time of Day
- Exterior Temperature
- Speed
- Inclination
- CO₂ emission value

Braking and steering sensor data sent at end of driving cycle

Location (lat/long) of where hard braking or sudden turning of the steering wheel occurred, along with the force of braking and details of steering movement.

Time of day; day of year; temperature and weather conditions

6.6.7 Collecting the Data

Data is collected from the vehicles using standards such as SENSORIS or in proprietary formats delivered to the individual OEMs’ telematics service providers. See Figure 24.

6.6.8 Delivering the Information

Data is delivered to the vehicles, either from one vehicle to other vehicles, or from the infrastructure to vehicles, using accepted industry standards, such as ETSI ITS-G5 DSRC/IEEE 802.11P or 3GPP LTE V2X. The standards development organizations in the U.S. have chosen to promote a vehicle-specific version of the DSRC standard, called Wireless Access in Vehicular Environments (WAVE), which is an amendment to the 802.11 standard. WAVE is known as IEEE 802.11p. In the EU, ETSI developed ITS-G5, which is based in large part on IEEE 802.11p, but it is not identical to it. It has a different protocol stack and has added a Facilities Layer between Networking and Transport and Applications Layers.
For 3GPP, the initial Cellular Vehicle-to-Everything (C-V2X) standard for inclusion in the Release 14 was completed in mid-September 2016. It contains a target specification for Cellular V2X (C-V2X) which builds on the existing LTE connectivity platform for automotive, enhances LTE Direct for V2X communications and leverages existing LTE networks for V2X network communications. 3GPP Release 14 is due to be finalized in early December 2016 and released in March 2017.

![Figure 29: LTE-V2V wireless technology seen as a useful interim step to enabling collision avoidance applications in consumer vehicles](image)

### 6.6.9 Business Models and Governance

Payment for traffic information services can be accomplished in different ways:

- Vehicle owner/driver pays for the service because of the value the service adds to the journey – flat rate or pay per use
- OEM pays for the service as part of the vehicle experience
- Public authorities pay for the service and deliver it free to vehicles as a way of promoting increased traffic safety and increased traffic flow
- The vehicle owner agrees to receive advertising in return for receiving the information.

The most likely scenarios are the vehicle owner paying for the service, either to the OEM or to a third party service provider (as shown below in Figure 30), and the OEM bundling the service cost into the cost of the vehicle or as part of a total package that the customer purchases with the vehicle. It is possible that traffic authorities may deliver certain types of emergency data, such as severe weather warnings, but not likely that they will provide the full range of traffic-related information. An advertising model with, for example, Google (as shown in Figure 31) could be a good alternative for cost-sensitive customers in lower-priced car models.

None of these options will require any changes in business models for the service providers since customers are currently paying for some services, receiving others free from the OEMs and public authorities, and receiving traffic and routing information as part of a bundle of services that come with a mobile phone subscription.
6.6.10 Big Data Challenges

The more advanced the Traffic Information Service, the more the need for Big Data Analytics!
6.6.11 Consequences for BADA-partners

**Trafikverket**

- Start finding a policy and strategy for the responsibilities regarding traffic information – what are Trafikverket responsible for and what can be done by commercial actors.
- Data needed for Trafikverket’s own business could be bought from commercial data suppliers.
- Develop the ways exchange of data and traffic information can be done to and from Service Providers and fleet management centres operated by fleet owners or OEMs.

**VCC, Volvo, Scania**

- Decide if operating a Traffic Control Centre is profitable.
- Define how to cooperate with PAs to get access to TMPs and information in a harmonized way.
- Shape the role versus large Service Providers.

**SICS**

- In order for the Big Data system to work there will be need to be a great deal of machine learning and data analytics tools developed

6.6.12 External Stakeholders

**Service providers**

- Determine which services should be free to end users due to the use of sensor data derived from their vehicles.

**Existing Data providers**

- Determine how to price data received from vehicles and how to charge for the use of the integrated data

**Urban traffic management**

- Determine how to ensure that an increased volume of traffic-related data is not used to disturb the quality of life as a result of an increase in the number of drivers selecting alternate routes to avoid traffic congestion.

**Data aggregators and analysts**

- Determine how to price aggregated data to service providers and to public agencies.
6.7 Traffic Management 2.0 and Beyond

6.7.1 Goal of Service
Traffic Management is provided by public authorities and road operators. The goal with Traffic Management is essentially the same as the overall goal for the society and for public authorities:

- Improved Traffic Safety
- Improved Traffic Flow
- Reduced Emissions

6.7.2 Service Description
Traditionally Public authorities and road operators have managed traffic flows by changing traffic light schedules, using VMS messages to change speed limit per lane or deny access to lanes, tunnels, bridges, etc. Traffic Management plans includes policy and strategy based plans and actions set by public authorities and road operators.

Traffic and travel service providers delivers traffic information to road users. Fleet management provided by fleet owners or in the future by vehicle manufacturer means direct access to in-vehicle system in their fleet. With the exchange of Traffic Management plans and other kind of traffic information between public authorities and service providers/fleet owners a new and higher level of traffic management could be reached. The traditional way of steering traffic via road side equipment like VMS, can be complemented by harmonized information, advice and orders directly to travellers, drivers and vehicles via in-car services.

The future of Traffic Management might include individual allocation of space/route and time for each vehicle. This emphasize the need for cooperation between different Traffic Management or Control Centres with exchange of information and hand-over of the control of the vehicles.

6.7.3 Service Levels and Timeframe
There are two service options that will be implemented over the next few years:

Option 1: Harmonized Traffic Management for each region as a result of interaction between road authorities and service providers.

Option 2: Harmonized Traffic Management on a pan-European level as a result of cooperation between different road authorities or Traffic Management Centres to achieve consistency and harmonization between TM-plans, principles and measures.

In addition to these two option a much higher level of Traffic Management might be possible to introduce in the long run. This level means individual allocation of space/route and time for each vehicle.

6.7.4 Actors and Roles
A reference architecture for TM 2.0 is established as seen below.
Mapping the actors in the above architecture with the actors identified in BADA will result in this:

- **Road Infrastructure Owner** = Traffic Authorities, although a road infrastructure owner can be a private actor.
- **Content Service Provider** = Actor integrating and processing data.
- **In Car Service Provider** = One kind of Service Provider (the most common)
- **Road Side Service Provider** = Another kind of Service Provider (in Sweden, usually the road infrastructure owner)
- **Service Consumers** = End Users (vehicle, driver, traveller)

As TM 2.0 means harmonizing Traffic Management with traffic information from service providers, the same actors as listed in the Traffic Information service are also valid for Traffic Management. Even if we look at a high level of Traffic Management with allocation of space and time for individual vehicles, the same kind of actors are involved even though the roles are a bit changed.
6.7.5 Value Propositions

Traffic Management provides the following value proposition for the driver/traveller:

- Greater peace of mind for travellers
- Less time wasted in traffic queues by drivers
- More dependable surface transport journey times

Traffic Management provides the following value proposition for the public authorities:

- Fewer traffic-related deaths and injuries
- More efficient use of the road network, which means more value for money
- Smoother and less congested traffic, which means reduced emissions

Requirements in order to fulfil the value propositions

- Road authorities can control traffic flow intensity and provide information about it to Service Providers. This means use of traffic lights or ramp meters to change the traffic flow. E.g. expected delays by change of traffic signal plans in the near future.
- Change of infrastructural objects status and the provision of information regarding that. Closing and opening of tunnels, bridges and road segments or actual delay at these objects. Closing and opening of lanes at these objects.
- Use of Variable Message Signs and provision of the intention of VMS.
- Provide recommended detours in case of traffic events (e.g. traffic jam).
In case of events (e.g. concert, exhibition) provide specific Traffic Management plans plus information on additional (temporal) parking areas.
- Driver/Vehicle feedback to Road operator/Traffic Control Centre.
- Information regarding origin-destination of people and vehicles available at Traffic Management/Control Centres.
- Information regarding HCT-vehicles and Platoons available at Fleet Management Centres and Traffic Management Centres.
- Information regarding AD-vehicles available at Fleet Management Centres and Traffic Management Centres.

6.7.6 Data Requirements

**Static data**
- Road network description in three dimensions including detailed lane information
- Traffic regulations
- Attributes describing the road network including VMS, traffic lights
- Pre-defined Traffic Management Plans including alternative and recommended routes
- Parking areas and multimodal exchange points

**Historical data**
- Accident and incident statistics
- Historical weather and road conditions
- Traffic flow statistics
- OD-statistics
- CO₂ emission value data summarized by vehicle type

**Real-time data**
- Vehicle location and destination
- Traffic flow
- Incidents
- Road conditions
- Road works
- Events
- Temporary closed bridges, tunnels, road segments, lanes
- VMS - actual message and intention
- Traffic light status and schema
- Current valid Traffic Management Plan when a specific TMP is in use for a certain area
- OD for vehicles and people
- Current air quality per road segment
- HCT-vehicle off mandatory route
- Location and status of Platoons
- Position and mode of AD-vehicle

6.7.7 Business Models and Governance

Payment for Traffic Management is usually by public authorities as a way of promoting increased traffic safety, increased traffic flow and reduced emissions.
Commercial agreements are needed between public authorities and road operators on one side and service providers and fleet operators on the other in order to find a way to exchange Traffic Management plans and other kinds of information.

**Figure 33: BADA Trafikverket Value Flow**

### 6.7.8 Big Data Challenges

Looking at the most advanced Traffic Management service delivery system when allocating space and time dynamically and individually for each vehicle and person, we are talking about a huge Big Data challenge!

### 6.7.9 Consequences for BADA-partners

**Trafikverket**

- Develop a way of exchanging TMPs and information with Service Providers and with fleet management centres operated by fleet owners or OEMs.
- The advanced level of Traffic management means huge challenges for Trafikverket and other operators of Traffic Management Centres. Start finding a policy and strategy for how to meet these challenges.

**VCC, Volvo, Scania**

- Decide if operating a Traffic Control Centre is profitable.
- Define how to cooperate with PAs to get access to TMPs and information in a harmonized way.
- Shape the role versus large Service Providers.

### 6.7.10 External Stakeholders

**Service providers**
• Determine which services should be free to end users due to the use of sensor data derived from their vehicles.

**Existing Data providers**

• Determine how to price data received from vehicles and how to charge for the use of the integrated data.

**Urban traffic management**

• Determine how to ensure that an increased volume of traffic-related data is not used to disturb the quality of life as a result of an increase in the number of drivers selecting alternate routes to avoid traffic congestion.

**Data aggregators and analysts**

• Determine how to price aggregated data to service providers and to public agencies.
7 Business Model Adaptations

7.1 Vehicle Manufacturers and Fleet Operators

There are precedents for vehicle manufacturers or fleet operators offering their cars or trucks as traffic probes and delivering time-stamped speed data. In some cases, the manufacturers or operators are paid for the data, while in others, their drivers receive processed traffic information in return for delivering data. With Big Data, there will be much more than simply time-stamped speed data, and the result will not necessarily be usable by an individual driver at a specific time and place. Vehicle manufacturers will need to develop more complex cost-benefit analysis calculations to justify the cost of delivering and administering data provision.

![Figure 34: The Connected Car Money Flow adding data flow from the vehicle (Source: M.L. Sena Consulting AB)](image)

7.2 Road Organisations

Today, infrastructure data that is provided to commercial entities or to governmental agencies is done so with commercial agreements. These agreements cover the eventual use and resale of the data. There should not be any need to change the current business model to adapt to Big Data-based applications.

7.3 Map Data Suppliers

The best map data comes from organisations that are in the business of delivering map data, not from organisations that are in a completely different business and use map data to support that other business. Google is in the advertising brokering business and its map data is an enabler of geographic searches for places that pay
money to Google. Companies pay Google to reference its map data, but these fees are a pittance compared to its income from advertisers. More importantly, Google is not dependent on its map data to remain in business and could one day stop supporting it, just as Microsoft stopped supporting its own mapping efforts. HERE and TOMTOM are in the map data business, and if they do not produce data that it can sell at a price acceptable to its customers, they are out of business.

**Figure 35: HERE Map Data on Connected Navigation Device vehicle (Source: M.L. Sena Consulting AB)**

During 2016, HERE (formerly NAVTEQ) redefined its business from being an infotainment map data and content provider to automotive and enterprise customers to being the operator of an Open Location Platform for strategic initiatives. They are a true Integration Platform Provider. With the addition of automated data collection tools and the recent addition of direct-from-vehicle feeds of sensor data from the vehicles of its three owners, Audi, BMW and Daimler, the amount of data that can be used to provide location context has risen dramatically.

### 7.4 Spatial Data Providers

In return for delivering data from vehicles, the car manufacturers (and/or the purchasers/drivers of the vehicles) would obtain financial rebates for map data, and have access to the latest research and test results for High Definition maps from HERE and TomTom that can be used in autonomous driving.

### 7.5 Navigation Hardware Providers

The hardware suppliers make money selling hardware and related services. If integrating spatial data helps the hardware suppliers sell more hardware, then the investments made in assembling, processing and delivering the data will be justified within their current business models. However, if there is no direct link between the data they deliver, even if they charge for it, and the eventual systems used on-board by the customers for this data, it is difficult to see a model that will support their
position as a competitor to companies that are already in the business of licensing spatial data.

7.6 Big Data Analytics Companies

Companies that are in the BDA business have developed two strategies: selling software and service support related to the software; and, selling BDA as a service, usually cloud-based. These companies are in a position to develop service provider capabilities, either growing them internally or acquiring existing service providers. Big Data Analytics service providers will not have commercial agreements directly with Service Providers. They will deliver the results of the analyses back to the Integration Provider or to a virtual Big Data Analytics Provider.

7.7 Service Providers

With Big Data that is integrated from multiple sources and then processed through an analytics engine that does not necessarily belong to the service provider delivering the results to customers, there will need to be business model adaptations. If Waze or Apple choose to become part of the Big Data ecosystem, and if there were payments attached to using the results, they would either have to charge users a subscription fee—which they do not at present—or they would have to find other ways of generating income. Traffic automation service providers earn money by providing a platform that connects information from the originators of the content (e.g., car park owners) and the customers who want to have the information. They are brokers. When they add a payment component, they earn additional money by charging a service fee to complete the transaction. If there is additional data that can be produced as a result of big data analytics, and there is a provider of this data that wants to reach end users, these companies could extend their platforms to include the additional data. There does not seem to be any business model change required to do so.

7.8 Customers

Customers are used to receiving navigation and ADAS services for free when they purchase the on-board systems that deliver the services. They are also used to paying for mobile telecommunications in order to receive free services on their smart phones, and they are now familiar with the business models that are based on the customer providing data (e.g., to WAZE or Facebook) in return to receiving services for free. Customers have not shown great interest in paying for map data updates or traffic information as a service.

7.9 Platform Operators

7.9.1 eMobility Marketplace Platform

An eMobility Marketplace Platform connects service and content providers with commercial and private users. With the rapid and expansive growth of both online mobility services and sources of transport data, there is a growing need for places where users can find service applications and where service and data providers and
transport operators can publish data and the services they offer. Today, those who are engaged in developing mobility applications (e.g., traffic information providers) negotiate contracts with those who have content they would like others to use (e.g., public road authorities) on a one-to-one basis, with no common set of rules on how to engage with other mobility operators on a pan-European level. An eMobility Marketplace Platform, like the one developed by the MOBiNET Consortium\textsuperscript{10}, delivers a set of technical components and the organisational structure for an e-mobility marketplace that enables and supports multiple business models.

Currently the deployment and delivery of services for ITS requires one-to-one negotiations between business parties. Multi-party negotiations take a considerable amount of time, and incompatible systems create barriers for providing services on a Europe-wide scale. These constraints on wider development and deployment also apply to obtaining data available from different public and private sources. The processes are inefficient. Implementing services in new regions or for new customers often requires expensive equipment or infrastructure, and business-consumer relationships may be limited to a specific set of services by specific providers due to technology.

MOBiNET is a European research and development project that has the goal of addressing these constraints. MOBiNET is a technical platform and EU-wide e-marketplace that enables the interactions between suppliers, developers and users of mobility-related content and services. It offers a directory for publishing and editing business-to-business (B2B) and business-to-consumer (B2C) services as well as functionality enabling and supporting interoperability between data sources. When operational, the services will be offered across Europe without the need for standardised hardware. The MOBiNET platform architecture provides the required infrastructure functionality to allow service providers to easily compose their services based on available data or other B2B services, and to deliver their services to end users. This is provided by core components as shown in Figure 36.

\textbf{Figure 36: MOBiNET eMobility Marketplace Platform Architecture}

\textsuperscript{10} MOBiNET is co-funded by the a consortium of thirty-three public and private organisations and the European Commission under the 7th TRD Framework Programme, Directorate General for Communications Network, Content and Technology (FP7-ICT-2011-6.7) – Grant agreement no.: 318485.
The guiding principle of for the MOBiNET platform has been to ensure that services and content offered via the platform will be compatible and interoperable with each other.

In parallel with the MOBiNET platform development, MOBiNET designed and developed a number of reference transport and mobility services with Europe-wide interoperability potential. The development and operation of these proof-of-concept services are enabled and facilitated by the availability of the core components services. These representative services have been demonstrated and tested in eight pilot sites in the nine countries represented in the project in order to evaluate and provide “proof of concept” of the overall credibility of the concept both from the technical and business standpoint. One of proof of concept services, Non-Stop Truck (NST), was developed by MOBiNET Project Consortium member Volvo Technology Corporation.

**MOBiNET Non-Stop Truck service shows Europe-wide deployment potential**

MOBiNET Non-Stop Truck (NST) service is one of the use cases trialed to demonstrate the MOBiNET “proof of concept”. The NST service transfers the weight information from a truck directly to the road administrator while the truck is in motion. The generic term for this type of function is Weigh in Motion (WiM). When the vehicle passes a road-side ITS-station, the in-vehicle ITS-station broadcasts the weight of the vehicle together with an identifier to the road-side ITS-station.

The benefits would accrue to both the truck operator and to the road authority. The truck operator avoid stopping at a weighing station, saving time and fuel. The road authority save on roadside equipment and operating costs of the weighing stations.

MOBiNET extends these advantages to trucks that cross national borders, allowing a fully pan-European WiM service. The NST application proves the integration of the national enforcement authorities with the vehicles via the MOBiNET platform. This means that the authorities in each country would have only one interface to all vehicles entering the country, via MOBiNET, rather than requiring all truck manufactures that wish to use their WiM service to adapt their systems to their specific message protocol or sensor technology. Fleet operators, from the largest to the smallest, would as a result have a major incentive to install the necessary technology to use the WiM service.
MOBiNET envisages a global multi-vendor business-to-business market place where service providers can publish and exchange their products and services and thereby enhance their offering and customer base. Public and private providers can publish services and data in the MOBiNET Service Directory to a wide and broad community, facilitating the creation of innovative solutions or enhancing existing service. MOBiNET provides a toolkit that can be utilised by developers to develop or further enhance their services.

MOBiNET innovations include not only a directory for any transport and mobility service, but also an authentication and identity management scheme for single sign-on by any user for multiple services, a unified accounting and billing framework to support roaming by users and payment clearing between providers. A secure operating environment for both in-vehicle and portable end-user devices provides service consumers with a view of available mobility services while offering service providers a view of all connected users. In addition, MOBiNET delivers tools for the B2B community for automatic negotiation of service agreements when adding extra service components and data sources to existing service offerings.

MOBiNET lowers the barrier of entry for SMEs and start-ups. The low organisational and technical barriers imply that it will be easy to deploy new, improved or complex services. It will speed up the development of new services because data that may be relevant for several services will only need to be referenced in MOBiNET’s Service Directory once. Having all the services and data referenced in the same directory will optimise their use and permit project partners to propose them to other cities and regions in European
countries.

MOBiNET enables interoperability among EU mobility services in terms of payment, billing and clearing through a dedicated component capable of managing financial transactions for membership and business fees. The MOBiNET platform gives each user a single identity. The MOBiNET Identity Manager authenticates the user who can connect from whichever provider’s login page and device using the user profile created with their own provider. With the help and support of the MOBiNET privacy framework, programmers can develop creative applications based on MOBiNET services without having to add the complexity of implementing privacy-oriented requirements. A certification framework for MOBiNET services, applications and data incorporates choices regarding the future development of MOBiNET, the rights and obligations of individual users and service providers and their business opportunities.

**MOBiNET e-marketplace to reinforce current business models for business and public authorities in Europe**

As a research project with specific business interest, MOBiNET examines not only the technical but also the commercial viability of a future commercial mobility platform. The development of the technical platform is therefore supported by a dedicated business analysis aimed at identifying the organizational options for MOBiNET’s eventual operation. Physical and virtual marketplaces have a well-defined business model as two-sided networks. A platform provides the opportunity for buyers and sellers to meet, and the platform operator takes a fee for enabling the transaction between both buyers and sellers. The MOBiNET Legal Identity (or MLE) is the project working term used for the organisation that will be responsible for the overall operation of a multi-vendor, multi-user platform for Europe-wide mobility services. To be sustainable, a marketplace must generate individual benefits to all participants involved, including the owners and operators of the marketplace platform. The MOBiNET project analyzed three legal entity options, one for-profit and two not-for-profit. Based on these options, three business models were developed to show the additional value of MOBiNET for the public and private participants. Each of the business models have budget implications for the initial building of the platform based on the assumptions of the type of organisation that would be established for governing the operations and the types of levels of service that the platform would offer.
The business model Canvas for MLE For-profit – High service

Figure 38: Business Model Canvas for a For-profit MOBiNET Legal Entity

Figure 39: MOBiNET integrated into the Big Data Integration and Analytics Platform
8 Privacy and legislation

On May 25 2018, the 1995 Data Protection Directive will be replaced by the General Data Protection Regulation (“GDPR”). The world of data has radically changed over the past years and so will the regulation. The regulation will have a great impact within the European Union, as well as on the future of the information society. GDPR will govern how business collect, utilize, and share personal data collected from European citizens. The aim of the new regulation is to harmonise the way data is handled across the Union. Furthermore, unified rules will allow businesses to make the most of the opportunities of the Digital Single Market by reducing regulation differences and enhancing from reinforced consumer trust. GDPR will aim to shift control of personal data back to the owner of that data. This rather than submitting all rights once a service is used and passing off ownership of submitted data to a service provider. It benefits companies that are EU-based to build data protection into their system design and infrastructure. Likewise it will affect organisations inside and outside the Union.

Organisations not complying with the regulation will risk severe penalties. For noncompliance, businesses will face fines of up to 4 % of their global turnover or 20 million euros, whichever is higher. The key elements of GDPR are first of all the right to be forgotten. This will require companies to have an advanced system of data management. Organizations must have access not only to the data, but also the context associated with data throughout the company. Capability to discover where and in what context personal information is situated will be essential. Some data are hard to access and discover, yet still obliged to be deleted. Secondly, individuals must consent to all use of their personal information. Thirdly, the new rules of mandatory breach notifications will force companies to achieve a fast response technology. Last but not least are the risks of large fines. Someone needs to be held accountable for the data. Even if an organization does not have a location within the Union, the organisation needs to comply with GDPR if their services are targeted at citizens within the Union.

As mentioned above, the aim of the GDPR is to protect the personal data and integrity of citizens in the European Union. This includes data such as their name, email address and IP-address. Basically everything that directly or indirectly can identify a living person are considered to be personal data. As such, a key component of the GDPR is building in privacy security from the start into all systems, so called “privacy by design”. Furthermore the GDPR also dictate a few fundamental new principles, one of them being that organisations should only store the data they absolutely need for minimum period of time. Once the data is no longer needed, it must be destroyed or anonymized.

Along with the requirements around keeping users data safe, the regulations also includes mandatory data breach notification rules. Companies need to actively work with data protection and privacy by design to assure a minimal risk of breach. Yet in the event of a data breach of personal data, the breach must be reported to the
supervisory authority within 72 hours of the breach’s discovery. Furthermore, in case
the organization contain high risk data, the organization may also need to notify every
affected user.

In this report we have attempted a risk based approach to five services of the BADA
project. The appropriate organisation’s controls must be developed according to the
degree of risk associated with the services. Data protection safeguards must be
designed into the services or vehicle from the earliest stage of development.
Moreover privacy-friendly techniques such as anonymization and pseudonymisation
will be encouraged to reap the benefits of big data innovation while protecting
privacy.
9 V2X-communication - standardization and legislation

A raising question is how to ensure reliable communication between the vehicles, infrastructure and servers to support future ITS-applications and how to build a mission critical network. Connectivity is definitely seen as a pre-requisite for Automated Driving and the vehicle clouds are part of the solution. Technical challenges related to the communication infrastructure include:

- Redundancy and seamless handover
- Interference
- Co-existence of cellular and ad-hoc communication
- Security issues

It is, however, important to have in mind that radio communication can fail.

It is agreed that hybrid communication solutions are needed, using both the cellular network (3G, LTE, 5G) and short range communication. Most of day1- and day-1.5-services are not time critical and can rely on the cellular network. When it comes to more time critical applications with low latency requirements, short range communication will probably be needed at least for V2V-services. ITS-G5 (IEEE 802.11p) has been the chosen standard for short range communication and safety applications in the 5.9 GHz-band, but we now have a situation where the mobile network industry and 5GAA (5G Automotive Association) promotes the alternative standard called Cellular-V2X (or initially LTE-V2X). The 5.9 GHz-band will probably not be enough to host both of them at least in the long run. The figure below shows the roadmap promoted by 5GAA.

Figure 40: The evolution of V2X short range communication according to 5GAA

Although mobile networks and wireless communication are very much in focus, one should not forget that fixed networks and fibres along highways can be seen as a sort of backbone for the communication infrastructure.
10 Vehicle Data Access

10.1 Options Recommended and Evaluated by DG-MOVE

The EC Directorate-General for Mobility and Transport (DG-MOVE) commissioned a study by the UK-based TRL, the title of which is Access to In-vehicle Data and Resources. The Report reviews the results of the EC-run C-ITS Deployment Platform WG6. This working group was established to examine potential ways to “give access to in-vehicle data and resources in order that service providers could propose services based on data to their customers.” Giving access means either encouraging or requiring through regulation OEMs to share any or all data that is collected by the vehicle from systems installed by the OEM and communicated from the vehicle using systems also installed by the OEM.

NB: There are no restrictions on either public or private entities offering devices to consumers that can be installed in a vehicle as a so-called ‘aftermarket fit’ device or a device that connects to the standard OBDII port. There are many such devices on the market today for all types of applications from stolen vehicle tracking and usage-based insurance to fleet management.

What is under discussion with the EC is the sharing of all data from OEM-installed, factory-fit devices with any entity that could propose services based on this data to the entity’s customers.

In Annex 1 to the initial report from the C-ITS WG6, the working group identified what it believes is current EU legislation on open platform architecture. It points to the ITS Action Plan adopted by the European Commission in December 2008 that includes the “adoption of an open in-vehicle platform architecture for the provision of ITS services and applications, including standard interfaces. The outcome of this activity would then be submitted to the relevant standardization bodies.” It also points to the ITS Directive (2010/40/EU) which calls on the Commission to adopt specifications and standards for linking vehicles with the transport infrastructure (priority area IV). These shall include the following:

1. Specifications for other actions

1.1. The definition of necessary measures to integrate different ITS applications on an open in-vehicle platform, based on:

— the identification of functional requirements of existing or planned ITS applications,

— the definition of an open-system architecture which defines the functionalities and interfaces necessary for the interoperability/interconnection with infrastructure systems and facilities,

— the integration of future new or upgraded ITS applications in a ‘plug and play’ manner into an open in-vehicle platform,
— the use of a standardisation process for the adoption of the architecture, and the open in-vehicle specifications.

The Council and the European Parliament reached an agreement at the end of 2014 on the Regulation of the European Parliament and of the European Council concerning type-approval requirements for the deployment of the eCall in-vehicle system and amending Directive 2007/46/EC. This agreement includes provisions regarding an interoperable, standardised, secure and open-access platform:

Recital (9) of Regulation of the European Parliament and of the Council concerning type-approval requirements for the deployment of the eCall in-vehicle system and amending Directive 2007/46/EC: "In order to ensure open choice for customers and fair competition, as well as encourage innovation and boost the competitiveness of the Union’s information technology industry on the global market, the eCall in-vehicle systems should be based on an interoperable, standardised, secure and open-access platform for possible future in-vehicle applications or services."

Article 10a (2) of Regulation of the European Parliament and of the Council concerning type-approval requirements for the deployment of the eCall in-vehicle system and amending Directive 2007/46/EC: "Following a broad consultation with all relevant stakeholders and a study assessing the costs and benefits, the Commission shall assess the need of requirements for an interoperable, standardised, secure and open-access platform. If appropriate and no later than [two years after the entry into force of the revised type-approval Regulation], the Commission shall adopt a legislative initiative based on those requirements."

It is unlikely that the automotive OEMs were paying strict attention to the ramifications of these clauses when they were included in documents that were intended to regulate vehicle-to-vehicle/infrastructure communication and eCall. Nevertheless, the Commission is now using them to attempt to require OEMs to deliver data that they had intended to use for their own business purposes. The European vehicle OEMs have argued, mostly through ACEA, its trade association, that the development of services by the OEMs, and the potential revenue that could be generated from these services, has been one of the principal incentives for their substantial investments in connected devices over the past two decades. ACEA has proposed what is called the Extended Vehicle (ExVe) ISO Standard 20077 and 20078.

The 250-page TRL Report evaluates the three technical solutions WG6 devised for providing unfettered access to in-vehicle data. They identified three basic solutions.

4. In-vehicle Interface
5. On-board Application Platform
6. Data Server Platform (DSP)

Three sub-options were included by WG6 for the DSP.

- Extended Vehicle
- Neutral Party Shared Server
- B2B Marketplace Platform
10.1.1 In-vehicle Interface

The In-vehicle Interface option would require OEMs to install a special, standardized on-board device communicating directly with public and private service providers. This is similar to the single function EU-eCall system that communicates directly with PSAPs. A set of standardized messages for different types of services would need to be pre-programmed on these devices (e.g., like the minimum set of data (MSD) for EU eCall), and interfaces to the vehicle’s ECUs and CAN would be required with access via a gateway provided by the OEMs.

Although an OBDII dongle approach is mentioned in the report as the solution for this option, this is clearly an error since it is possible today to install any type of OBDII-compatible device in any vehicle and to send data messages directly to service providers when the appropriate communications module with an internal SIM or tethered interface to a mobile phone are provided. This solution is not, however, allowed with EU 112 eCall since the device must be integrated and type approved as part of the Whole Vehicle Type Approval process.

![On-board Devices Communicating Directly with Public and Private Service Providers](image)

**Figure 41: On-board Devices Communicating Directly with Public and Private Services Providers**

10.1.2 On-board Application Platform

This option separates the on-board device from the data assembly and communication function, but it still involves the OEMs installing something in their vehicles that is, in a sense, out of their control. The idea is that the application platform would be programmed to develop multiple message types that could then be communicated directly to the various public and private service providers. It is also suggested that this platform could be updated with new message packages for different types of services.
10.1.3 Data Server Platform

10.1.3.1 Extended Vehicle

The solution proposed by the vehicle OEMs, and the one recommended by the BADA Project Team, is the ISO-standardized Extended Vehicle in which the vehicle communicates as it does today, to the OEMs’ own TSP’s back-end servers, either run by themselves (as Scania and Volvo Trucks do) or by trusted third parties (as Volvo Cars does with WirelessCar and Ericsson). From the TSPs, data would be transferred to service providers. There are two solutions allowed by the EU eCall regulations, one in which a standard EU 112 eCall is made from the vehicle and connects directly as a voice call with an embedded Minimum Set of Data message. The other is a so-called Third Party Service in which the vehicle connects to a call center operated or contracted by the OEM to filter false eCalls before connecting real eCalls with the appropriate PSAP. This second solution routes data messages to the TSP and the voice calls to the third party service provider (TPSP).
Each OEM’s TSP would integrate message providers for any service. The messages should be standardized in the same way as those coming directly from the vehicle with the on-board Application Platform.

**10.1.3.2 Shared Server**

The second option is termed a Shared Server in which a neutral third party would operate the back-end server to which all vehicles would communicate their data, with the exception of eCall data. With such a solution in which the OEMs’ TSPs are disintermediated, it would probably make most sense to have all eCalls travel directly to the PSAPs.

This is not a solution supported by the OEMs. During the past twenty years, vehicle OEMs have gradually developed connectivity solutions that fit their own business models and the needs of their customers. Some OEMs have chosen to take all of their connectivity management in-house so that it can be integrated with their CRM and VRM systems. Others have continued to work with trusted third parties in order to take advantage of the latest communications technologies. A one-size-fits-all TSP would not be in the interests of the individual OEMs nor their customers, and establishing a business solution by decree is beyond the scope of governments.
10.1.3.3 **B2B Marketplace Platform**

A third sub-option is a B2B Marketplace Platform, such as MOBINET, in which public or private entity would operate the shared server on market terms. With a B2B Marketplace Platform, the OEM would have the opportunity to decide whether to deliver data directly to the Marketplace Platform or to deliver data via its own TSP.
10.1.4 Commission Evaluation Principles

Guiding principles proposed by WG6 to be used for the evaluation of the alternatives were the following:

1. Data provision conditions: Consent
   The data subject (owner of the vehicle and/or through the use of the vehicle or nomadic devices) decides if data can be provided and to whom, including the concrete purpose for the use of the data (and hence for the identified service). There is always an opt-out option for end customers and data subjects. This is without prejudice to requirements of regulatory applications.

2. Free and undistorted competition
   Subject to prior consent of the data subject, all service providers should be in a fair, reasonable and non-discriminatory position to offer services to the data subject.

3. Data privacy and data protection
   There is a need for the data subject to have their vehicle and movement data protected for privacy reasons, and in the case of companies, for competition and/or security reasons.

4. Tamper-proof access and liability
   Services making use of in-vehicle data and resources should not endanger the proper safe and secure functioning of the vehicles. In addition, the access to vehicle data and resources shall not impact the current liability of vehicle manufacturers regarding the use of the vehicle.

5. Data economy
   With the caveat that data protection provisions or specific technologic prescriptions are respected, standardised access favours interoperability between different applications, notably regulatory key applications, and facilitates the common use of same vehicle data and resources.

10.1.5 TRL Report Conclusions

The Report evaluates the five options using the five Guiding Principles of WG6. Based on its own assumptions about the technical solutions, it concludes that the OEMs would have advantages over service providers—and thereby consumers—with all of the DSP solutions because the OEMs could design their HMIs to be much more user-friendly for a car owner/driver for ensuring data privacy and consent of data usage for its own services. This would create a disincentive for the owner/driver to select an alternative service provider.

On the issue of security, the report admits that the DSP solution may appear to be more secure from tampering and hacking, but then uses the single access point to the vehicles, the TSP, as a disadvantage because one hack could affect multiple vehicles. What the report fails to note is the major difference between the Extended Vehicle...
solution and Neutral Platform. With the Extended Vehicle, a TSP has access only to a single brand of vehicles, but with the Neutral Platform, all vehicle brands are communicating with that platform. If the OEM-to-TSP solution is vulnerable, the Neutral Platform is more so. However, the only problems that have occurred with hacking of a vehicle bypassing the TSP are Tesla and Chrysler. Tesla is the most problematic because all of the vehicles’ functions are exposed to the on-board updating platform that connects to the Tesla back-end via the Internet. Once the problem was identified, Tesla immediately took steps to close the loophole in its security system.

**10.2 BADA Project Recommendations**

The BADA Project recommends support for the Extended Vehicle solution because it is most consistent with the objectives of security and privacy and it can meet the desire for choice of service providers without compromising either of these objectives. It is also the solution that enables the collection of big data from vehicles in the most effective and secure manner while allowing the sharing of data using flexible commercial agreements with Big Data Integrators and Analytics service providers.
11 Value and Handling of Data

In this chapter we will review how the value of data can be measured, what effects ownership of data will have on its value and how different actors can use data in order to strengthen their position in the ecosystem.

11.1 Measuring Data Value

It has been often said of late that ‘data is the new oil’, that it is fueling the massive growth of the technology companies, both large and small, and supplanting petroleum as the world’s most valuable commodity. Clive Humby, a UK mathematician, is credited with coining the phrase Data is the New Oil in 2006. He is quoted as saying: “Oil is valuable, but if unrefined it cannot really be used. It has to be changed into gas, plastic, chemicals, etc. to create a valuable entity that drives profitable activity; so must data be broken down, analyzed for it to have value.”

Figure 46: Market Value of Companies

Oil combined with the knowledge of how to refine it laid the foundation for our modern physical product production system. In the chart above, as late as 2006, three of the top six companies in the world with the largest market capitalization were oil/energy companies. Only one, Microsoft, was a technology company. Ten years later, the number one company in 2006 moved to fifth place on the list, while the remainder were all tech companies, led by Apple, and their market capitalization values were nearly double what they were ten years earlier. Oil was—and still is—valuable because it is the basis of so many other things besides fuel, such as plastics, fertilizers, clothing, lubricants, solar panels and much, much more.

In a recent article in Dagens Industri (Tuesday 10 October 2017), titled: Data är nya oljan (Data is the New Oil), a graphic with data attributed to McKinsey Global Institute stated that “the amount of data that is moving around the world today has exploded in size and has already a greater impact on the world’s BNP than trade with physical products.” The winners from this development can be seen in the chart above. They have converted data to money, and compared to the oil giants of the 20th Century, the
data barons have a huge advantage: the raw material is free. Or at least it has been free. Consumers around the world have been convinced during the past ten years that obtaining ‘free’ services in exchange for handing over their data for free works to their advantage. The DI article points to several examples that show clearly how a company’s unrestricted use of data compiled from the users of its service can have negative effects, both individually and collectively. For example:

- Profiling individuals on the basis of ethnicity for exclusion from receiving particular advertisements (such as apartments for rent)
- Targeting advertisements with negative content about a particular candidate (such as against Hillary Clinton)
- Collecting payment records of credit cards and what products were purchased in order to direct specific types of ads to the individuals

If the source of this data suddenly became restricted or was no longer free, the business models of companies like Alphabet/Google and Facebook would collapse. This is why they fight so hard against efforts to curb data collection and provide greater transparency to users. Every entity that is involved in the Alphabet advertising business model scheme earns money when an individual clicks on something in a Google search, but the person doing the clicking is paid in kind, not with money, and, thus far, individuals who actively use all of these platforms and provide their data—whether they think about the consequences or not—seem to be satisfied that they are receiving value. Nevertheless, governments, in the name of consumers, are gradually restricting this free access.

Here is the dilemma: Those companies that are profiting from the massive amount of data being generated by people and their things (as in Internet of Things) know precisely what the value of that data is for them. It is the extremely high value of the margins they make over and above what most other companies make. They are employing ever more sophisticated AI techniques to process and further refine the increasing amounts of data. Data providers (i.e. everyone else) are told that it is not the data, per se, that is of value, but what is done with it. Also, we are told by, among others, Bruce Reading, that the value of an individual data item is miniscule compared to the aggregate, and the individual data item’s value decreases over time, while the aggregate data value increases.\(^{11}\)

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\(^{11}\) Bruce Reading, CEO of VoltDB.
Figure 47: Data Value Chain by VoltDB CEO Bruce Reading

James Kobielus, Big Data Evangelist with IBM, is skeptical about Reading’s approach, which separates data value from actual business outcomes. He believes that it is better to focus on data’s instrumental value in decision support. He suggests returning to IBM’s Four Vs of Big Data to put a monetary value on the Customer Lifetime Value of Big Data. He says that CLV is “a standard metric that you can calculate from big-data analytics’ impact of customer acquisition, onboarding, retention, upsell, cross-sell and other concrete bottom-line indicators, as well as from corresponding improvements in operational efficiency.” We can attempt to apply this approach to Big Automotive Data Analytics using Trafikverket as an example:

- **Volume-based value:** The more comprehensive your 360-degree view of road users and the more historical data you have on them, the more insight you can extract from the data, and, all things considered, the better decisions you can make in the process of providing safer and more efficient road infrastructure.

- **Velocity-based value:** The more data on road users that you can ingest rapidly into your Big Data platform and the more questions that a user can pose more rapidly against that data within a given time period, the more likely you are to make the right decisions at the right time to achieve your road user safety and efficiency objectives.

- **Variety-based value:** The more varied road user data you have—from all systems that monitor the use of road networks, the costs building, operating

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and maintaining them, from social media, call center logs, from all source—the more nuanced portrait you have of the safety and efficiency of the roads and the satisfaction of the road users with those roads. As a result, your decisions will be better-informed.

- Veracity-based value: The more consolidated, conformed, cleansed, consistent current data you have on road users, the more likely you are to make the right decisions based on the most accurate data.

It should be possible to develop a CLV for road users by establishing equivalents for the product-customer approach used for businesses.

<table>
<thead>
<tr>
<th>Business Criteria</th>
<th>Trafikverket Equivalent</th>
<th>Value</th>
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<tbody>
<tr>
<td>Customer acquisition</td>
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<td>Onboarding</td>
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<td>Upsell</td>
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<td>Cross-sell</td>
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<tr>
<td>Operational efficiency</td>
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</tbody>
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Several other data value indicators have been found that can be added to the above list:13

- Time Value - This metric measures the present value of data taking into account its value over its entire lifetime. How will the data’s value change with time? Will this value grow, reduce or fluctuate over time? How likely is it to retain its value? Some data will have a limited life, and some data is evergreen/ will be valuable forever. Most data will decay and be less valuable with time.

- Legal Constraints - This metric measures how valuable specific data is for many use cases after all legal limits on the data have been taken into account. Data may carry legal restrictions of usage. Provisions must be made to protect privacy and confidentiality, but if data is to carry a high value, it must also be able to be used for valuable future use cases. Many of the uses aren’t known yet, so, a balance must be made between protecting privacy and leaving legal agreements more open as to how the data can be used to create future value.

- Context Value - This metric relates the number of contexts in which the dataset is useful. Specific data may only be useful for some industries. The more a dataset can be used, the more overall value it will have. Some narrow-context datasets, however, could be extremely valuable, depending on the

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context area. An interesting challenge will be in creating data value arbitrage between contexts. The data owner will want to collect data that is lower in value but has the potential for novel uses that will increase its value. This will allow smart people to buy data sets, with lower perceived value, and to turn them around to be used in new contexts for a profit on the difference.

- **Quality** - This metric measures the quality of the data. For data to be useful, it must have a high quality in terms of accuracy, completeness, and reliability.

- **Acquisition and Storage** - These metrics measure how much it costs the business to acquire the data and then store it. The cost of acquiring data must contain the business costs of acquisition. It’s not just about the technical cost to acquire, but the amount paid to collect or purchase the data in the first place. Maintenance and storage data also has costs associated. These can reduce the value of the data in question.

- **Access** - This metric measures the level of access that the company has to data from both size (amount of data) and number/variety of data access channels. This may be driven by where the company lies in a larger multi-company value chain. Data gathered directly from customers, partners, and from sensors could all fall under this measure. A company with only one channel of data acquisition could be less valuable than one with many channels of data collection. The amount of data collected would also matter. So, it would be a mix of the measure of the size and variety of data channels available to the company.

- **A.I. Model Training Value** - This is the metric for the trainability of the data. A.I. is the area where the exponential value from data will be unlocked. A.I. systems are trained by using data. The data to be used in machine learning training will be a big indicator of its value. The more the data fits the definition of good training data, the higher the value will be.

### 11.2 Data Ownership Effects

There are two sides to the argument on vehicle-related data ownership. On the one side are consumer and governmental agencies who state that any data generated by operating a vehicle belongs to the owner and/or driver of the vehicle, even if that data cannot be accessed by the owner/driver and even if it cannot be processed into useful information. The General Data Protection Regulation, which enters into effect on 25 May 2018, applies to personal data, not technical data, but there are interpretations of this regulation that extend the definition of ‘personal’ to data that is generated as the result of an action taken by an individual, such as driving a vehicle. On the other side of the argument are the vehicle manufacturers who state that by aggregating data obtained from the vehicles they have manufactured, using systems which they have developed and paid to have installed in the vehicles, they are able to improve the operation and safety of vehicles on the road as vehicles that will be built in the future. Since the vehicle data is not ‘personal’ in the sense that it does not identify a living person, the data does not belong to the owner/driver.

Before there were computer systems in vehicles that could assemble digital data from electronic control units and relay that data to external computer systems (initially via
direct linkage to on-board systems and later via wireless networks), there were no
discussions of digital data ownership because there was no digital data. Before
governmental bodies legislated that vehicle manufacturers were obligated to lease
their diagnostic systems to third parties who could use these systems to perform
repairs on the cars, vehicle manufacturers assumed that all data coming from the
ECUs in the vehicle belonged to them. This occurred within the European Union in
1995 as a result of what was called a ‘block exemption’ of the automotive industry
from the competition laws. Under the Motor Vehicle Block Exemption Regulations
(BER), the industry was allowed to continue to operate a franchised dealer network,
controlling who would sell their products and where they could do so (i.e., operate a
selective and exclusive distribution network, which was prohibited under the
completion laws in effect within the EU). One requirement placed on the automotive
industry was that technical data and repair instructions should be made available to
the independent motor trade so that car owners were not obligated to take their car
to a franchised dealer for service or repair. This also ensured that data was available
to motoring organisations (e.g., Motormännens Riksförbund) to enable these
organisations to fix cars at roadside. In addition, updates to the BER ensured that
individuals were not obligated as a condition of warranty to have their car serviced by
a franchised dealer. Multi-brand showrooms were allowed, and it was not necessary
that a sales and service were combined.

Motoring organisations and the independent workshops want to extend data access
to messages sent from telematics units, such as requests for emergency or roadside
assistance, which today in all vehicles are sent to a telematics service provider, either
operated by a third party (e.g., WirelessCar) or internally.

The effects of data ownership become both more complex and more substantial from
a financial standpoint when data from individuals is aggregated and processed, as is
the case with Big Data. If my vehicle stores data about average speeds and locations
of delays on my on-board navigation system, and if that system is able to process that
data and suggest alternate routes on different days of the week or different times of
day, I benefit from having paid to buy the navigation system with this added
functionality. But it only works on those routes which I have driven myself and done
so frequently enough for the system to be able to generate useful information. If the
vehicle manufacturer suggests that I deliver all of my data to a central processing
location in return for obtaining alternate routing information on many more roads in a
much larger geographic area, I benefit even more. However, I may not want to use
such functionality, or I may have other reasons for not wanting to share my data.

The question is whether the choice of sharing such data rests with the driver/owner of
the vehicle, or whether the vehicle manufacturers can take the same liberties as
companies like Alphabet and Facebook have taken and assemble all types of types of
data from their users, aggregate it and deliver services that can be monetized in
similar ways as the technology companies. The answer to this question could well
determine if vehicle manufacturers stay in business. Many of them have market
capitalizations which are 10% or lower that of Facebook, which is number six among
the highest valued companies. Only Toyota, with a market cap of $183 billion (19 October 2017) can come up to the a level that is respectable compared to the tech companies, and only Tesla, with a market cap of $48.7 (19 October 2017) that recently exceeded Ford’s ($45.6) and is approaching GM’s ($51.2) has captured the imagination of investors.

While G.M. and Ford may have strong profits and healthy balance sheets, Tesla offers something Wall Street loves much more: the potential for dramatic growth.

“Investors want something that is going to go up in orders of magnitude in six months to six years, and Tesla is that story,” said Karl Brauer, a senior editor at Kelley Blue Book. “Nobody thinks Ford or G.M. is going to do that.”

Tesla vehicles are all equipped with connectivity devices to both send and receive data from Tesla’s servers. Customers receive a copy of the Customer Privacy Policy when they purchase their vehicle. In it there are long descriptions of what data is collected from or about the customer or their devices, from or about the Tesla vehicle, and from or about Tesla’s energy products. It states how the data will be used by Tesla and shared with third parties, what security measure will be taken with the data, how long the data will be retained and other conditions. It also states specifically that the customer may opt out of data collection. Read the opt out statement that is included below the Vehicle Data conditions and decide whether there is much point in the customer owning the data.

If you no longer wish us to collect Telematics Log Data or any other data from your Tesla vehicle, please contact us as indicated in the “How to Contact Us” section below. Please note that, if you opt out from the collection of Telematics Log Data or any other data from your Tesla vehicle (with the exception of the Data Sharing setting detailed above), we will not be able to notify you of issues applicable to your vehicle in real time, and this may result in your vehicle suffering from reduced functionality, serious damage, or inoperability, and it may also disable many features of your vehicle including periodic software and firmware updates, remote services, and interactivity with mobile applications and in-car features such as location search, Internet radio, voice commands, and web browser functionality.

11.3 Using Data to Strengthen Position

Today, the relative strength of a company, either public or private, is measured in its market capitalization, EBITA (Earnings Before Interest, Taxes and Amortisation) and cash flow. Monetary value will be supplemented in the near future with the amount of monetizable data that a company can capture, consume, store and utilize. “Data will become measured and accounted for as an asset. AI will make this even more apparent as it mines more value from current and future datasets. A relatively small organization that is rich in current data and the ability to collect future data is seen as more valuable than a high-revenue but data poor company.” Think of Tesla compared

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to most automotive companies and Uber compared to taxi companies. It is highly likely that data will increasingly become a competitive weapon. Today’s large, data-rich companies could well become even more dominant due to their access to large amounts of valuable data.
12 Data Security

There are currently no common standards or industry practices for how an on-board connected vehicle system should be designed to achieve the highest level of security for safety and security services and the broader range of infotainment services. What is known by all OEMs is that security of their on-board connected vehicle systems can be breached, and the consequences can be dire. Researchers have shown that existing wireless connections can allow them to hack into cars and take control of vehicle locks and brakes. In 2015, two researchers were able to successfully break through whatever security shields Fiat Chrysler Automobiles and Sprint set up around its UConnect on-board systems and wireless network to take control over the most mission critical functions of a Jeep Cherokee. Starting with the climate controls, the radio and the windshield wipers, the attackers moved to the transmission and the brakes. Eventually, the vehicle was brought to a standstill on a major artery in St. Louis, Missouri in the U.S. The driver of the vehicle, Andy Greenberg, a journalist with Wired Magazine, was a willing victim, but his description of his experience in Wired indicated that he was truly frightened while he sat helpless in the vehicle while it was being controlled remotely from ten miles away.

The entire process appears to have been extremely well planned and executed over a two-year period, culminating in having the author of the article that would describe the experience serving as, in his own words, the ‘crash dummy’. Miller and Velasek first had to learn to speak ‘CAN’, the vehicle bus standard intended to link microcontrollers and devices in vehicles to communicate with each other without a host computer. They had to find the most likely candidate for their experiment, which they did, according to Greenberg, by applying for and obtaining “mechanic’s accounts on the websites of every major automaker and downloaded dozens of vehicles’ manuals and wiring diagrams.” They used this information to determine how the on-board systems connected to the Internet, and then which vehicles were the most vulnerable. Jeep Cherokee was selected as the most vulnerable.

They identified one vulnerable access point that lets anyone who knows the vehicle’s IP address gain access to a chip in the vehicle’s head unit where the chip’s firmware is rewritten and new code can be deposited. The new firmware can send commands through CAN to any mission critical component, like the brakes, engine, transmission or sensors. Before the test drive, Miller and Velasek provided Fiat Chrysler Automobiles with enough information to allow the company to issue a recall on July 16th 2015 for 1.4 million vehicles to close the security hole in their vehicles.

Miller has said that remote updates will add a new target for hackers, but he notes that so far, no malicious hackers have taken over cars, and he says remote updating systems can be made secure—“It’s possible to screw it up. But it’s certainly possible to do it right,” he says. Even if the change is slow, Miller says, remote software updates for cars are inevitable. As the amount of software in a vehicle—and the potential for bugs—increases, remote updates “are going to have to happen,” he says. With the current approach of bringing cars into dealerships, “It can be months before software
gets updated. It might never get updated,” he says. “That leaves a lot of cars in a vulnerable state.”

A properly designed system that provides for as high a level of security as is possible must protect each of the four levels of vehicle electronics systems:

- Information and entertainment systems
- Fail safe body function systems
- Fail safe driving and vehicle dynamic function systems
- Fault functional driving and vehicle dynamic function systems

![Vehicle System Security Levels](image)

**Figure 48: Vehicle System Security Levels**

Data security for vehicles must cover all of the following conditions:

- Protection of the vehicle’s systems to perform in a safe manner by ensuring that no unauthorized messages are received from roadside units or telematics service providers. All data received by the vehicle must be sent from an authorized source in an authorized format for an authorized application.
- Protection of the owner’s, driver’s or passengers’ data privacy. All data sent from the vehicle must be protected from redirection to an authorized receiver, and all data stored on the vehicle must be protected from access and theft by unauthorized parties.
- Protection of the systems of other vehicles to which the vehicle communicates (V2V).
- Protection of the data integrity of off-board systems to which the vehicle communicates (V2I).
- Data exchanged between public applications (e.g., social media services, e-mail, web search), with one of the access points being in the vehicle, must be physically separated from all vehicle systems.

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15 Miller and Valsek were hired by Uber in August, 2015. Miller has left Uber, but Valsek remains as of March, 2017.
12.1 Messaging

12.1.1 Telematics

Increasing numbers of vehicle OEMs are gradually incorporating two-way communications devices in their vehicles for messaging purposes. Initially, these devices provided safety and security services, such as assistance in the case of a crash or tracking of the vehicle in case it was stolen. They used the mobile network, initially the analog AMPS and then the digital CDMA and GSM networks. They delivered both voice and data to specialized customer service centers, with the data in the GSM networks arriving in the form of an SMS via a short message service center. With the arrival of 3G mobile networks, GPRS could be used to send larger data messages at faster speeds to the on-board device once a connection had been initiated from the vehicle. These messages from and to the vehicle were encrypted and often required a security key exchange.

Each OEM, along with its hardware, mobile network operator and connectivity services provider, has taken its own approach to the development of a system, service and security infrastructure. Early attempts in Europe to standardize an over-the-air messaging protocol called GATS (Global Automotive Telematics Standard) resulted in limited acceptance by only two OEMs, BMW and Volvo. GATS included a security approach that used keys stored at the message receiver location. Before a message could be sent to a vehicle, a key exchange needed to occur. BMW implemented this approach, while Volvo did not. The dominant protocol for messaging was the one developed by Motorola, called ACP (Automotive Communications Protocol), because Motorola was the supplier of the majority of early telematics systems to GM/OnStar, Mercedes-Benz, Ford and others.

Around 2010, BMW, SEI and WirelessCar developed a new, more robust and more secure service framework called Next Generation Telematics Protocol (NGTP). The ‘P’ was later changed to ‘Platform’ and then ‘Pattern’. It uses ASN.1 or XML for encoding, TCP/UDP/HTTP for transportation and SIP for voice services.

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16 General Motors was first with its OnStar system in 1996. The systems and services have been referred to as ‘telematics’ (remote acting). Connected Cars is the current term.
Figure 49: NGTP 2.0

For a high-risk service, such as locking or unlocking the vehicle using a mobile app or web service, security is managed as follows:\(^\text{(17)}\)

- Customer logs in with his/her account using mobile app/web portal.
- Customer sends request to lock the vehicle’s door. This Short Message Service (SMS) is encrypted by the wireless carrier provider.
- The SI will receive the request and forward it to SH after verifying the customer information with the Content Provider (CP).
- The SH forwards the request to Dispatcher after identifying the customer’s subscription.
- The Dispatcher will decrypt the SMS message to direct the request to the right vehicle after validating the VIN# and Mobile Dialup Number (MDN).
- The vehicle will receive the request from the Telematics Unit and send it to the Body Control Module (BCM) to execute the request.

12.1.2 European eCall

Beginning on the 1st of April 2018, all new type-approved cars sold in the EU must include a standardized European eCall device. This device must be designed to send a standard so-called minimum set of data (MSD) to a public safety answering point in the case of a crash or an emergency. The device may be triggered manually by a vehicle’s occupant or automatically. The solution, shown below, consisted of a standard 112 telephone call with a data message embedded in the call, placed there by in-band modem software, and a mobile network ‘flag’ designating the 112 call as coming from a vehicle.

It took ten more years for all the parties responsible for implementing this solution to agree to accept it. Vehicle OEMs, represented by ACEA, were the most vocal critics of the solution. They said that in-band modems were even in 2004 a relic of analogue cellular telephony and they were already developing their own service solutions based on SMS and GPRS messaging that could provide multiple services as well as emergency assistance in case of an accident. The Commission was initially firmly against private, so-called ‘third party’ solutions. Mobile network operators objected to accepting additional costs for special handling of eCall 112 calls, but agreed to add the ‘eCall flag’ as long as there was no legislation forcing them to do so.

After the EU 112-based eCall service becomes officially active on 1 April 2018, vehicle owners will still be able to obtain services from so-called Third Party Service Providers. These TPSPs include vehicle OEMs, such as BMW and Volvo, who provide SOS services along with a range of many other value-added service to purchasers of their vehicles. TPSPs also include companies that supply on-board units that are after-market fit, such as Allianz Insurance, Vodafone Automotive Telematics and Octo Telematics.

EN 16102 addresses technologies and methods of delivering data and voice from the vehicle to the TPS Call Center premises. EN 16102 bases its own data set on EN 15722 (MSD format), however EN 16102 does not describe or suggest the technology to be adopted for data and voice transmission from the vehicle to the TPS. Technological choices of data and voice transmission are left to the car manufacturers and TPS providers, provided they can achieve the same level of detailed information as the regular pan-European eCall. This means that TPSP may use whatever technology it chooses to collect data included in a MSD-like package sent by a vehicle requesting intervention and make it available to PSAPs. To reach this goal, the TPSP must take all
technological measures to be equipped with MSD and voice reception, deal with any retransmission request from a car to TPSP premises and the forwarding of same to the respective PSAPs.

The main technical issue for the TPS solution is how—or whether—to transfer the minimum set of data or any additional data (called TSD) from the TSP to the PSAP. It is evident from all the standards work performed on this topic that those involved have not understood that it is not the call center speaking to the caller that must create a link to the PSAP; it is the telematics service provider (TSP in the diagram above) that is the link to and from the vehicle that manages the data and would package any data message to the PSAP.

12.1.3 Vehicle-to-Everything Messaging

Government and the auto industry fully agree that when vehicles can communicate with other vehicles in their vicinity, either directly or via roadside units, many types of accidents will be avoided and lives will be saved. Added benefits will be reduced emissions and increased road capacity due to improved traffic flow.

For more than a decade, in public- and industry-funded initiatives in all of the major automotive markets, vehicle communications technologies have been developed, tested and standardized. Activities have focused mainly on solutions that work at relatively short range, provide instantaneous connections between senders and receivers and would be free to the users. The U.S. Department of Transportation has proposed to make a recommendation during the second quarter of 2017 that a selected technology known as WAVE—based on the same standard as products marketed as Wi-Fi, which are part of the family of DSRC technology—be made mandatory in all new vehicles on a phase-in schedule beginning in 2019. This would apply only to Vehicle-to-Vehicle systems since there are no plans in the U.S. to build out a Vehicle-to-Infrastructure system. The Europe-based CAR 2 CAR Communications Consortium in July 2016 endorsed deployment of vehicle-to-vehicle as well as vehicle-to-infrastructure communication using basically the same technology as that proposed in the United States.

While the benefits of vehicles communicating with each other are clear and accepted, there are two problems with moving forward with the proposed WAVE/DSRC approach:

- Cellular technology has developed quickly during the past decade and its supporters, such as 5G Americas and the 5G Automotive Association, believe it can do all that WAVE can do plus a lot more; and,
- Although there are similarities and overlaps in how the technology would be implemented in the different regions of the world, they are not identical.

One of the key advantages of a V2V communications solution over one based on V2I is the saving of cost for the roadside unit infrastructure. V2I requires on-board ITS Stations as well as the roadside ones, so it makes sense to begin with installing the on-board systems in any case. The problem with a V2V-only solution that has been
identified is security, specifically, issuing a certificate that authorizes an on-board unit to send messages to other vehicles, reporting misbehaving behaviour and revoking a certificate from a vehicle that abuses the privilege of being part of the V2V community.

In a survey conducted for the International Telecommunication Union on the subject of V2X technology, 18 58% of the respondents said they did not believe a V2V solution could be implemented without a V2I solution to providing security certificates. Most of the comments were directed at a WAVE solution and stated that some form of infrastructure would be needed for issuing the certificates, either units or cellular. One respondent disagreed on the basis that V2V can indeed provide a way to issue certificates between vehicles, referring to work being performed by CAMP (Crash Avoidance Metrics Partner), but this method is still in a study phase. If there are secure methods for delivering certificates to and revoking certificates from vehicles that do not require a central server and an out-of-vehicle infrastructure, they are not well-known amongst the automotive industry.

When asked whether cellular networks would improve the security for V2X systems, 67% of respondents said they would. This indicates that a significant majority of the respondents are either committed to a cellular solution or are unaware of the potential for V2V systems to function without a supplementary infrastructure.

### 12.2 Over-the-Air Updating

To lower costs and increase customer satisfaction, vehicle OEMs will want to use Over-the-Air updating for both performance improvements and fault corrections, including both official recalls and non-recalls. Regulators are interested in correcting faults as quickly as possible that are of a level of severity to require a recall. An eventual standard for secure over-the-air updates must absolutely address the fault correction issue, but one that covered performance improvements as well would be of the greatest value to all parties. The current recall process, and even the current process used for informing customers of new features, relies on physical mail and/or electronic mail being sent to a customer. There are numerous problems with this method of contact because mailing lists quickly become out of date. People move without updating their physical addresses, and change e-mail addresses without leaving a trace from their old to new address.

OTA updating is already in use among some vehicle OEMs (e.g. Tesla and Mercedes-Benz) as an alternative to performing the software updates using a vehicle workshop system. However, this practice is still very new and limited. A reason why it is not more widespread is the lack of security of the systems. Tesla, which uses OTA extensively, has been shown to have severe security leaks.

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In a future OTA scenario, whether the updates are performed in the workshop or remotely, there remain both technical and business reasons for using the dealer network for performing the updates. Unlike a company like Tesla Motors, which sells cars directly to customers and which does not have a dealer network, vehicle OEMs are dependent on their dealers and National Sales Companies for customer contact information. Many, if not most, vehicle OEMs do not have a central database containing the names and most recent contact information on the owners or drivers of their vehicles. Dealers with workshops want to continue to have the direct relationships with customers in order to sell service and accessories, and to eventually sell the customer a new vehicle. They will resist any attempt to short circuit them.

Balancing the dealer interests on one side are customer demands on the other side for greater convenience and lower cost of ownership. Constant notices that a vehicle must be returned to the dealer for repair—which, as stated, principally involves updating software—will not be tolerated. The public is aware that their phones and computer devices are capable of being updated with new features and ‘bugs’ being fixed by quick and efficient over-the-air updating. They will expect the same with the vehicles.

Sending a message to the vehicle has its own set of issues, including ensuring that the message is received, that it is received by the person who is authorized to take the action required and that there is a way to maximize the security of communications among the entity sending the update, the authorized owner or the registered driver and the vehicle receiving the update.

If OTA were performed using an embedded communications device over the cellular network, it would be the mobile network operator who provides the SIM in GSM solutions—and the equivalent in CDMA solutions—that would have the most reliable information about the vital links in the chain: the location and status of the communications device, and the SIM’s IMSI and the MSISDNs associated with it. The mobile network operator is in the optimum position to monitor the flow of data from the server where the updated software is sent to the mobile station in the vehicle. From the time the data enters the vehicle until it is applied to the appropriate ECUs, it would be the responsibility of the vehicle OEM and its tier one suppliers to ensure the proper flow and application of the update. However, the confirmation of successful completion would have to pass back through the network.

Offsetting the advantages of using the cellular network provider for the highest level of certainty of reaching the greatest number of devices are the needs to keep the costs of transmission as low as possible, to provide a continuous connection to the vehicle for as long as is required to successfully complete the update and to achieve the highest level of security. For the lowest cost, a Wi-Fi connection with today’s technology would probably be the optimum solution. For ensuring that the update is completed, which can take from a few minutes to a several hours, an external power source would provide the greatest reliability that the battery is not drained. For
security, a closed connection to the vehicle, versus an open IP connection, would be preferred.

There are different conditions that must be satisfied compared with using the mobile network, and these will be identified in this report. Concerning technology, including the use of 4G, which is already in use by many vehicle OEMs to achieve the highest data throughput for infotainment, or 5G which will most likely be ready by the time standards need to finalized, these issues are out of the scope of this report.

In summary, in order for an over-the-air software update standard to be useful and accepted, it must meet the following conditions:

- It must address the entire end-to-end life-cycle processes for the vehicle and its electronics systems.
- It must use the most secure and cost-effective method for performing the updates. It is not simply a matter of defining a protocol or delivering confirmation of completion.
- The standard must address the design of the embedded system, including how the system is activated and provisioned with its contact logic, and how it interfaces with the mobile network or other networks, such as Wi-Fi.
- It must address what to do when a system should perform as if it has been de-activated (e.g. if the customer does not wish to have an actively connected vehicle).
- The design of the system must also conform to the regulations of privacy that are in effect in the jurisdiction where the vehicle is located when the update is performed.
- Above all, the updating process should be done in complete alignment with the safety and environmental regulations that are in effect in each of the jurisdictions where the vehicles are sold.

12.3 Blockchain: A new approach to secure communications

Imagine an internet of value where buyers and sellers could safely store and exchange value without intermediaries. This is what blockchain technology promises. Sharing of data is a domain that is highly affected by trust between transacting parties. In the financial sector trust is typically managed by proxies such as banks who facilitate transactions between users. These indispensable processes are dependent on complex processes and digital systems, the costs of which end up with customers seeking to make business in a secure way. Just how complex these systems have become became apparent in the 2008 financial crash. This came about as high-risk, so called “toxic loans” were mixed with low-risk assets in complex products and sold on, effectively unbeknownst to buyers. This practice eventually compromised the entire economy. As a response, the trustless and transparent “cryptocurrency” was suggested in a seminal paper.\(^\text{19}\) Implemented in 2009, bitcoin is the only implemented public cryptocurrency with actual global reach, and blockchain is the technology upon which it is based. Although blockchain was developed specifically for bitcoin, in recent

\(^\text{19}\) (Nakamoto 2008)
years the technology has increasingly been suggested to apply to other business challenges in a wide variety of domains.

There are a number of distinct features of blockchains that together form a potentially disruptive way of managing trust, some of which are:

- Redundant decentralized architecture
- Transparent transactions
- Distributed verification
- Very robust cryptographic implementation

A blockchain facilitates automated trust between untrusting parties seeking to trade a given thing, virtual or physical, with each other. It does so by making transactions visible to all users. It uses private key cryptography that makes it nearly (but not totally) impossible to hack. It is decentralized, meaning that there is no single point of failure to the system. It is validated by a community of actors.

12.3.1 Transparent transactions and decentralized architecture

Essentially the blockchain is an encrypted and distributed network of duplicated databases, a ‘distributed ledger technology’ (DLT), where transactions between users are recorded. The transaction is the focal unit of a blockchain system. It contains a reference to a previous transaction, a specification of what is exchanged, and the recipient of the transaction. This means that a bitcoin or fractions thereof can be traced individually, and that there is a trace of all transactions a specific unit of currency has ever been part of, thus preventing ‘double spending’. Only one actor can own any given resource on the blockchain at any given time. This principle can be extended to any type of record keeping. The blockchain is encrypted and involved parties use a private key to access their data. In an open ‘permissionless’ blockchain, anonymity is key. For instance, in bitcoin there is no way of knowing who manages any given blockchain address. However, since all transactions are visible, it is to a degree possible to infer such information by observing transaction patterns.
The amount of data stored in each transaction is typically very small. Instead, additional data hosted external to the transaction can be referenced. However, with each additional add-on of components like these, the blockchain could potentially become less robust. Transaction systems are generally optimized for speed and efficiency. The generally known permissionless blockchains are instead highly redundant. There is no single point of failure. Each so-called full node could replicate the entire blockchain, making the infrastructure very robust. What makes the bitcoin blockchain theoretically reliable is that no single operator can make unilateral changes to the database. To do so would require controlling a majority of the computing power used to validate changes to the database.

12.3.2 Distributed verification process

The verification process is performed by a multitude of competing actors, in theory making it impossible to tamper with unnoticed. Essentially, blockchain is touted as a solution to the so-called Byzantine Generals problem,\(^\text{20}\) where a group of actors, any of whom can be malicious, attempt to agree and coordinate an activity. To validate the integrity of the databases and keep them all updated and synchronized, an incentive model is required. The exact incentive model varies between implementations and their security demands.

The bitcoin blockchain utilizes a so-called ‘Proof of Work’ mechanism. When a transaction of an amount of bitcoin is posted to the blockchain architecture, it initially

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\(^{20}\) (Lamport, Shostak et al. 1982)
lands in a buffer of unverified transactions. To get verified, the blockchain must agree to include it in a new block consisting of several recent transactions. These transactions are managed by so-called ‘miners’. Miners utilize increasingly specialized hardware and software to solve cryptographical problems, for which they are rewarded in bitcoin, growing the amount of currency available. However, for the transaction to become an attractive proposition to include in candidate blocks, a fee to miners is generally included in the transaction. Once a correct solution to the problem has been found, a miner can claim a reward and the new block is verified by the nodes and added to the previous block. This very process is what has given the blockchain its name. The complexity of the challenges grows overtime, making it increasingly expensive to mine bitcoin. Eventually, there will be no more new bitcoins and verification will have to be funded by fees alone. The entire bitcoin blockchain implementation is thus self-sufficient and independent from external influence.

For the end user, most of this can be managed by digital services called ‘wallets’. They provide a convenient service to facilitate access to blockchains, including calculating reasonable fees. The verification time is dependent on the current network load. For bitcoin, the current time is about 10 minutes before a first confirmation. However, the verification is considered more robust for each additional new block added after it. By 6 such confirmations, or added blocks, the transaction is definitely considered verified. Taking roughly 1 hour, this might seem a long time, but this is still highly efficient compared to many traditional financial applications. For minor transactions, a first confirmation is generally considered adequate. Costs for transactions are about equal to or considerably less than fees for credit card companies (about 0-2%).

A definite drawback to the bitcoin Proof of Work mechanism is power consumption. One pessimistic estimate indicates that bitcoin blockchain mining currently consumes more electrical power than the annual electrical consumption of all households in the Republic of Ireland.\(^\text{21}\) There are several alternatives, each suitable for specific applications. Practical Byzantine fault tolerance (PBFT) is by comparison a swift and resource efficient starting point.\(^\text{22}\) It requires permission to use, but this is not necessarily a problem in consortium-based applications.\(^\text{23}\) This is the consensus mechanism used by Hyperledger and Ripple.

### 12.3.3 Smart contracts

Blockchains enable the automation of more than secure transactions. Smart contracts and Distributed Autonomous Organizations or Corporations (DAOs or DACs) are other areas of interest. Smart contracts are computer programs that automatically validate conditions that have to be met in order to complete a transaction.\(^\text{24}\) Again, trust and third party monitoring is replaced by transparent record keeping and cryptography. Smart contracts can enforce stipulations and record transaction conditions or

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\(^{21}\) (O'Dwyer and Malone 2014)
\(^{22}\) (Castro and Liskov 1999)
\(^{23}\) (Vukolić 2016)
\(^{24}\) (Szabo 1997, Swan 2015)
activities concerning financing, insurance policy and legal rights pertaining to the contractual agreement.\textsuperscript{25} Essentially, smart contracts are moving blockchain towards Turing Complete computing\textsuperscript{26} in which complex rules can be scripted and acted upon when certain criteria are met.

The term “smart contracts” was coined as early as 1994\textsuperscript{27} but actual implementation has only recently been possible through the use of blockchain technology. Leading this development are Ripple’s Codius and Ethereum. The Ethereum platform has a flexible design regarding capacity demands from stored content. Designers can therefore add complex scripts, but need to pay for the added processing requirements.

Smart contracts exist in many guises. Though smart contracts can be designed only utilizing data available within the blockchain, (e.g. time, actors and currency), it reaches its potential when scripted to react to external data (e.g. price fluctuations in markets, weather forecasts, logistic data). The potential business effect of smart contracts is similar to that of cryptocurrencies, minimizing transaction costs associated with law practice, such as contracting, documentation and enforcement.\textsuperscript{28} Hence, it makes low-value “micro-contracting” economically beneficial for businesses.\textsuperscript{29} This implies that the role of lawyers and financial advisors could change from processor of contracts to providers of contract design patterns, providing tested templates of contracts that can be enforced on the blockchain.\textsuperscript{30}

12.3.4 Current applications and domains

With the addition of new platforms (e.g. Ethereum, Ripple, Litecoin, Hyperledger, etc.), the field has entered an early phase in the innovation cycle where there are different designs of codebase, use of tokens, consensus mechanisms, and last but not least the degree of openness. Blockchain implementations are either open (e.g. bitcoin) or closed (e.g. some cyber security applications) or consortium controlled (e.g. most projects developed by the banking industry). Among early adopters, there is an ongoing debate about whether any blockchain that is not open and permissionless is in fact a blockchain at all.

An emerging trend is the application of blockchains in established cloud solutions. Examples of initiatives that deliver blockchain-as-a-service (BaaS) include Microsoft’s Ethereum Consortium Blockchain Network on Azure and IBM’s recent solution in cooperation with the Linux Foundation’s Hyperledger Fabric.

Actual and proposed applications for blockchain technology are wide ranging, encompassing cryptocurrency, payment systems, clearing and settlement, securities

\textsuperscript{25} (Swan 2015, Taylor 2016)

\textsuperscript{26} A Turing Complete system means a system in which a program can be written that will find an answer (although with no guarantees regarding runtime or memory).

\textsuperscript{27} (Szabo 1997)

\textsuperscript{28} (Cassano 2014)

\textsuperscript{29} (Taylor 2016)

\textsuperscript{30} (Taylor 2016)
trading, supply chain management, identity management, notarial services, the Internet of Things, land transfer and registration, health recordkeeping, voting, and intellectual property management. Some see no limit to the uses to which blockchain technology can be put to help solve societal and business problems. There are even predictions that the impact of this technology will be as far reaching as the Internet.

The banking sector is driving incumbent interest in the technology beyond bitcoin. R3 is a startup collecting about 70 backers including major banks. It is attempting to develop a common crypto-technology-based platform. Incumbent interest in blockchain technology is generally departing from the open and completely transparent implementation of bitcoin, opting instead for a more secluded design, more in tune with their existing business model. A major issue is regulator acceptance, and closed solutions will likely develop the means for authorized institutions to see and disclose required reporting information while masking it from others.

Lately, interest in blockchain technology has progressed beyond the financial sector and there are activities in such diverse fields as identity management, asset tracking, cybersecurity and transport and logistics, among others. Public sector examples include the UN ID20 initiative. It aims to provide every person on the globe with an immutable digital identification, and blockchain is being promoted as a promising technological solution by, amongst others, Microsoft. Swedish Lantmäteriet is examining the possibility to place the Swedish fastighetsregistret in a blockchain, increasing transparency and ease of management. A nationwide cyberattack on Estonia in 2007 promoted new R&D in cybersecurity for guaranteeing critical system integrity. Guardtime is a company formed by those experiences and centered around a blockchain solution designed to resist external tampering in critical systems. Guardtime has recently been invested in by Ericsson.

In logistics and supply chain management, there are several initiatives targeting authenticity. Initiatives targeting counterfeit products includes initiatives such as Provenance, and Everledger and recently Chinese retail giant Alibaba recently disclosed an initiative targeting food quality. Logistics giant Maersk together with IBM recently announced an initiative to use a Hyperledger blockchain to manage and track the paper trail of tens of millions of shipping containers across the world. If adopted at scale, the solution has the potential to save the industry billions of dollars.

In March 2018, a non-profit organization called FETCH was formed with the purpose of becoming the principal custodian of a network that would allow data seekers to ask questions to data holders, suppliers or originators. This would allow an organization to ask questions about datasets residing on another organization’s servers. The FETCH network would keep track of which datasets have been used to answer the queries so that future queries could be directly more quickly and automatically to the

32 (Lantmäteriet 2016)
appropriate sources. The idea is that payments to ask the questions would be made in
digital tokens, and that the more organizations make their data searchable on the
FETCH network, and the more organizations or individuals pay to ask questions via
FETCH, the more the tokens will be worth. The company was founded by an early
investor in DeepMind and former employee of that company. DeepMind was an AI
company that was acquired by Alphabet, having gained notoriety by defeating the
best players in the world in the game of Go.

There are even non-blockchain distributed ledgers popping up. One of them is IOTA,
an open-source distributed ledger that does not use blockchain. It claims to have
developed a new “quantum-proof protocol, known as the ‘Tangle’ that allows zero
fees, infinite scalability, fast transactions, secure data transfers and many others.” It is
initially focused on serving as the backbone of the Internet-of-Things. IOTA is the unit
of crypto currency, the total number of which is 2.779 x 10^{33}.  

12.3.5 Possible BADA-related applications

Blockchain technology is being touted by some as the final component in the ongoing
digitalization revolution that will enable the secure implementation of Internet of
Things, distributed ledger technology and smart contracts. If this turns out to be the
case, blockchain could have significant influence on BADA. Among the areas in which
blockchains could play a part in a future BADA ecosystem are:

- Vehicle and infrastructure access
  - The controversial startup Arcade City uses Blockchain to disintermediate
    the taxi business even beyond what Uber currently does by letting drivers
    and passengers negotiate directly with each other.
  - Dynamic fees could be implemented by authorities for vehicles that
    require access to congested infrastructure
- Vehicle ownership and driver information
  - Secure and transparent vehicle registries, mimicking ongoing initiatives in
    realestate registries and healthcare in Sweden, Estonia and elsewhere
  - Dynamic coupling of blockchained IDs for drivers and vehicles to manage
    infrastructure access rights and privileges
- Data use consent management
  - Global blockchained personal ID to trace consent through multiple levels
    of use
- Open data and transparency management
  - A blockchained ID-system could help monitoring, administering and
    revoking access to private data
  - Datasets could use a blockchain to log additions and block efforts to
    tamper with it automatically \(^{34}\)
- Critical systems security

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33 https://iotasupport.com/whatisiota.shtml
34 (Tapscott and Tapscott 2016)
12.3.6 Challenges

Blockchain technology was near the top of last year’s Gartner Hype Curve and there is reason to believe a modicum of level-headedness will eventually replace the current buzz. Though the potential is immense, there has been only limited actual use of blockchains outside payment. Early entrants include securing commitments,\textsuperscript{35} distributed auctioning\textsuperscript{36} and decentralized prediction markets.\textsuperscript{37} However, none of these startups has attracted large-scale use to date, and they each face significant competition from incumbent firms with processes using more traditional system design patterns.

There has been widespread critique of the bitcoin and reckless disintermediations and deregulations of the taxi business (Arcade City) and markets (Silk road).

There is a dearth of critical reflection and research of issues of privacy, security and trust and of establishing long-term authenticity of digital records as evidence of transactions. Questions have been raised about governance of the blockchain challenging the notion that it is truly decentralized. Following the DAO exploit on the Ethereum blockchain in June of 2016 and the Hong-Kong Bitfinex bitcoin exchange security breach in August of 2016, critical investigations on blockchain security, information assurance, and risk management are on the rise.

The ‘hard fork’\textsuperscript{38} response to the DAO exploit prompted questions about whether blockchains are truly immutable and free from interference, while the consolidation of mining capacity in the bitcoin network raises concerns about the potential for attacks and manipulation of the historical blockchain record. Considering the yet unknown interpretation of the new EU privacy regulation, the prospect of a strict enforcement of citizens ‘right to be forgotten’ may even collide with the fundamentally immutable nature of distributed ledger technology.

12.4 Edge Computing

Mainframe, minicomputer, terminal, workstation, personal computer, client-server, wireless device, cloud: This is the evolution of general computing in a nutshell. It is a story of far and near and then far again. The automotive sector has had its own computer evolution: isolated electronic control units (ECUs), networked ECUs, autonomous navigation controller, wireless device and cloud-connected head unit. Both general and automotive computing are now part of a larger force, the \textit{Internet of Things (IoT)}, and in this larger framework we are now moving from very far away in

\textsuperscript{35} (Clark and Essex 2012)
\textsuperscript{36} (Andrychowicz, Dziembowski et al. 2014)
\textsuperscript{37} (Clark, Bonneau et al. 2014)
\textsuperscript{38} Any alteration to bitcoin which changes the block structure (including block hash), difficulty rules, or increases the set of valid transactions is a hard fork.
the so-called cloud, back to where things are really happening, the EDGE, close to and in our intelligent devices.

**Edge Computing** refers to the computing infrastructure that exists close to the sources of data, says GE, the masters of smart, data collecting devices. This is a general definition that has the *Internet of Things* as its context, and includes industrial machines like wind turbines, airplane engines and hospital scanning equipment. According to some estimates, industrial IoT will create $7.5 trillion (€6,000 billion) in value by 2025. The goal is to apply big data, advanced analytics and machine learning to operations in order to reduce unplanned downtime, improve asset performance, lower cost of maintenance and open up potential for new business models that capture as-yet untapped value from machine data, states GE. The problem is that the more data that is collected from the smart devices, the greater is the problem of moving all of this data to the clouds where processing is taking place. Cost is one issue. Latency is another.

You can’t get much closer to the sources of data than a vehicle. Brian Krzanich, CEO of INTEL, says his engineers have estimated that a car equipped for highly automated driving, with all its sensors, radar, cameras and computing systems, will generate as much data as about three thousand people with their individual computers, phones and tablets, around 25 Gbytes per hour, or nearly 30 times more than a high definition video stream. “A million autonomous cars will generate three billion people’s worth of data. It cannot all go back and forth to the big cloud.”

Besides the obvious advantages of processing data in real time—assuming you have the computing power to do it, which companies like INTEL and NVIDIA are trying to ensure that we will—there is the matter of the cost of transferring, storing and processing data in those gigantic service centers being built by Amazon, Microsoft, Google and Alibaba. For them, a paradigm change from the relatively new Cloud to the Edge is a threat, unless these companies can extend their reach and cover both far (Cloud) and near (Edge) better than individual Edge players can do on their own. They are promoting an AI model in which the algorithms are trained with gargantuan amounts of data in the Cloud, and then the algorithms are deployed on local (i.e., Edge) devices or in local networks for transfer to devices for real-time operation. This is the model most applicable to highly automated vehicles.

**12.4.1 Automotive Edge Computing Consortium**

The **Automotive Edge Computing Consortium**, defines itself as a “consortium for driving the network and computing infrastructure needs of automotive big data.” It was announced and formed on 10 August 2017. Founding members include Denso Corporation, Ericsson, Intel Corporation, NTT, NTT Docomo, Toyota InfoTechnology and Toyota Motor Corporation.
Its members claim that the current forecasts for vehicle data volumes and data transfer capacity in the 2025 timeframe are grossly underestimated. “We estimate that the data traffic will reach 10 exabytes per month around 2025, approximately 10,000 times larger than the present volume.”39 This means there will be a need for “new network architectures and computing infrastructure to support massive computing resources and topology-aware storage capacity in terms of balancing quality and cost.” 3GPP has not fully addressed this challenge, they say. “We believe that the current mobile communications network architectures and conventional cloud computing systems are still not full optimized to handle the requirements of connected vehicles effectively.”

The Consortium’s solution for addressing these problems is Distributed Computing on Localized Networks (see diagram below). The idea is to add localized networks in between the cloud and connected vehicles in order to be able to process local data more quickly and improve response times.

NB: What this diagram does not show is the current connectivity architecture adopted by the vehicle industry which uses an OEM or third party provider Dispatcher in order to deliver data messages to and receive data messages from the vehicle. Each vehicle OEM has its own, proprietary implementation of various communications interface standards. In some cases, data received from the vehicle triggers a service request, such as a request for emergency services or roadside assistance. In other cases, data is passed to data processing applications, including BADA. In the future, when secure, standardized vehicle-to-X processes are developed, data may be passed directly from on-board sensors and other devices to other vehicles, to roadside units and to the cellular network, and at this point the Edge Computing Localized Network could be employed.

Figure 53: Diagram of distributed computing on localized networks proposed by AECC

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39 Information is obtained from the AECC’s White Paper (www.aecc.org)
Where’s the Edge?

The Edge Computing technology the Consortium intends to use for its concept consists of two components: the network and the computation resources. The network will be designed to split data traffic into what the Consortium says will be “localities that cover reasonable numbers of connected vehicles.” The computation resources will be hierarchically distributed and layered in a “topology-aware fashion to accommodate localized data and allow large volumes of data to be processed in a timely manner.” The ‘Edge’ means “the hierarchically distributed non-central clouds where computation resources are deployed, and the Edge computing technology can be used to design such a flexible topology-aware cloud infrastructure.” The vehicle itself is included as a ‘non-central cloud’ where resources are deployed.

HERE has a similar view to the one promoted by the AECC while using different terminology. HERE sees the ‘Edge’ as the end user device in a vehicle or in the hands of an individual. They refer to the local networks as ‘forks’. These are data centers that are close to the vehicles. Large amounts of data are sent from the Edge devices, pre-processed there and then a digested part of the data is sent to the cloud for further processing and distribution.

12.4.2 ETSI – European Telecommunications Standards Institute

Multi-access Edge Computing (MEC) offers IT service and cloud-computing capabilities at the Edge of the mobile network in an environment that is characterized by proximity, ultra-low latency and high bandwidth. Furthermore, it provides exposure to real-time radio network and context information.

According to ETSI, MEC is a “development in the evolution of mobile base stations and the convergence of IT and telecommunications networking.” Multi-access Edge Computing will enable new vertical business segments and services for consumers and enterprise customers. Use cases include:

- Video analytics
- Location services
- Internet-of-Things (IoT)
- Augmented reality
- Optimized local content distribution and
- Data caching

It uniquely allows software applications to tap into local content and real-time information about local-access network conditions. By deploying various services and caching content at the network Edge, Mobile core networks are alleviated of further congestion and can efficiently serve local purposes. MEC industry standards and deployment of MEC platforms will act as enablers for new revenue streams to operators, vendors and third-parties. Differentiation will be enabled through the unique applications deployed in the Edge Cloud.
The Multi-access Edge Computing (MEC) initiative is an Industry Specification Group (ISG) within ETSI. The purpose of the ISG is to create a standardized, open environment which will allow the efficient and seamless integration of applications from vendors, service providers, and third-parties across multi-vendor Mobile-Edge Computing platforms. The initiative aims to benefit a number of entities within the value chain, including mobile operators, application developers, Over the Top (OTT) players, Independent Software Vendors (ISVs), telecom equipment vendors, IT platform vendors, system integrators, and technology providers. All of these parties are interested in delivering services based on Multi-access Edge Computing concepts.

The work of the MEC initiative aims to unite the telco and IT-cloud worlds, providing IT and cloud-computing capabilities within the RAN (Radio Access Network). The MEC ISG will specify the elements that are required to enable applications to be hosted in a multi-vendor mobile-Edge computing environment. MEC will enable applications and services to be hosted ‘on top’ of the mobile network elements (i.e. above the network layer). These applications and services can benefit from being in close proximity to the customer and from receiving local radio-network contextual information.

12.4.3 5G Automotive Association (5GAA)

5GAA is a multi-industry association created in September 2016 to develop, test and promote communications solutions, initiate their standardization and accelerate their commercial availability and global market penetration to address societal need. Founding members are: Audi, BMW, Daimler, Ericsson, Huawei, Intel, Nokia and Qualcomm. The 5GAA states that it “supports the idea that 5G will be the ultimate platform to enable C-ITS and the provision of V2X. 5G will be able to better carry mission-critical communications for safer driving and further support enhanced V2X communications and connected mobility solutions.” In March, 2018, 5GAA submitted a position paper to the U.S. Department of Transportation Federal Highway Administration (FHWA) recommending that the FHWA rely on Cellular-V2X (and not 802.11p/WAVE) for advancing towards the next generation of North America’s transportation network. (For more information see 5gaa.org/.)

In a December 2017 White Paper, Toward fully connected vehicles: Edge computing for advanced automotive communications, 5GAA outlines its vision for connected vehicles, and especially autonomous driving vehicles.

“Edge Computing based Vehicle-to-Cloud solutions enable Edge Cloud capabilities for different levels of autonomous driving, including Highly Autonomous Driving (SAE Level 4) and Fully Autonomous Driving (SAE Level 5) through providing different services for the driving process, including high definition real-time maps, real-time traffic monitoring and alerts, and richer passengers experience. These will support vehicles on the roads to drive more cooperatively and to be aware of road hazards, providing better user experience and trust to drivers and passengers.”
The White Paper describes a number of automotive use cases and explains how Edge Computing delivers compute/storage/networking capabilities in closer proximity to the vehicles than is possible with Cloud Computing. It further describes how Edge Computing is a supporting technology for multiple services for connected and autonomous drive vehicles. The proposed Edge computing solution is the Multi-access Edge Computing (MEC) standard developed by ETSI.

Three features are identified as being beneficial to Edge Computing:

- **Network Slicing** – this tailors the capacity and capabilities of the network for each different service;
- **Service-specific profiles** – allows for dynamic assignment of service-specific hardware acceleration to optimize the compute and storage based on simultaneous service requirements; and,
- **Hierarchical deployment of the Edge Computing environment using a hierarchy of gateways/roadside units with the Edge Computing servers arranged to reduce the latency and distribute the processing.**

Included in the White Paper are examples of new business opportunities for the automotive ecosystem that are potentially powered by Edge Computing, as shown in the table below.
The main implications of adopting an Edge Computing approach for Big Automotive Data Analytics is that another layer will be added to the eco-system. This layer will consist of local networks (aka Edge Clouds) that will receive data from vehicles and send data to them. Reducing costs and minimizing latency are the principal advantages, but there are many unanswered questions about the practical issues of operation. How will these local networks be financed? Will they add significantly to the costs of communications and data processing, or will the savings realized offset their costs? Who will operate them? Will there be different operators for different types of data, for example one set for public data and another set for private? It is even more essential that there is single standard used for the interface between the vehicle and the local clouds and not multiple standards for different actors.

The diagram below exhibits a scenario in which there are separate local networks for private and public data sources, with data being passed from the vehicle both via the OEMs’ telematics service providers and via a standardized and secure V2X connection to the local networks.
Figure 56: BADA Value Flow with Edge Computing
13 Possible Future Scenarios

13.1 Scenario Methodology

Scenarios provide a networked perspective on future developments in each context, here the development of Big Data in the automotive sector. Scenarios are not forecasts describing THE future but present plausible, consistent pictures of the future – alternatives of “what could be”. Which of these alternative pictures will correspond to the actual future is uncertain, and most probably the actual future might include elements of several scenarios – and even elements that we cannot foresee today: new developments and trends, innovations and disruptive events.

Scenarios initiate the discussion and debate of objectives, strategies, tools and measures and foster long-term oriented, sustainable thinking and action. “How do we want to act, and how should we act?” This benefit materialises even when deriving conclusions from undesirable, negative scenarios. Each scenario will encompass negative and positive aspects, also depending on the perspective – and thus be in a good position for inspiring thoughts on new strategies and actions. The main benefit of scenarios is not the answers it provides, but the questions it inspires.

Scenario implications consider potential strategies of all relevant players in a field and should include also those strategies which – from today’s point of view – are less probable or even undesirable. Therefore, scenarios should not be regarded as propositions. Neither should the reader expect that the measures described in the scenarios lead exactly to the depicted results.

Last but not least, scenario projects are processes of communication, also because they greatly reduce complexity. Both the quality of the results and their acceptance – key requisites for a successful later use – depend on involving relevant internal and external experts from an early stage and “translating” the results into a language and format that can be easily used for dissemination among relevant target groups.

13.2 Development Process

The three scenarios in this report were developed in a five step process including key factor generation and prioritization, key factor projection, raw scenario generation and eliciting implications and evaluation.
The start was the compilation of a list of 24 influencing factors which determine the future development of BADA. In a workshop with BADA project participants, the longlist was reduced to a short list of 11 key factors by selecting the factors with the highest impact and the highest uncertainty. In that same workshop, participants started developing future projections (trajectories) for each key factor, which were then consolidated by the RISE Viktoria project team. The criteria for identifying projections was plausibility, comprehensiveness, and mutual exclusiveness and the timeframe was set to 2030. The key factors along with their projections make up a so-called morphological box.

The project team then connected projections that are consistent with each other to plausible stories, resulting in 3 “raw scenarios”. While one scenario described a desirable (but not necessarily business-as-usual) future, the other scenarios paint pictures of alternative, even disruptive futures, in a positive or negative sense. The morphological box represents the raw scenarios as follows:
In a second workshop, these were then enriched to full-fledged scenario stories exploring each scenario’s driving forces, risks and benefits, impacts for technology and transport systems, and implications for key actors. A version of the written scenarios was submitted to the project group and resulting suggestions and clarifications were applied. This report now represents the consolidated scenario stories in the form of consistent narratives as well as the implications and recommendations for key actors.

13.3 Scenario 1: Fast-track Innovation

13.3.1 Scenario 1: Description

The positive attitudes towards innovation associated with the accelerated digitalization revolution continues and Internet of Things continue unabated. Though reports of data misuse still exist, it quickly becomes an expected and manageable price to pay for the unprecedented productivity gains afforded.

As things increasingly become connected, the capacity to manage and analyse vast amounts of data rapidly becomes paramount. Though manufacturing sectors benefit tremendously from the digitalized “industry 4.0”, the significant gains are mostly coupled to incremental improvements of their extant manufacturing processes. Amidst a shortage of specialized knowledge workers, OEMs and the public sector struggles to acquire analytics competency. Data driven business models and players are rapidly becoming dominant in most fields, as incumbent actors are unable to exploit the full potential of the growing streams of sensor data for analytics and service design.
Recognizing the inertia of the existing structures, governments implement changes to their research funding strategy moving the emphasis from established industries and large multinationals to increasingly favour small innovative actors. Incumbent data driven firms vigorously invest in and buy many upcoming new businesses, but the rate of growth of new prosperous digital businesses is greater than their capacity to absorb new additions. A virtuous cycle of small scale innovation and rapid growth shows no signs of weakening.

Incumbent actors in big data analytics leverage their core competences to gain influence in the BADA sector. Automotive communication standards and digital platforms are increasingly developed by data driven actors outside the current automotive sector. As a consequence, a new and integrated cross-sectoral system outlook between actors in the automotive and IT as well as public sectors is established.

### 13.3.2 Scenario 1: Transport technology and business models

While purely digital businesses make inroads into automotive development and services, the OEMs retain competitive advantage in core areas such as deep learning for vehicle automation. However, these areas are essentially still within a vehicle manufacturing paradigm and OEMs cannot compete with actors specializing in mobility services and fleet management. As that industry accelerates, OEMs increasingly focus on core competence and eventually become suppliers of advanced hardware to service providers. They become more reliant on analytics services, but primarily to rationalize design and maintenance processes. Vehicles are increasingly not designed as stand-alone products, but as components of integrated mobility services.

ITS infrastructure development progresses and both dedicated short range communication and 5G infrastructures are deployed in a coordinated fashion. Governments find that added spending on DSRC helps mitigate certain aspects of increasing congestion and safety issues and while telecom and OEMs have largely favoured 5G, clear prioritizations of which types of functionalities go where are quickly set. There are clear and globally applicable guidelines for upper layer services deployment, which greatly facilitates development of V2I, V2V and V2X services.

As ITS infrastructure development is stabilized and deployed, advanced traffic control is implemented enabling detailed control of traffic flow to mitigate congestion and pollution issues through automated incentive structures to regulate infrastructure
access. Mobility operators offer integrated solutions to citizens and freight owners creating a new and influential service industry. Limited privacy regulation means that detailed analytics on the resulting digital mobility patterns enable highly efficient infrastructure and urban planning as well as a market for services utilizing automotive data as input.

13.3.3 Scenario 1: Implications

*Life cycle excellence:* mediators dominate the end user part of the automotive value chain. However, as cars ownership is becoming a rare occurrence, OEMs can utilize a wealth of data on actual usage to design ever more efficient and sustainable vehicles. Components are built to last and for ease of maintenance as well as catering for recycling, disassembling and upgrading.

*Mobility as a service:* Dedicated service operators can customize their offerings to citizens and corporate customers and offer a wide variety of service levels catering to almost all mobility needs. The necessary vehicle hardware is provided by OEMs through automated service level agreements.

*Sustainability first:* An unprecedented access to high resolution data on all forms of mobility means that sustainability policies can be enforced through advanced traffic control, and analyses to follow up changes to local or national policy is available with little or no delay.

*Open innovation:* In a fast-moving technological environment, cooperation with cutting Edge start-ups will be increasingly important. This poses a significant challenge for large established firms, public as well as private, who are used to a slow-moving landscape of established suppliers. Processes in e.g. purchasing and strategies for collaboration will need adaptation to cope.

<table>
<thead>
<tr>
<th>Actor</th>
<th>Implications</th>
</tr>
</thead>
</table>
| Trafikverket (Road authority) | • Market supplies both data and services  
• No need for stimulation of market, there are adequate private incentives thriving on their down accord  
• Increased automation and demands to control flow in urban areas will push Trafikverket to promote development of V2I, but with preference of cellular infrastructure.  
• The BADA competence supply will deal mainly with purchasing of external services, not inhouse development or maintenance  
• Trafikverket will likely struggle to acquire skilled workers  
• An abundance of data can be used for detailed and quick policy follow up and modification leading to new forms of data-driven transport policy processes  
• A fast-moving service provider landscape place rising demands of operational flexibility to reap the benefits of the |
swift BADA innovation pace – Trafikverket will have to learn to move faster to cooperate
- Very strong need for cooperation between public and private actors to promote sustainable transportation.
- Increased focus on environmental issues will demand increased cooperative traffic management actions for where and when different kind of vehicles will be allowed to be used as well as different kind of incentives/penalties to encourage vehicles to follow common advice on where and when to be used.
- Mobility-as-a-Service will be a common part of public transport.

**Volvo Cars**

- Digital platform development becomes dominated by non-automotive IT-actors and OEMs will cooperate in alliances or buy them off-the-shelf
- VCC will find it difficult to adapt quickly enough and will likely be forced away from Mobility as a service leadership.
- Focus on cars and Vehicle data (collected by the vehicle - usage, service, traffic, etc.) as MaaS-components for service operators
- Competing through automation and service/maintenance excellence instead of direct customer contact.
- There will be changes in organizational structure to accommodate fewer global service operators rather than thousands of dealers
- During a transition period, allow flexible leasing offers with subsidies for customers willing to participate in C2B-programs
- Vehicle maintenance part of deals with operators.
- Vehicle designs will adapt to suit needs of service operators
- Automation leads to focus on sensor packages and superior analytics rather than physical and passive safety
- Data access negotiation will likely be the responsibility of fleet operators, not OEMs, who only operate the digital infrastructure (e.g. clouds) to facilitate this
- VCC or other partner owning the fleet with rate effect on balance sheet.
- Continued innovation regarding possibilities with “connected car”

**Heavy Vehicle OEMs**

- Platform development becomes dominated by non-automotive IT-actors and OEMs will cooperate in alliances and/or purchase.
- Construction vehicles and other products designed to operate in closed off areas (such as BRT) will lead the way to automation.
- Commercial vehicles are already focusing on fleet customers and operators, but supplying transport capability as a service is still a big step, but commercial vehicle OEMs might try to move towards a service oriented BM.
13.4 Scenario 2: Coopetition and Steady Progress

13.4.1 Scenario 2: Description

As European OEMs realise that they must gather forces to accelerate technological development and counterbalance the growing dominance of the mostly American IT sector, they intensify cooperation among each other mainly, but not exclusively, in the areas of IT, Big Data and autonomous driving. They become able to determine the course of automotive IT R&D, secure a major part of public funding and even venture capital, and, at least in their core automotive applications, to outcompete major IT consortia. OEMs manage to create a dynamic, competitive research environment within their organisations and thus attract human capital to the European automotive hubs. Talented coders and developers no longer prefer Silicon Valley over Stuttgart, Gothenburg or Södertälje.

OEMs manage to become less dependent on large IT and electro-technical suppliers as they can increasingly incorporate most of the necessary competencies and capacities themselves. Start-ups and other innovators in automotive IT are usually being integrated into the consolidated OEM “empires”, enabling them to streamline technology development according to their needs. They compete with IT companies in standardisation and platform development. A consolidated market, divided between a handful of actors, results in a de facto oligopoly, with some standards and platforms having their origin in the vehicle industry, others in the IT market.

By joining forces with competitors, OEM thrive and can free themselves from outside pressures. Their economic strength enables them to venture into a more service-oriented business model. They focus on the expansion of operational leasing, but also increase their proprietary car sharing services, even if more cautiously. Less and less cars end up in individual ownership, and OEM can retain control over many of their vehicles. This co-ownership, along with continuously lax data security regulations, greatly facilitates data sharing and services. OEM maximise their service and

- Will likely struggle to acquire skilled labor, but some specific skillsets pertaining to e.g. automation will still attract expert workers
- Data access negotiation will likely increasingly become the responsibility of fleet operators, not OEMs, who only operate the digital infrastructure (e.g. clouds) to facilitate this
connectivity value, and competition among OEM is no longer focused on vehicles and technologies only.

13.4.2 Scenario 2. Transport technology and business model

Though OEM join forces, the lack of powerful binding regulations and standards from policy makers lead to a regionally fragmented deployment of BADA services. Despite progress in performance of ITS and traffic control – also due to increased data availability – the transportation system cannot keep track with an ever increasing number of vehicles which grows unabatedly due to a lack of regulation. After authorities – and manufacturers – recognise this gap, they begin pricing and taxing roads, travel slots, and parking more heavily. Soon car owners or operators do not only purchase or lease vehicles but also access to roads, parking, and information and navigation services. Saving time becomes the top priority of drivers and operators, and cost savings are willingly given up for time savings.

Solving clients’ pains and increasing their gains means to cater to each driver’s or fleet operator’s specific local and time-based needs in an on-demand manner. This is greatly facilitated by various big data applications which tap on traffic flows, individual driving behaviour, and route management. OEM-owned clouds then enable manufacturers and fleets to exchange data securely. However, providing on-demand services requires OEMs to shift their product-based positioning on the market. Competition among OEMs is no longer about the product, but about services and service-enabling technologies.

A connectivity infrastructure bottleneck, originating in competing visions on dedicated shortrange or cellular 5G dividing OEMs, telecom and public sector actors is resolved in a de facto fashion. As OEMs have little interest in investing in external infrastructure, DSRC implementation V2I and V2X developments are bogged down in arguments about cost distribution, leaving low latency 5G solutions as the preferred solution for most applications.

With OEMs determining the course of R&D the industry moves by adding more and more automated features, progressing through level 1 to 5, eventually ending up in full level 5 automation. Level 4 automation reaches technological maturity, while market introduction is gradual, and level 5 features are beginning to be deployed. As expected, a higher share of autonomous vehicles or functions significantly improves safety on the roads. Along with the limited access to road space – which reduces
vehicle miles, crowding, and emissions – other transport policy goals are being catered to as well.

13.4.3 Scenario 2: Implications

*From manufacturer to service provider:* This scenario describes a highly dynamic development for OEMs. Data-driven services become key components to new end-to-end business models of hardware production and maintenance as well as data-driven mobility service design. Existing models such as leasing, carpooling, rentals as well as privately owned vehicles can be combined into tailored offerings. These are eventually completed with “access packages” to help drivers/users navigate highly regulated urban traffic environments and patchy regulation. Smaller manufacturers will likely need to cooperate in consortia to be able to offer a full complement of vehicle types to their customers cost effectively.

*Connectivity infrastructure:* With a low level of state interference, slow development of connectivity infrastructure can lead to significant deployment gaps and stall development and dissemination of key applications. Policy makers and OEM should therefore push for parallel solutions, meaning developing and deploying both cellular and V2I based infrastructure to benefit from both technologies.

*Regulation:* Privacy protection is not a cause of concern in this scenario. However, as OEMs are positioned in direct contact with customers, the management of trust is still essential to their brands and care has to be taken to avoid any perceived misuse of private data. As OEMs increasingly transform their business model to providing mobility service, issues of data ownership will be seen in a new light and political pressures to open access to vehicle data will gradually disappear.

*Data access:* As OEMs assume an end-to-end responsibility for mobility services, massive amounts of data will likely be managed within these organizations rather than opened for a broader BADA ecosystem. Authorities and OEMs will likely have to be actively involved in keeping an innovative landscape open for new entrants and ideas to develop BADA services for environmental sustainability, improved traffic flow and safety.

<table>
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<tr>
<th>Actor</th>
<th>Implications</th>
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| Trafikverket (Road Authority) | • No centralized platforms on e.g. EU-level, cooperation with commercial partners necessary  
                               | • Able to exert some influence of innovation through R&D policies           
                               | • OEMs will be a gateway to automotive data access, not owners or fleet operators, which is similar to the situation today  
                               | • As DSRC development slowly grinds to a halt, Trafikverket will not be authoritative in the provision of ITS-connectivity. |
| **Volvo Cars (Car OEM)** | Instead low latency cellular communication will provide the backbone of most services V2V, V2I or V2X.  
- As automation progresses steadily, Trafikverket will have ample time to expand their capacity to take advantage of mass scale automotive data when and if it appears.  
- Since mass data provision is neither mandatory nor voluntary, applications for policy development and monitoring will likely develop slowly.  
- Balanced focus between environment, traffic safety and traffic flow, and at the same time increased cooperation with commercial actors, means cooperative traffic management solving the same issues as today but in a much more efficient way.  
  
- Close cooperation between OEMs to design and standardize basic digital platform elements and standards  
- There are a small number of competing platform alliances  
- Platform consortia will be either OEM or IT-dominated  
- Volvo will have to decide on joining one dominated by bigger OEMs or non-automotive actors.  
- Could move from selling cars via lease to selling mobility services. This change will fundamentally change the nature of the organization. The bridging of two logics: production and service provision will be a constant source of tension.  
- Big data will have to be applied to better understand the customer’s mobility needs. Analytics of sensitive information from a privacy perspective such as travel patterns will have to be considered.  
- CRM will have to shift from traditional ownership to also incorporate usership.  
- As a service provider, a small OEM like VCC would likely have to collaborate with other OEMs to provide a full complement of vehicles types.  
- Selling mobility as a service rather than products transforms car maintenance from revenue to cost.  
- Focusing on low latency 5G and V2V, OEMs can prune and rationalize their innovation portfolio developing cost efficient services based on a lean and standardized digital infrastructure  
- OEMs retain their influence of public R&D streams and control the innovation landscape.  
| **Heavy Vehicle OEMs** | Close cooperation between OEMs to design and standardize basic digital platform elements and standards  
- There are a small number of competing platform alliances  
- Platform consortia will be more dominated by OEMs than in the car sector  
- Volvo will have to decide to take a leading or following role  
- Could move from sell products via lease to selling of mobility services. This change will fundamentally change the nature of the organization. The bridging of two logics: production and service provision will be a constant source of tension. |
13.5 Scenario 3: Risk-averse World

13.5.1 Scenario 3: Description

In the wake of increasing concerns about cybersecurity and the proliferation of digital traces from citizens, unregulated digitalization eventually reaches its limit. Mutually reinforcing trends move society towards a protective and risk-averse stance.

Rising concerns of privacy issues makes a growing number of people minimize exposure of digital traces in social media and elsewhere. For those who remain connected, data about their everyday life is being shared with little discretion, generating a “little brother” society. Identity theft is a common issue.

A series of unfortunate incidents including unintended accidents involving automated test vehicles and deliberate exploitation of connected vehicle security breaches have a profound impact on the perception of connected and automated vehicle development. At the same time, continued urbanization and associated congestion challenges reach critical levels, and increasingly vocal protests demand political action.

Citing reasons of security and safety, authorities become actively involved in the development of both automated and connected vehicles. In a few years, the collective

- The portfolio of products will develop to match the needs of future supplychains. However, OEMs will provide transport services, but not directly to transport costumers, but rather through logistics actors. These will choose transport services to fit their demands and combine OEM offerings as they see fit.
- Selling mobility as a service rather than products transforms car maintenance from revenue to cost.
- Focusing on low latency 5G and V2V, OEMs can prune and rationalize their innovation portfolio developing cost efficient services based on a lean and standardized digital infrastructure.
- OEMs retain their influence of public R&D streams and control the innovation landscape.

- Big IT continues proliferating personal data for analytics, eventually provoking significant public concern for privacy and data safety.
- Government eventually responds by implementing strict interpretations of data privacy and safety regulations; it also attempts to introduce strict BADA-related standards.
- Patchy coverage and uncoordinated national strategies means that various actors attempt to implement overlapping services in both short-range and cellular infrastructures, slowing down innovation.
- Technological progress inadequate to convince public or government about the feasibility of full automation.
- OEMs cannot find a profitable path to digitalization and servitization, leaving e.g. fleet operations and services to other players.
perception of digitalization has morphed from being hailed as the prime driver of open society economies to being viewed as a very real threat to the same.

As a response, governments introduce strict interpretations and enforcement of regulations that affect all things digital, affecting major players in the IT sector and the BADA sector alike. The recently introduced General Data Protection Regulation (GDPR) is used to demand strict adherence to distinct consent for each use case, and the right to be forgotten. The effects are felt not only in the social media and search sectors, but also in the fledgling BADA sector. OEMs are further discouraged from developing their digital portfolio of vehicle sensor data as the delegated act on free access to traffic related data is implemented in a comprehensive manner, effectively eliminating private incentives. The EU C-ITS platform initiative accelerates pushed by public sector agendas. However, the prioritization between infrastructural options is often at odds with vehicle manufacturer and telecom interests and there is no definite resolution.

13.5.2 Scenario 3: Transport technology and business models

As the pace of maturation and acceptance levels of vehicle automation seems increasingly discouraging, OEMs and others active in the field decide on a modest gradual and low impact strategy. Automation development generally stops at level 2. Some isolated instances of level 4 reach maturity, but they have limited impact on the global transportation system.

Though there is a clear pressure on municipalities to enhance the urban traffic environment, the digitalization of traffic control is sluggish. Echoing the troubled development of the e-Call ITS service, further development of advanced ITS services develops into a protracted deadlock between commercial forces dominated by OEMs and telecom on the one hand and authorities and government on the other. Developments of dedicated short range communication infrastructure and cellular low latency are uncoordinated. Nations and regions choose to implement various standards for varying services. ITS data supply becomes scarce, patchy and fragmented in terms of information standards.

OEMs are successfully able to resist complete regulation of C-ITS. Ever stricter regulations are taking their toll on entrenched digital actors in social media and search, who gradually find their source of competitive advantage – user data – dented. In the absence of external pressure, OEMs can keep the current business
model. There are no obvious incentives to push initial experimentation with servitization and circular business models to replace the current business model.

The combination of the above-mentioned factors drives BADA service development costs to levels requiring massive returns to merit investment. Few actors have the resources necessary and most major applications are used by, or heavily subsidized by the public sector, with limited interest in extending the use of data beyond the initially intended functionality.

13.5.3 Scenario 3: Implications

Niched automation: BADA services are dependent on massive amounts of data from automated vehicles, and the slow growth of such data in this scenario leads to a slower growth of the field. However, for OEMs that cater for niche automation, such as cordoned off Bus Rapid Transport systems or construction equipment, there will be opportunities for data reuse for vehicle design process improvement and maintenance.

Business as usual: There will not be any significant incentives to switch business models for OEMs. Changes to the organizations and their core processes remain clearly within the current automotive paradigm. To mitigate potential stock value affecting negative publicity following incidents of any kind, any radical developments in automation and BADA services could be moved outside the OEM core to subsidiaries. For authorities, traffic control capabilities will progress, but at a slow pace. This further reduces the growth of available data for BADA.

Data access: Though an open standardized platform would, in theory, grant authorities access to a wealth of vehicle data, it would likely be prohibitively expensive as OEMs struggle to retain a competitive Edge by implementing cordoned off digital platforms and capabilities in parallel. Such inefficiencies could paradoxically lead to lower amounts of data and BADA service development. From a government perspective, harmonization and non-invasive meta standardization is preferable, striking a balance between data accessibility and ensuring cost efficient development.

Coping with fragmentation: Given a highly fragmented infrastructure, local adaptation will become increasingly important. Actors that cater for specialized services and infrastructure to cope with this complexity will become winners and an indispensable component in service design and delivery.
| Trafikverket (Road Authority) | • Trafikverket will be involved in the development of standardized platforms for promoting e.g. C-ITS  
• Mandatory detailed standardization of platform and communication standard will enable easy integration of data sources across brands  
• However, OEMs will struggle to retain competitive Edge by developing parallel platforms, leaving standardization to conform with bare minimum demands. This will be costly and the amount and variety of data for BADA innovation will be negatively affected  
• ITS connectivity continues, but not in a coordinated fashion. DSRC will enable advanced service implementation locally, but at a high cost. Data will frequently be locked into subsystems and difficult to utilize for BADA innovation  
• A decrease in public funding will give less coordination of local efforts both nationally and regionally.  
• The projection of traffic patterns will not change radically since automation development stalls. Future challenges will be much the same as those present today, but more acute.  
• Automotive data access negotiation is the responsibility of the end-user. This affects data procurement methods and legal procedures.  
• The data provided by standardized platforms have potential to drive policy development. However, privacy regulation and complex access negotiations encumber innovation.  
• As cooperative traffic management will be difficult to establish, we will still see uncoordinated traffic information messages to travelers coming from public road owners vs commercial service providers causing traffic flow problems and high emissions. |
|---|---|
| Volvo Cars (Car OEM) | • Heavy regulation of platforms and mandatory services make it difficult to differentiate branded platforms as well as offerings  
• Differentiated data provision and innovation for service revenue will have to be implemented in redundant parallel architectures.  
• Ensuring global vehicle compliance with ITS services implemented on various variants of DSRC and cellular implementations will be a continuous and costly activity.  
• Customer trust is at stake as debates on commercial use of private data traces intensify, motivating a conservative or cautious approach to BADA. Strict interpretations of GDPR means having to comply with right to be forgotten and privacy demands in all areas. BADA |
innovation will be subject to expensive protracted legal analysis case by case.
- BADA will primarily be used for internal purposes such as enhancing decision making within R & D, manufacturing and service contracts based on predictive algorithms.
- Mechanisms for removing digital traces of customers will have to be implemented to use automotive data. (i.e only eCall active)
- Since automation development stalls, cars will resemble current technology levels in terms of number and types of sensors and data streams.
- The OEM business model will remain the same. Limited BADA innovation will not prompt a move towards a service oriented model.
- In a fragmented landscape of infrastructure, data standards and policies integrators will become crucial for BADA development

<table>
<thead>
<tr>
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</tr>
<tr>
<td>- Ensuring global vehicle compliance with ITS services implemented on various variants of DSRC and cellular implementations will be a continuous and costly activity.</td>
</tr>
<tr>
<td>- Costumer trust is at stake and use of commercially sensitive data is risky, motivating a conservative or cautious approach to BADA.</td>
</tr>
<tr>
<td>- Some commercial vehicles (e.g. buses) will develop lvl4 automation, but most commercial vehicle types will not.</td>
</tr>
<tr>
<td>- Since automation development stalls, most vehicles will resemble current technology levels in terms of number and types of sensors and data streams.</td>
</tr>
<tr>
<td>- The OEM business model will remain the same. Limited BADA innovation will not prompt a move towards a service oriented model.</td>
</tr>
<tr>
<td>- In a fragmented landscape of infrastructure, data standards and policies integrators will become crucial for BADA development</td>
</tr>
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14 Scenario-specific Consequences and Recommendations

14.1 Consequences and Recommendations for Trafikverket

14.1.1 General consequences and recommendations common for all Scenarios

- The use of large amounts of data and Big Data analytics will enhance mobility and traffic management in order to allow more efficient use of the roads, which should result in reduced need for building new roads.
- For Trafikverket as a public authority it is extremely important to find its role in the eco-system of data exchange and also in the whole eco-system of mobility and transportation. Act to help the internal market without interfering with the market.
- As data and data analytics are the enablers for advanced mobility services such as MaaS, it is important for Trafikverket to understand how to promote the market in order to establish mobility services using sustainable business models.
- Before collecting data for Trafikverket’s own operations, consider if the data might be available from commercial data suppliers.
- Trafikverket will benefit from superior data analysis in its long-term planning.
- Big Data Analytics for better understanding of accidents and incidents will result in better traffic safety. Figuring out how to make or buy is a question to be considered in this case. In favour of buy would be the potential to share the gains with other road authorities in other markets.
- Trafikverket will be able to follow up on road maintenance more efficiently.
- Road maintenance services will likely be more efficient and less costly if the contractors utilize the service by using the information generated about the road segments that they are responsible to maintain.
- Start finding a policy and strategy for how to meet challenges regarding traffic management and traffic information.
- Develop the ways exchange of data and traffic information can be done to and from service providers and fleet management centres operated by fleet owners or OEMs.
- Develop a way of exchanging TMPs and information with service providers and with fleet management centres operated by fleet owners or OEMs.
- Regarding traffic information, decide what Trafikverket is responsible for and what can be done by commercial actors.

14.1.2 Specific recommendations in the case of Scenario 1

- Cooperation with external actors becomes very important.
- Resources are needed for data sharing - analysis, processes, strategy.
- Determine what Trafikverket needs to do internally and what can be put on external actors.
- Acquisition of expertise will be difficult but important.
- Develop incentives / fees / penalty models to control vehicular traffic in a desired way.
- Customize urban planning and construction to fit MaaS and a greater occupancy rate on the vehicles (i.e. fewer parking spaces, etc.).
- There is no need to promote and finance data exchange as the market will race in that direction anyway.
14.1.3 Specific recommendations in the case of Scenario 2

- Trafikverket must be more active in promoting data exchange between market actors than in Scenario 1.
- It is also a need for Trafikverket to be more active in standardization and harmonization.
- Scenario 2 is relatively costly to Trafikverket, because there are different islands with data and different ways to access data.

14.1.4 Specific recommendations in the case of Scenario 3

- Trafikverket need to use resources to work with:
  - Own data collection.
  - Legal requirements to control traffic and establish services.
  - More monitoring.
  - Hard standardization.
- It is necessary to prepare for more political governance.

14.2 Consequences and recommendations for vehicle OEMs

14.2.1 General consequences and recommendations common for all Scenarios

- Introduction of Connected and Automated Transport systems and the ability of Big Data Analytics will cause a radical shift of OEMs’ business models.
- Depending on the available strategic options pursued, an OEM could occupy a role similar to that of today, or as a powerhouse driving the complete integration of the multimodal automated transportation system of tomorrow.
- Functions for in-car data collection and redistribution exists between Volvo-brand cars, but standardized vehicle-to-vehicle, vehicle-to-infrastructure, vehicle-to-cloud and cloud-to-third-party methods will be needed to complete the data exchange with third parties, such as other car manufacturers, service providers, road owners, public authorities and contractors. It is a strong need for the OEMs to promote standards for data exchange that enable each OEM to achieve its desired role in the eco-system and to secure the vehicles from cyberattacks.
- The OEMs needs to establish functionality for integrating and analyzing Big Data, either by themselves or in cooperation with other actors.
- Shape the role versus large service providers.
- Decide if operating a Traffic Control Centre is a role to take and if it desired and profitable.
- Define how to cooperate with public authorities and private road owners to exchange data and to manage the respective fleet in an efficient and harmonized way.

14.2.2 Specific recommendations in the case of Scenario 1

VCC

- Very important to decide what position to take in data exchange with others actors:
  - Develop yourself.
  - Develop with other OEMs.
  - Cooperation with external major actors.
• Identify which business rules you want control of yourself and be able to process in proprietary clouds and which can allow external actors to process.
• Determine how to get large amounts of data by determining which actors to cooperate with.
• Predictive maintenance becomes extremely important and are examples of business rules you want to control yourself, to know how many vehicles you need to provide to keep promised quality and uptime levels.
• Develop requirements to be able to interact with providers of mobility services in a harmonized manner.
• Active participation in standardization of data is important - categorization of data see ACEA.
• Quality is very important.
• Establish add-on services, as it is important to distinguish yourselves from others.
• Customize the vehicles for higher km:s/occupancy rates and shorter life-cycles.
• Prioritize passengers in the vehicle at least as much as the driver.
• Generally changing requirements for the product car.
• Life cycle view of the car - including recycling included.
• Can reduce costs but do not control profit.

Volvo AB and Scania
• Most recommendations will be same as for VCC.
• Identify where you want to be in the business chain.
• Focus on connectivity with all key partners to optimize logistics, loading, and driving.
• Identify and prepare for new customers.

14.2.3 Specific recommendations in the case of Scenario 2

VCC
• Much as above (Scenario 1), but supplemented/modified with the following.
• Customize to own the customer in a completely different way than today.
• Ownership of the fleet, which allows for control of the entire chain and the customer.
• Collaboration with other OEMs in order to offer customers full service.
• Optionally supplement the vehicle range to reach full service.
• Requires skills in Big Data.
• Can both reduce costs and increase profits.
• Need to adapt the organization to national/local services to provide full service to customers.

Volvo AB and Scania
• Keep the ownership of the vehicles.
• Collaborate with other OEMs to provide full service to customers.
• Requires competence in Big Data.

14.2.4 Specific recommendations in the case of Scenario 3

VCC
• More legal competence needed.
• New requirements to ensure that data is not leaking.
• Build your own internal ecosystem.
• Big Data more for product development than for service development.
Meeting legal requirements means to be able to collect certain data and send to authority-servers.

**Volvo AB and Scania**
- Most recommendations will be same as for VCC, but it might be easier for Volvo AB/Scania to meet the requirements regarding Scenario 3, than it will be for VCC.

### 14.3 Consequences for external actors

#### 14.3.1 General consequences common for all Scenarios

Likely there will be many competing initiatives and services comprising divergent data sources and analyses. If the cost of establishing contextualized analytics competence is not insurmountable, new actors could initiate or buy aggregation or analytics capabilities and provide services to existing actors. The concept Systems-of-Systems will be the common way to establish services.

#### 14.3.2 Specific consequences in the case of Scenario 1

**Big IT companies**
The winner in this Scenario as they have the capability to process and benefit from the huge amounts of data that will be available.

**Medium sized service providers**
Can struggle in a tough competition against the larger companies with power.

**Small actors and start-ups**
Successful start-ups will probably be bought by large IT companies as consolidation of the market will be a trend in Scenario 1.

#### 14.3.3 Specific consequences in the case of Scenario 2

**Big IT companies**
Not as dominant as in Scenario 1. The big IT companies will provide all kind of services but the OEMs still owns the customer.

**Medium sized service providers**
These SP will play a major role providing services to the customers/travellers/vehicles along with the large IT companies and in cooperation with the OEMs.

**Small actors and startups**
More room for smaller actors than in Scenario 1.

#### 14.3.4 Specific consequences in the case of Scenario 3

**Big IT companies**
Will survive and provide services and as Google provide their own eco-system.

**Medium sized service providers**
Will struggle to make profit as the data needed for their services will be difficult to obtain.

**Small actors and startups**
Difficult to grow in a closed market, but some of them might find niches that will be profitable.
15 General Conclusions and Recommendations

As stated in the Introduction to this report, the aim of this work package, BADA Business Models, is to identify how Big Data can reinforce the current business models, or perhaps lead to modifications in the current business models, that will result in better performance on the BADA partners’ important indicators of success. For the vehicle OEMs, success results in higher revenue and higher profit margins. For the Swedish Transport Administration, success results in fewer vehicle-related deaths and injuries, lower harmful emissions and improved traffic flow.

In order to arrive at the consequences of Big Data on the BADA partners and provide recommendations for adaptations and modifications to current business models of each of the partners, we have investigated the issues, problems and opportunities for future mobility, elaborated on the ecosystem of data exchange, its principal actors and their roles, analysed the implications of Big Data on a number of key transport services and reviewed the legal implications of processing data obtained from public and private vehicles. We have identified the following consequences and recommendations that apply to all of the partners:

- Data have the potential to drive your organization. Prioritize accordingly!
- It is highly recommended to raise Big Data analysis at executive level to benefit from it at all levels and in all businesses.
- For all actors it is important to find their desired role in the ecosystem of data exchange and work hard to achieve that role.
- Using Big Data processes for transport requires much more cooperation among many parties in order for the desired results to be achieved. That cooperation extends to both the public and private sectors.
- Public authorities at all levels of government need to integrate their data assembly and integration processes. Private companies must be willing to integrate data which they collect with other companies’ data and with data from the public authorities.
- Standards are more important because data exchange among many parties is essential.
- In order to obtain the full benefits of Big Data, all vehicles should be connected in order to deliver and receive data and information.
- Access to vehicle data will be extremely important and it can be executed in different ways. It is important to work towards a common agreed concept that take into account the interests of all major stakeholders.
- Security and data privacy become more important because of the potential for cyberattacks on the connected vehicles.
- Big data and the use of AI, neural networks and deep learning will make it possible to find patterns and new ideas that haven’t been possible with earlier technologies. Practical methods need to be developed in order to utilize the potential of big data in business development.
- We recommend to establish a multidisciplinary forum/group within each organization that can discuss issues regarding data exchange and how Big Data and AI can be used and support the business. Each organization needs to develop policies, strategies, roadmaps, action plans, etc. and allocate relevant competence to implement them.
- To promote the interests of the Swedish actors on a European and global market, we also recommend the establishment of a group/forum with representation from the project partners to continue to jointly drive issues regarding the use of Big Data.
Big Data, access to data and how we interact for efficient data exchange and policies and strategies regarding these issues.
## 16 References

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