Geo data – the fuel of the self-driving car

An exploration of the relationship between the self-driving car and geo-information

Geonovum

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Chapter 1

Introduction

Geonovum has conducted an exploration into the relationship between the self-driving car and geo-information. In this chapter the cause and scope of this exploration will be described.

1.1 Why this exploration?

If we are to believe all the mobility experts, we are on the verge of a transition in the way traffic and transport in the Netherlands, and beyond, is going to be organised. Vehicles are being equipped with more and more sensors and ways of communicating; they are becoming smarter and able to communicate with each other and with the road infrastructure. Eventually, cars will be more autonomous, increasingly assuming the drivers' role and driving by themselves.

The government wants the Netherlands to create a supportive environment for the further development of self-driving cars. Self-driving cars can communicate amongst themselves and with the road. The expectation is that they will make a positive contribution to traffic flow, traffic safety and the environment. In this context, and from the point of view of encouraging innovation, the Minister of Infrastructure and the Environment intends to achieve the status of frontrunner.

> *"I want us here in the Netherlands, to not only be ready for this, but to take the lead internationally in this innovative development."* [1]
>
> *Minister Schultz Van Haegen of Infrastructure and the Environment (2014)*

To make large-scale testing of self-driving cars on public road legally possible, the decree allowing exemption for exceptional transport movements [2] has been amended so that, from 1 July onwards, the Department of Road Transport (RDW) will have the power to allow vehicles with innovative and automated features on certain sections of public roads. This requires a technical inspection to be performed on vehicles to assess their safety. In addition, in consultation with highways departments, the most suitable testing sites will have to be determined and, where necessary, appropriate safety measurements taken, to enable safe participation in traffic.

In this way, the Netherlands will become a testing country for self-driving cars. The Netherlands Organisation of Applied Scientific Research (TNO), in collaboration with, among others, DAF, the Port of Rotterdam and the Dutch Association for Transport and Logistics (TNL), is preparing a test involving autonomously driving lorries, and the province of Gelderland and Wageningen UR are currently exploring the possibilities of self-driving vehicles in the agro food region - Food Valley.[3]

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[1] Source: http://www.rijksoverheid.nl/nieuws/2014/06/16/schultz-zet-in-op-grootschalige-testen-zelfrijdende-auto-s-op-nederlandse-wegen.html

[2] Decree of the 15 June 2015 amending the decision regarding the exemption of exceptional vehicles (development of the self-driving car). Stb. 2015/248

[3] See http://davi.connekt.nl

1.2 Scope and objective

The Ministry of Infrastructure and the Environment has asked Geonovum to explore the framework of the (geo) data-infrastructure and to determine what is needed to support the transition to the self-driving car.

The purpose of this exploration is to determine what geographic information government bodies, companies and research institutes need to enable them to conduct experiments with self-driving cars, and then to identify to what extent the current availability and accessibility of national and local geo-information services (including the geo key register) are meeting these needs. The role of the government in the field of geo data and the self-driving car is central to this exploration.

This interim report contains the results of a first exploration into what is currently happening in the field of geo data, both from, and for, the self-driving car. We performed this analysis by speaking to various domain experts and by attending 'information days' and other meetings held on self-driving vehicles and smart mobility. Based on this information, we analysed the social and scientific discussion and used this discussion as a 'lens' for our subsequent discussions with domain experts.

The basic questions - 'need for' and 'meet the need of' geo data for the self-driving car proved difficult to answer, because the technology of the self-driving car is in its early stages and is still being conducted largely in a lab environment. This resulted in the further identification of the consequences of the introduction of the self-driving car on the role of the national government with regard to geo data. These questions are clustered according to work packages.

1.3 Book mark

This document focuses on the topic 'Self-driving car'. That comes within reach because of emergence of the Internet of Things: a development of the internet where everyday things, such as buildings, telephones and vehicles are connected to the network and are able to exchange data.

In the introduction to this document we first describe the observations and reflections made in the exploration of the role of government geo data for the self-driving car and the role of the self-driving car's geo data for the government. In Chapter 2 a general introduction to the self-driving car is given. The subsequent chapters contain the results of the discussions with domain experts about the meaning and significance that geo data has for the self-driving car (Chapter 3) and the governance questions associated with geo data and the introduction of the self-driving car. (Chapter 4). In Chapter 5 we discuss the development of the self-driving car in a broader perspective of related technological and social developments and trends. In Chapter 6 five clusters of sub-questions are determined based on a conceptual model of the data-infrastructure of the self-driving car.

Chapter 2

The self-driving car

In this chapter we provide a general introduction to the self-driving car.

2.1 Automated driving

The car industry is concerned with innovations in the field of automated driving. Cars are increasingly equipped with features which support the driver or which can fully assume the driver's tasks. Examples are:

- *Adaptive cruise control:* a system which, without any form of communication taking place with other vehicles, enables the equipped vehicle to follow the speed and distance of the vehicle ahead.
- *Lane assist:* a system that warns the driver when the vehicle detects that it is drifting off lane, or can even correct the driver by steering the vehicle back into its lane.
- *Park Pilot:* a system which helps to parallel-park the car or which can even park the car all by itself.
- *Sign Assist:* a system that can read road signs with a camera, and based on that information, can adapt the drive speed.

There are often four levels of automation that are distinguished for automated driving, where level 0 is the lowest level of automated driving and level 4 is fully autonomous driving. At level 3, all the above techniques are combined in such a way, that the car is able to drive by itself but, in complex situations (for example, in cities with a lot of traffic), asks the driver to assume control. At level 4, the car is driving in a fully autonomous manner and the support of the driver is not required. Experts doubt whether the step from level 3 to level 4 can be made.

One example of a fully autonomous driving vehicle, is the Google Car. Many car manufacturers and electronics manufacturers too, are engaged in the development of autonomous vehicles:

- For several years *Google* has been testing a self-driving car in its Self-Driving Car Project. https://www.google.com/selfdrivingcar/
- *Apple* expects to be testing a self-driving car very soon. http://www.nu.nl/gadgets/4106832/apple-gaat-zelfrijdende-auto-binnenkort-testen.html
- Since the autumn of 2015 *Tesla* has fitted its cars with software that can drive on highways at level 3. http://www.nu.nl/gadgets/4145592/tesla-model-s-deels-zelfrijdend-software-update.html
- *Mercedes* has developed a prototype of a luxurious self-driving car with rotating chairs. http://www.nu.nl/gadgets/3967151/mercedes-toont-zelfrijdende-auto-met-draaiende-stoelen.html
- *Asian car manufacturers* (including Honda, Nissan, Toyota) expect to introduce a self-driving car on the market in 2020, for example http://www.slashgear.com/testing-hondas-tech-for-its-2020-self-driving-car-27411711/

It is anticipated that, between 2020 and 2030, the first self-driving cars at levels 3 or 4 will be introduced on the market (please see Figure 1). The development of the self-driving car is reliant upon the development of the cars ability to communicate and cooperate among themselves and with their environment. This is indicated by the term *connected cars* or *cooperative cars*. It is assumed that the self-driving car can only be successful if it is also *connected*; the Google Car is an example of a car that is completely autonomous, but which does not communicate with fellow road users.

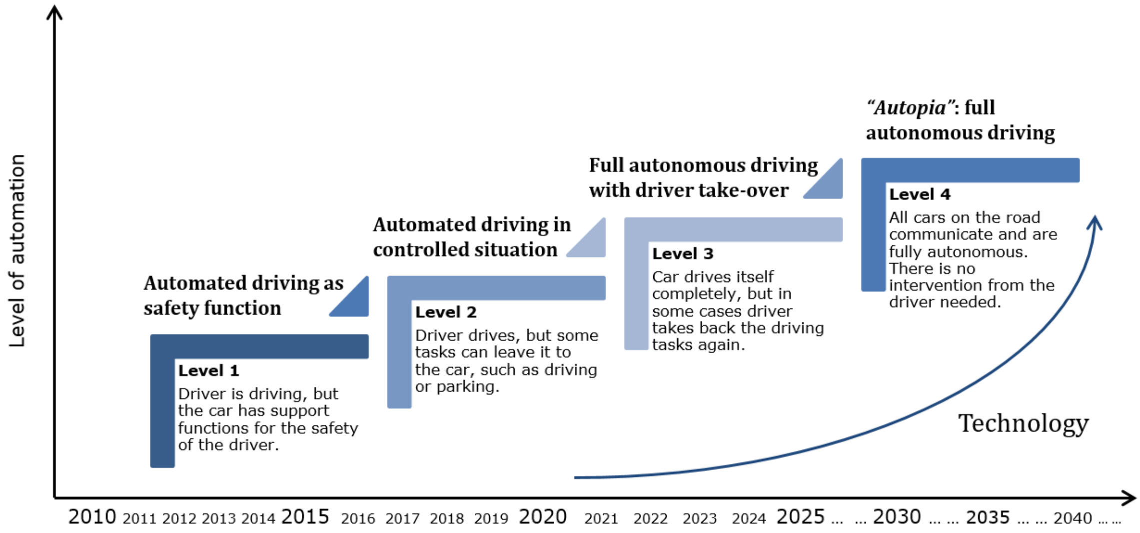

Figure 1. Expected planning of the worldwide transition to the self-driving car

2.2 Sensors

A self-driving car is a vehicle that can drive in traffic to a specific point independently without the intervention of a human driver. It is able to observe its environment with techniques such as radar, laser altimetry (LiDAR) and automatic image recognition. It can also navigate to its destination using satellite position determination systems (GPS, Galileo etc.) combined with detailed maps of the road networks. A self-driving car therefore is loaded with sensors observing the environment and the driving conditions.

Chapter 3

Geo data and the self-driving car

In this chapter we describe the significance of geo data from, and for, the self-driving car.

3.1 Geo data for the self-driving car

A self-driving car is able to navigate to a destination independently. To make this navigation possible two points of information are significant: the current location and a route from the current location to the destination.

3.1.1 Positioning

The current location can be determined using positioning techniques. A well-known example of these is GPS, a global satellite positioning system developed in 1967 by the Ministry of Defence of the United States. The signal was initially encrypted by the US government and a decidedly poorer version was created for the civilian market. This Selective Availability (SA) was set aside in 2000, and since then it has been possible for civil applications to determine a location on earth with much higher accuracy (~10m). This resulted in the emergence of mobile car navigation systems.

To improve the position accuracy of GPS, a method of differential GPS (DGPS) can be applied. Using reference receivers, the difference between the position that can be determined using GPS and the more accurately determined position on the reference receiver, can be calculated. Deviations can also be sent to other mobile GPS-receivers. In the Netherlands there are several networks of DGPS-reference receivers: six private networks and one network of the government, NETPOS.

To reduce the dependence on the American GPS, other countries and continents have also developed, or are still developing, satellite positioning systems, for example the Russian GLONASS, the Chinese BeiDou and the European Galileo. According to current planning, in 2019, Galileo should be fully operational worldwide and, like the GPS system, will be available for everyone to use for time reference and positioning, free of charge. In addition to this free open service that will be more accurate than GPS, Galileo will also make extra commercial services available, including a guarantee for the correctness of the position. Millimetre positioning would then be possible.

Other positioning techniques that are mentioned in relation to self-driving cars are:

- *GPS-RTK:* a special form of differential GPS in which the phase (differences) of satellites are also included in the calculation of the position. With GPS-RTK an even higher positioning accuracy can be achieved than with DGPS.
- *VSLASM* (Visual simultaneous localisation and mapping), a technique where photos are compared with a database of geo-referenced photos. By comparing a photo taken from a vehicle with a photo taken at the side of the road, the position of the car can be determined. There are doubts about whether this technique could work independently for the positioning of a self-driving car, but it could be complementary in regions (cities) which have no, or hardly any, GPS range.
- *WIFI-P:* a form of Wifi which is especially optimised for vehicle communication networks. To facilitate the communication between vehicles and with the side of the road, a network of Wifi-P

beacons have been positioned along the roadside. The question is to what extent these Wifi-signals can be used for positioning.
https://en.wikipedia.org/wiki/Wi-Fi_positioning_system

3.1.2 Geo data

To determine a route from the current location to the destination, a self-driving car needs to know on which roads to drive and what it will encounter along the way. A self-driving car is packed with sensors monitoring the environment of the car. Together with a basis map of its environment, the car uses this (geo) information to navigate safely and easily to a particular location.

A basis map of the environment is a three-dimensional geographical file containing the topographical characteristics of the landscape and built objects such as buildings, bridges and viaducts. It can also contain other elements such as trees, overhead signage, lighting poles and traffic control installations.

A basis map is made up of several geodesically collected geographical datasets. In the portal for Dutch geo-information, Public Services on the Map (PDOK[4]), various geo datasets are freely available (*open data*). These datasets, which are required for the self-driving car, are obtained, managed and used by Dutch government bodies such as municipalities, water boards, various provinces and the Dutch Water Authorities. These datasets have been made accessible via open standards and open licences, and are available for re-use by third parties. The datasets are updated daily, monthly or (half) yearly, so are therefore relatively static. Some examples of the geo datasets in PDOK which can be used as a basis for the self-driving car are (see also Figure 2):

- The Key *Registers[5] - Addresses and Buildings (BAG)* contain all the addresses and locations of buildings in the Netherlands.
- The *Key Register - Large-Scale Topography (BGT)* is a topographical file in which objects, such as buildings, roads, railroads, water ways, parks and forests are listed for the entire country in a uniform way concerning content and quality.
- The Dutch elevation map (*Actueel Hoogtebestand Nederland AHN)* is a digital contour map with detailed and precise height information for the entire Netherlands.
- The *3D map Nederland* is a digital topographical file which combines all the objects in the Key Register Topography (BRT) with the up-to-date Dutch Elevation Map. This results in kerbs and quay walls being listed as vertical surfaces and houses as blocks.
- The *National Roads Database (NWB)* is a digital geographical file of almost all the Dutch roads that have a street name or number and are managed by a road administrator.

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[4] See https://www.pdok.nl

[5] A Key Register is a register officially stipulated by the government which contains high quality information that must, without further research, be used by all government institutions when carrying out public tasks. The Dutch government has a system of Key Registers, in which the government information that is often used, is recorded, such as addresses, personal data, company names and geo information. See: http://www.digitaleoverheid.nl/onderwerpen/stelselinformatiepunt/stelsel-van-basisregistraties.

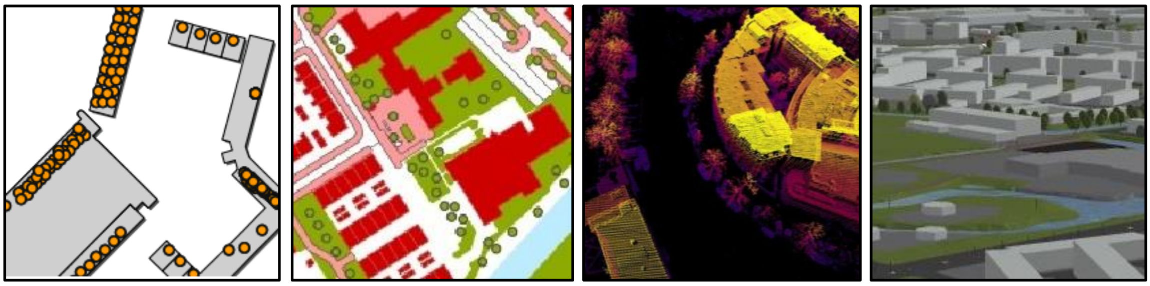


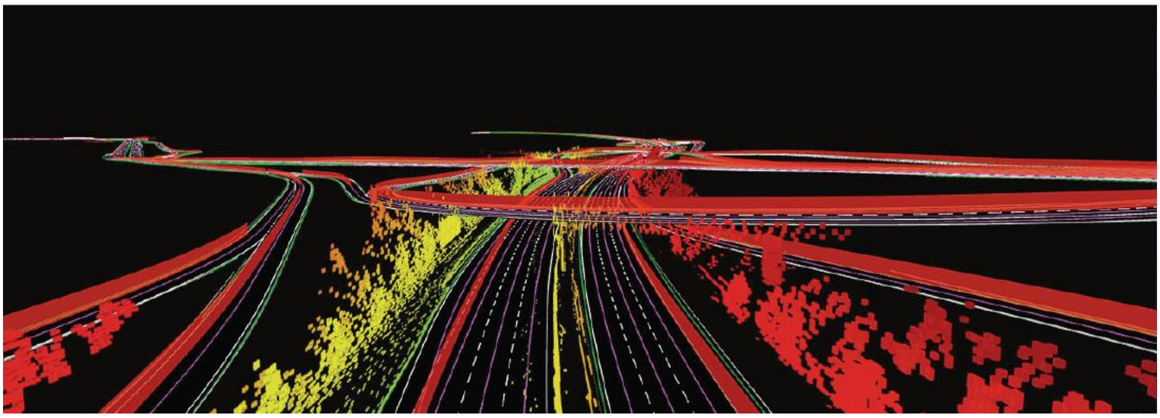
Figure 2: Example of datasets available in PDOK, v.l.n.r. BAG, BGT, AHN, and 3D Map NL

As well as having static data about the environment, a self-driving car also needs dynamic (*real-time*) traffic data to navigate safely and easily. Examples of dynamic traffic data are - data about congestion, construction work, diversions and the opening hours of bridges. The National Data Warehouse for Traffic Information (NDW) makes up-to-date traffic data available as an open data service. Every minute data is transmitted about the number of vehicles (often subdivided into vehicle categories) that is passing by the measuring points, its average speed and/or the average travelling time measured between two points. This service also provides status data, such as data about road works, traffic jam announcements, opening hours of bridges and data about other (dynamic) users of the road.[6]

Requirements of the self-driving car in relation to geo data

The discussions about what requirements the self-driving car has with regard to the basis map of the environment have been mixed. On the one hand, it is stated that it is alright if the basis map is of a low geometric and thematic quality, because the self-driving car can obtain the missing information with the help of its own sensors. On the other hand, it is stated that the basis map should be very detailed with an accuracy of down to a few centimetres (also indicated by the term High Definition (HD) map).

In the first case, where a Low Definition map (LD map) is used as the basis map for the self-driving car, the Key Registers can play a crucial role. Parties such as TomTom, for example, now use the Key Registers of Addresses and Buildings as the basis for their own navigation maps. However, in the second argument which states that HD-maps are a requirement of the self-driving car, the current quality of the key registers is such, that the self-driving car cannot, or would only be able to, make minimal use of this information. Market parties such as Nokia Here and TomTom are therefore obtaining and generating very detailed maps (see Figure 3).



[6] Source: http://www.ndw.nu/

Figure 3: Example of TomTom's HD-map.[7]

Data collection is effected using *mobile mapping.* This is a technique involving a vehicle equipped with several sensors such as cameras, laser scanners and satellite positioning which observe the environment; after processing this information, a key registration map can then be depicted.

Note. These vehicles are, therefore, fitted with the same sensors as a self-driving car; see also paragraphs 2.2 and 3.2

The government stays, in principle, outside this development. A whole new market of mapping services seems to be evolving, HD mapping. The automotive industry is very interested in these HD maps; this is evidenced by, among other things, the acquisition of Nokia Here by a consortium of three car brands (BMW, Audi and Daimler/Mercedes-Benz).

3.2 Self-driving cars' requirements' for geo-information from the government

The self-driving car appears to have huge potential in regard to the collection of all kinds of data. It is, after all, equipped with all the sensors and means of communication necessary, and so could collect real-time data and transmit it to other cars and several organisations.

Three types of possible benefits are recognised:
1. Higher level of accuracy (in that data would be more up-to-date) of existing basis datasets
2. More effective traffic management
3. More effective and more efficient asset management and management of the road network

1. Higher accuracy of current events of existing basis datasets

The self-driving cars continuously collect data about the environment. This provides a real-time image of the close vicinity of the environment of the car. This data can be used to check existing (static) geographical datasets to see if they include a recent event and, where necessary, to make/keep it up-to-date. This can be done both for the key registers and Basis Registers.[8] Modifications in the 3D file or the file containing data about all the roads, could be detected at an earlier stage by the self-driving car. This information could then be reflected via regular and periodic maintenance of these mutations and datasets.[9]

2. More effective traffic management

The self-driving cars not only collect information about the static environment, (buildings, for example) but also about the location of other road users. This data can be used to direct traffic more efficiently, for example, when bridges and locks open and close, and redirect traffic if congestion builds up or an accident takes place.

3. More effective and more efficient asset management and management of the network of roads

As well as the basis data, self-driving cars also collect data about the condition of the road surface and, indirectly, they offer the opportunity to monitor the load on the road surface. Examples of applications

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[7] The photo is from TomTom, source: NRC, http://www.nrcq.nl/2015/06/27/niet-jij-maar-tomtom-zit-straks-aan-het-stuur

[8] Basis Registers are, within this context, geographical datasets that are not legal Key Registers, however they are managed by government institution. A Basis Register could contain further details about a Key Register, for example, in a sector model (management of public space) on the information model of a Key Register (Key Register Large-scaled topography).

[9] To be accurate it should be noted that the total network of roads comprises approx. 3% of the total surface of the Netherlands.

such as this include the monitoring and regulation of the load of roads and bridges, and submitting notifications about public space if the condition of the road surface has deteriorated (potholes and ruts).

For these user cases it is not necessary for the car to be driving fully autonomously. However, the car should be able to collect this data and to store and exchange it with other cars and the local environment (the road side), in short, it must be a *connected car*.

The nagging question thrown up by these user cases is: how will the government obtain the data from the self-driving cars? First, it is currently unclear who owns the self-driving car data: is this the owner of the car, the manufacturer of the car, the importer, the software provider, or the data provider, etc.? So, the government does not know who to approach for the data.

Second, the market, in principle, determines the price and other conditions under which the government can use the data. The government may not be able to afford this. The question then arises as to whether there are other options that the government can work towards to smartly use the data from the self-driving car.

Third, there is going to be a discussion very soon about the use of data from self-driving cars and the processing of personal information, within the meaning of the Data Protection Act (Wet Bescherming Persoonsgegevens). This personal data must not be (re) used (by the government) in a manner which is incompatible with the purposes for which it was obtained.

Chapter 4

The governance of geo-data

This chapter discusses the issues related to the role of the government in the governance of geo data from, and for, the self-driving car.

4.1 Geo-information from the government for the use of the self-driving car

The self-driving car needs a basis map to be able to navigate. As the government has a role in the regulation and certification/approval for admitting (self-driving) cars on the road, the question is whether, and to what extent, the government can make it mandatory for the self-driving cars to use the geo data from the government, particularly the relevant key registers. A feature of the Dutch Key Registers is that the integrity of the data is guaranteed, and that continuous maintenance takes place.

So the question is to what extent the government is *willing* and *able* to make the use of the Key Registers mandatory as the basis for the geo data for the self-driving car? What should the government do and organise, both legally as regards the 'mandatory' use of data, and the liability for incorrect data, but also regarding assuring that the content in the key registers also complies with the requirements of the self-driving car's technology? And what does this ask of the Key Registers and the (owners of these) sources, which, in principle, were not collected for this purpose?

In the field of legislation and standards, the government has a facilitating role. For the self-driving car, this should be organised at an international level, as driving does not stop at national borders.

4.1.1 Liability of the government in regard to the use of government information[10]

If there are errors or inaccuracies in the data, others may suffer damage because of that. Since the relevant government data is available as open data, any liability for damage which results from incorrect or incomplete data should be based on a tort held by the provider.
Liability for faulty or incomplete data can arise if the open-data offeror, by offering the data, has acted in breach of the social standard of care and can be blamed for this. More specifically, what this hinges upon is whether the provider acted carefully enough when distributing the data. When we clarify the content of the duty of care this question is crucial: has the government acted unlawfully by creating a dangerous situation?

4.1.2 Self-driving cars are using open government data

Although the authors conclude that the liability risk is limited for open data providers,[11] it is true that they must act carefully. For example, they have to take precautions to ensure as much as possible, that there are no errors or inaccuracies in the data. Perfection cannot be required, however they should show their commitment to preventing errors and to improvement. Metadata describing the data may have a crucial role here as the user of the data can, in this way, determine whether the data is suitable for the purpose he or she has in mind.

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[10] Text derived from Ploeger, H.D. and B. van Loenen. (2013). De mogelijkheid van een open data beleid voor het Actueel Hoogtebestand Nederland nader onderzocht. TU Delft.

[11] Also see Scheltema. (2008). Gemeenschappelijk recht: wisselwerking tussen publiek-en privaatrecht, Deventer: Kluwer, pp. 349-355 (over ongerichte overheidsinformatie); also see De Vries, M. (2012). Aansprakelijkheid en Open Data; Van Erik Engerd naar J.J. de Bom.

The situation is very different if the government makes it *mandatory* for the self-driving car to use a specific government dataset. In that scenario, the government will have to make sure that this dataset is suitable and allows the self-driving car to navigate safely and easily. If any damage results from the incorrectness or inaccuracy of government information, there will probably be a higher liability risk for the government than there would be if they only offered open data. But, should the government make the safe and easy navigation of the self-driving cars one of its public service remits and, if so, what role should government information play in this context? Can the Dutch Key Registers, for example, comply with the requirements that the self-driving car has for safe and easy navigation?

4.1.3 Certification of software and data

The Department of Road Transport (Rijksdienst voor het wegverkeer - RDW) is the government body in the Netherlands that oversees the admission and registration of vehicles. This institution also monitors the compulsory inspections, the General Periodic Inspections (Algemene Periodieke Keuring - APK), that road vehicles are legally required to have to promote traffic safety and protect the environment. The admission and inspection of cars currently focuses on mainly the technical and physical aspects. As more cars are now being equipped with electronics and sensors and the related software, the admission and inspection process may be changed to cover self-driving cars.

The most important components of a self-driving car are sensors, software and (geo) data; the two latter components will require continuous updating and improvement. Software-updates for a vehicle can be transmitted via a network connection. The (geo) data will also continuously change throughout a network of *connected cars* when it is returned to a data warehouse, as a result of changes in the environment (topography, intensity of traffic etc.).

The question is how a body, such as the government, must organise the certification (admission and periodic inspection) of self-driving cars with these dynamics. The process of certification could increasingly take place through a system of software and data management, instead of the technical condition of a car at a specific time.

4.2 Geo information from the self-driving cars for the government

The self-driving car is packed with sensors and is continuously observing the environment. The data that is generated by these vehicles offers a great potential for other applications, for example, keeping track of geo-datasets and Key Registers. The general question is, to what extent the government can ensure that the data generated by the self-driving car is made available to the government and third parties, so that extra social value can be created with it.

The location of the self-driving car (and, therefore, the passengers) will be considered as personal information. Processing will thus be bound by strict conditions; for example, permission from the person/s involved is often required before this data can be processed. In addition to the purpose limitation which is carried over to a subsequent processing (recycling) there are other requirements of the Data Protection Act (Wet Bescherming Persoonsgegevens - Wbp) that are relevant. Personal data, for example, should no longer be stored in a form that makes it possible for the person involved to be identified, nor should it be stored any longer than the time required to realise the purpose it was collected for and then be processed. Furthermore, with regard to the purposes for which the data is collected or then will be processed, personal data may only be processed to the extent to which is considered adequate, relevant and not excessive.

To limit any possible side effects of the government data, it follows that the data from the self-driving car must first be stripped of any information that links the self-driving car to the owner/passengers. One possibility would be to consider the maintenance of Key Registers as not incompatible with the goal "the safe and easy navigation" of the self-driving car.

If the owner of the car is also a passenger, he/she could, in case of a request (from the government) give permission for the processing of his/her personal data. Some people may ask money for this.

When a self-driving car is involved in an accident, there may be a vital interest of the person involved to protect (i.e. a life-threatening situation). In such a case, the self-driving car can instantly send a notification to the emergency services. This (eCall) service will become compulsory on 31 March 2018 for all new cars in the EU.[12]

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[12] See: http://www.transport-online.nl/site/56602/auto-waarschuwt-vanaf-2018-automatisch-112-bij-ongeval/

Chapter 5

Related trends and developments

In this chapter we briefly discuss the relevant technical and legal trends associated with the data revolution in which the self-driving car is developing i.e. the development of open platforms and context brokers which can combine geo data with a diversity of various data, the communication structure in which the self-driving car is embedded and the emergence of open data.

5.1 Open platforms

The self-driving car is part of the development of the Internet of Things (IoT) and the data explosion which has resulted from this. The IoT makes it possible to combine geo data with other data: data from other objects (such as cars, for example), but from many other types of objects too. It also facilitates the linking of data and the development of open platforms.

To make this various data widely available and applicable, open, standardised access to it is needed. In the European context, this is focused on an open software platform for IoT-applications: called Future Internet Ware, FIWARE.[13] In this type of platform, the *middleware*-layer is limited compared to previous generations: the platform makes is possible to generate, collect, publish and search through data from very different sources. In practice this means that the basis, the databases, largely exists of open data with *application programming interfaces* (APIs) added to this and a top layer of all types of modular (web) applications. System development is no longer a matter of huge, time-consuming projects carried out by the large ICT-companies, but rather a focus on concrete information services which, with the help of open data, can be created by small web companies and communities.

5.2 Data communication

The self-driving (*autonomous*) car does not necessarily have to be a (*connected*) car dependant on communication with other vehicles and the road infrastructure (of 'cooperative communication systems'). Based on a 3D-model, the *autonomous* car is developing, using cameras, GPS, radar and supportive programs and a basis map of the environment. Vehicles can, with this model, independently 'read' their environment and, based on this information, take over the driving tasks of car drivers.

The Rathenau Institute[14] notes that embedding self-driving cars or connected cars in a 'cooperative communication structure' is also essential if we are to fully realise the social benefits of this innovation. That means that the (public) requirements and conditions of data communication in relation to the self-driving car, and the demand to regulate the openness and free availability of this data, should be considered within the context of the 'cooperative embedding' of the self-driving car in the entire communication network around that car. Therefore, the Rathenau Institute argues for an integrated approach to the self-driving car in which the self-driving car (vehicle technology and private data communication) and traffic management (smart roads, data communication-infrastructure and influencing)

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[13] https://www.fiware.org/.

[14] *Tem de robotauto. De zelfsturende auto voor publieke doelen*, [Tame the robot car. The self-driving car for public purposes]. Rathenau Instituut, Den Haag, (2014)

are considered as a whole. So that means that the car must be seen in relation to the infrastructure, even if this is about geo data.

5.3 Open data

Public data is a source of value, and the basis for many social solutions. More and more often, public data is therefore open. There are clear frameworks for the use of the Key Registers by governing bodies. European directives, such as INSPIRE,[15] the Directive on the Re-Use of Government Data[16] and the Directive on Intelligent Transport Systems,[17] are still at the very beginnings of their development. The standard in the latter Directive is the open availability of location-based vehicles for optimal traffic management.

When public data is open, there are all sorts of legal issues; one of these is the integrity of privacy. The same issues also seem to play a role in relation to the large datasets that companies develop on their clients. Recent statements by the Dutch Data Protection Agency[18] seem to indicate that private providers, in just the same way as governments, are held to strict conditions in terms of ownership (at the source: consumers), safeguarding integrity (openness and accessibility in correction and review), transparency of the company about the data collection, mode and duration of storage, and the precautions companies must take to avoid the possibility, when connected to other databases, of using data in advanced (*big data* and *linked data*) analyses techniques that is traceable to the personal data, even if it is encrypted or extracted after said connection. That makes the development of clear procedures and processes for the ownership, opening, managing, using and valuing of large public datasets even more necessary.

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[15] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) was published in the official Journal on the 25th April 2007. The INSPIRE Directive entered into force on the 15th May 2007. This Directive was implemented in the Netherlands in the Implementation of the EG Directive on Spatial Information Infrastructure (2 July 2009).

[16] Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information. This was implemented in the Netherlands in the Law on the Re-use of Government Data (18 July 2015).

[17] Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the Deployment of Intelligent Transport Systems in the field of road transport, and for interfaces with other modes of transport. This Directive was implemented in the Netherlands via an amendment of the Road Traffic Act (15 May 2010) and in the regulations set out by the Minister of Infrastructure and the Environment, nr. IENM/BSK-2014/160572 (26 March 2015).

[18] For example, CBR, the Wifi tracking of mobile devices in and around shops via Bluetrace, z2014-00944, 13 October 2015

Chapter 6

Conceptual model data infrastructure

In this chapter, all the issues raised about the data-infrastructure required for the self-driving car are positioned in a conceptual model comprised of five clusters of relevant research themes:

1. ***basis map:* the supporting map layer for navigation from A to B**
2. ***sensor data:* dynamic information from sensors of cars and the side of the road**
3. ***data centre:* private data infrastructure from the automotive industry and road authorities**
4. ***data broker:* public or private reseller of (open) data from distributed data centres**
5. ***information services*: (non) commercial services and apps based on (open) connected car sensor data**

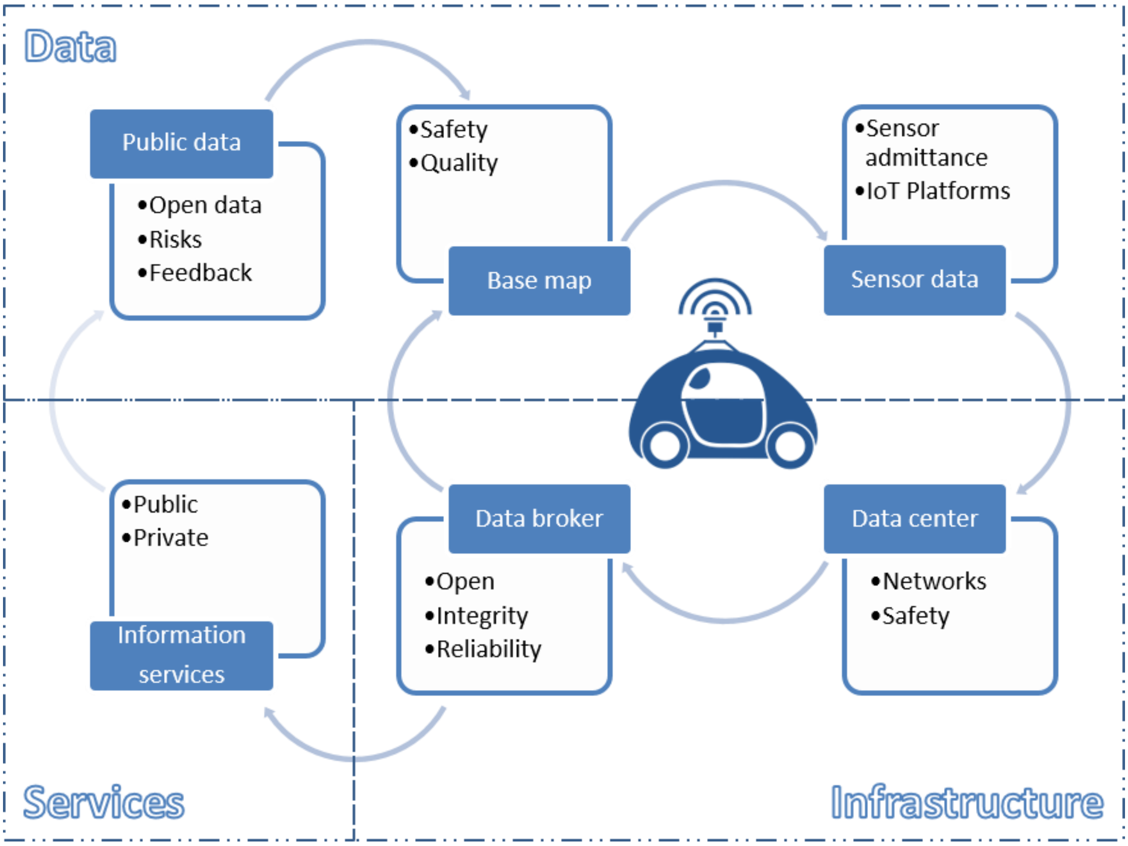

Figure 4: Conceptual model for the data infrastructure of the self-driving car.

6.1 Basis map

Based on the open and private geo data files, a basis map is available in which all objects in the traffic infrastructure are listed. Traffic sensors add minute details onto this map, combining the information about the use of infrastructure with additional contemporaneous data; the map is periodically refreshed and thus becomes dynamic. For the 3D geographical model that is required for the self-driving car, the quality in terms of completeness, contemporaneity and correctness of the available information, must be much higher. There are two ways to achieve this:

1. Enlarging the available basis map so that is precise down to a few centimetres, and making continuous updates (one-way traffic);
2. Supplementing the basis map with data already generated by all the other sensors on, and around, the road: cars themselves, data from the telecommunication between smartphones and mobile networks, Wi-Fi-data - all communication around and on the road (two-way traffic).

Whatever way is chosen; the openness of data is crucial. Issues that could be discussed within this context are:

- What demands does the self-driving car have in regard to the quality of public open geo data?
- Which quality of dynamic geo data should the government provide?
- Is the sensor data from self-driving cars of added-value for the system of Key Registers? And if so, what requirements should then be demanded of the sensor data in order to update the Key Registers or include them as a part of them?

6.2 Sensor data

Standardisation and the openness of geo data do not come automatically. Geo data is a hybrid creature. Somewhere in the process of data communication, through legislation and regulations, or otherwise, standards must be developed, established and maintained. Think of the sensor technology that is used, or the ownership of data, or the data communication and data processing. Applying sensor data to social solutions (for example, good traffic management) moreover, requires the use of robust open platforms with *context brokers* who can manage the differences between the databases so the sensors actually function as a connected network.[19] One major concern is the reliability of such platforms: they are at the heart of the data communication and influence traffic and, in that way, form vital infrastructure. A hack, for example, could have far-stretching consequences and might even bring an entire society to a standstill. Questions that could be addressed in this context are:

- What is necessary for sensors (car, driver, traffic infrastructure) to achieve a connected network which is robust enough for the self-driving car?
- What does the emergence of the self-driving car mean for the sensors and actuators that are used by the government itself for traffic management?
- How can the openness of crucial geo data and sensor data be secured for the self-driving car?
- What technical requirements does the diversity of data demand of the technical platforms used by the government?
- In what way can such platforms be protected as vital infrastructure (technical)?

6.3 Data centres and infrastructure

The network of connections between cars, data centres and traffic influencing, has become more versatile over the past years. Physical (glass) data fibre cables in and around the road, mobile networks, Wi-Fi-networks, LORA-networks and also the direct Bluetooth communication which is still being used over short distances – has meant the available space has increased enormously. The core question here is whether this magnification can keep increasing at the same pace as the data space that is required for the emergence of the self-driving car, both upstream (sensors transmitting information) and downstream (data that is transmitted to applications).

[19] In a European context, for these types of services, an open source platform for social, open, data-based information services has been developed over the past years: https://www.fiware.org/

Only a small part of these connections is in public ownership. The national government maintains its own digital geo positioning network, the Netherlands Positioning Service (NETPOS).[20] This signal is still locked, but the Ministry of Infrastructure and the Environment intends to open it. However, there are also private networks offering a better service level, especially now that *cloud-based navigation* is breaking through and seems to be becoming the basis for many of the information services which make the self-driving car possible.[21] There is, therefore, further research required into the relationship between private data traffic and public traffic management.

A major concern here, is safety and security. Current knowledge in the area of cyber security is needed to protect the vital infrastructure. The development of the European satellite positioning system Galileo is interesting in regard to the reliability, accuracy and availability of the positioning infrastructure. With Galileo, positioning can be significantly improved (sub-cm) compared to GPS. Therefore, the dependence on the American GPS will be limited. Questions that could be discussed in this context are:

- What does the self-driving car demand (from the availability of) data networks?
- How can the openness, integrity and reliability of geo data communication with the self-driving car be guaranteed?
- How can the security, availability and integrity of data connections be ensured? What kinds of scenarios and fall-back options are required to cover temporary network failure?
- How can Galileo's Open Service signal be used for the positioning of the self-driving car?

6.4 Data brokers and management

Managing geo data is about big data analysis, data processing and editing and the integral management of processes which are dependent on geo data, such as traffic management. The whole system of geo data should be involved: from the car (the electronic vehicle file)[22] to the management of user data (the integrity of the management and correction, ownership by the private user).

When information is organised, as it is in a web, there is only one remaining possibility regarding ownership, according to the principles of the *information value chain management* the user him/herself owns his/her information. Protection and support for this ownership are necessary. Users, for example, are easily inclined, in exchange for a lower purchase price of the car, cheaper maintenance of the car or a reduction on their car insurance, to put the ownership of their information out of their hands. This way we lose the option of being able to organise a bottom-up integrity check. For effective data management, accessible data visualisations are indispensable.

As the self-driving car is completely data-driven (Level 4, driving without human intervention), a number of specific (mostly legal) risks will be created that need further exploration:

1) *Liability in case of accidents caused by the data used:* who is liable in the event of an accidents? When datasets are connected, the individual liability for the integrity of information ´disappears´. At the same time, the car driver, as the final user, cannot really be held fully responsible.
2) *Privacy:* How can the privacy of the car driver be guaranteed in a web of data relations in which corporate liability disappears? How can the principle of 'my car - my data' be operationalised?
3) *Re-use:* Data mining is the core of big data-analyses. How, and to what level of detail, can the geo data provided by private persons, be (re)used? What support do European directives and Dutch legislation offer?

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[20] http://www.kadaster.nl/web/Themas/Registraties/Rijksdriehoeksmeting/NETPOS.htm

[21] http://www.navads.nl/wp/wp-content/uploads/2015/03/Whitepaper-The-Future-of-The-GPS-Market-by-Navads.pdf

[22] http://www.gic.nl/innovatie/rdw-wint-publieksprijs-battle-of-the-schools-tijdens-holland-webw

6.5 Information services

The fact that the emergence of the self-driving car calls for investments to be made in the infrastructure of geo data is clear. The question is, what proportion of this investment will be met by the government. When determining the role and the share of the government in these investments, it is simply about investments but about the social and public added-value of the self-driving car in the development of (information) services as well. For the government this is, in any case, about:

1. Geo data that improves the quality of traffic management;
2. Management of the road infrastructure including objects (asset management);
3. Information about how already developed infrastructure behaves itself, to determine more precisely how roads not only should be managed, but also how they should be built (for example, qualities of asphalt);
4. Management of other objects around the roads other than the traffic infrastructure, particularly green management;
5. Big data analyses which give insight into location-specific factors that contribute to the traffic safety;
6. The added-value of sensor data for the existing Key Registers and other government registers.

Questions that may be relevant to this latter point are:

- What is the impact of the self-driving car on services that the government itself is providing?
- What is the impact of the self-driving car on the role the government has, in relation to companies working with geo data in the field of car mobility?