institute

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Warning systems for speed cameras

Enforcement and impact of in-vehicle speed camera warning systems on driving behaviour

FEDERAL PUBLIC SERVICE
MOBILITY AND TRANSPORT

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Summary

Speed cameras are used to enforce speed limits – to be able to escape the fines, drivers used to install radar detectors or radar jammers in their vehicles. As the technology evolved, nowadays, many smartphones are equipped with a navigation system, and these often include speed camera warnings. In response, some countries strengthened their laws and also limited the use of speed camera alerts from smartphone apps or similar. Should Belgium adapt its legislation? What is the impact of these in-vehicle systems on driven speeds and traffic safety?

To tackle these questions, the report starts with an overview of current legislation in Belgium and other countries, followed by a literature review on navigation systems, routing and overall impact on traffic safety. Based on these insights about the current situation, several further data collection efforts and data analyses are defined. An online questionnaire in over 2000 Belgian drivers, representative of the Belgian population, reveals current ownership and use of different systems, but also attitudes and behaviour with respect to speed and legislation. Subsequently, two analyses use data from the popular smartphone app Waze (an application that includes alerts for speed cameras) to evaluate the impact of legislation and alerting on driven speeds. Both studies use a robust design with speed data collected from many vehicles nearby mobile (hidden) speed cameras and fixed speed cameras respectively. Finally, all results are combined and lead to recommendations for policy makers.

The main results of the study are presented in Table 1.

Table 1 Conclusions of the research project "Warning systems for speed cameras – Enforcement and impact of in-vehicle speed camera warning systems on driving behaviour".

Research question	**Conclusion**
Chapter 1 International benchmark of the legislation	
What is the current Belgian legislation?	▸ Radar detectors and radar jammers are prohibited. ▸ Speed camera warning systems using info from databases or receiving real-time alerts from other drivers are allowed.
What regulations exist in the various countries concerning navigation systems with speed camera warnings?	▸ Radar detectors and radar jammers are prohibited in most countries. ▸ Some European countries have a stricter regulation as compared to Belgium. For example: ○ In France, warning systems should only indicate a 'danger zone' with a possible speed camera. ○ In Germany, speed camera warning systems cannot be used by drivers. In Switzerland, the law is even stricter, and locations of speed cameras cannot be communicated in any way.
With regulations in place, how are they enforced?	▸ Enforcement is difficult. There are many grey zones in countries that (partly) prohibit the use of speed camera warning systems.
Are restrictions imposed on providers of navigation systems on the functions they offer to users, or the routes they recommend (e.g. to limit cut-through traffic). If so, what form do these restrictions take?	▸ None identified.
Chapter 2 Literature review: Navigation system routing	
What do we mean by navigation systems for route planning?	▸ Static ('offline') and dynamic ('real-time') navigation systems. ▸ Types: Built-in, portable, app on smartphone, hybrid systems.
What is the effect on road safety?	▸ More traffic on local roads, changes in total vehicle kilometres when alternative routes are used, changes in driving speed, more manoeuvres, distraction and stress.
What measures can be taken to prevent cut-through traffic?	▸ Traffic calming, access restrictions, road pricing, adjusting the digital road network or the routing algorithm, changes in spatial planning and the physical road network.
What are the possibilities for traffic management via navigation systems?	▸ Partnerships between road authorities, private parties, and the user are still in their infancy but are promising.

Chapter 3 User survey	
What are the reasons for ownership/use; what is the frequency of use; which systems and functionalities are popular?	▸ 37% of drivers commonly use a warning system; 2.6% use an illegal system. ▸ Dominant users: young men, with good jobs and company cars, who drive long distances.
How many are potential rat runners/diverters? How likely are drivers to follow cut-throughs suggested by navigation apps?	▸ Between 6% and 41% of regular drivers might sometimes use cut-through routes; some of them unintentionally.
Can the usage of different systems be related to attitudes on speed, cut-through traffic, safety, or to actual speed violations or crashes?	▸ Users of speed camera warning systems get more speeding tickets than non-users per 10,000 km. ▸ Users of a speed camera warning system have less strict opinions about speed and show more risky driving behaviour, e.g. they more often agree that exceeding the speed limit is safe when a road is deserted, they more often than others drive faster when they know for sure that there is no speed camera nearby.
What is the public support for a ban on speed camera warning systems? What type of policy do people prefer?	▸ 36% of drivers is in favour of a ban of systems that warn for the exact location of a speed camera (47% of non-users, 18% of users). ▸ Most drivers favour a system that indicates a 'danger zone'.
Chapter 4 Experimental study (speed enforcement by the police combined with Waze speed camera alerts)	
How long does it take for a mobile speed camera to be included in speed camera warning systems? How long does it take before it is removed? Do some remain undiscovered?	▸ All 22 studied mobile speed checks on two highways in the Province of Limburg have been discovered. ▸ 93.7% of the time with a mobile speed check, an alert was active in the Waze app. ▸ On average, an alert stayed active for 20 minutes after the police speed check ended.
What is the positional accuracy of the alerts?	▸ On average 175m from the real speed camera location.
Are there more speed violations before an alert is entered in a speed camera warning system? Are there differences in speed with and without an active Waze alert?	▸ Without an active Waze alert, 23.4% of drivers drive faster than 120 km/h. At times with an alert, this is only 19.8%. ▸ With an active Waze alert, average speed of all vehicles is 1.15 km/h lower than at times without an alert.
Do drivers experience a higher chance of being caught speeding when using speed camera warning systems?	▸ No difference.
Is the awareness about one's speed different in drivers with speed camera warning systems compared to non-users?	▸ Frequent users of speed camera warning systems state to be less aware of their own speed.
Chapter 5 Big data study (fixed speed cameras combined with probe vehicle data in Belgium, France and Germany)	
Do vehicles equipped with a speed camera warning system adjust their speed close by a speed camera? And do they drive faster further away from the camera?	▸ Yes, kangaroo jumps nearby speed cameras were observed in all countries using speed data from Waze users.
Do drivers with a speed camera warning system behave differently with respect to speed near a fixed speed camera in countries with different regulations on these warning systems? If they do, how do they behave differently? We compare three countries: Belgium, France, and Germany.	▸ No differences in speed nearby fixed speed cameras between countries could be observed on rural roads. The number of users of Waze was much lower, however, in Germany likely because of the legislation.

A harmonized European approach on in-vehicle police alerts would be preferred. Furthermore, the introduction of more stringent ADAS systems, such as intervening ISA, would be much more impactful as this could limit speed on all roads. In the meantime, Vias is in favour of adapting the current Belgian legislation and ban systems that allow drivers to escape speed cameras or other police checks as a clear signal that risky behaviour on the road cannot be accepted despite the difficulty in quantifying the combined impact of these systems on traffic safety. There seem to be no constitutional objections.

Introduction

Speed cameras are used by the police to enforce speed limits. In 2022, more than 6 million fines for speeding were issued in Belgium. To escape fines for speeding, devices in several forms were developed to obstruct the detection of offences. Where it used to be specific devices to detect or even disturb the signal of speed cameras (radar detectors or radar jammers), nowadays drivers are warned for speed cameras via their navigation system or via an app with real-time traffic information shared by other drivers. The latter devices are also used for other purposes than warning for speed cameras. Coyote claims to have more than 1 million Belgian users; the routing app Waze has 1.6 million active users (monthly, data for the year 2020). Both systems can warn drivers for upcoming speed cameras.

In the current project, different aspects related to in-vehicle speed camera warning systems are explored: legislation and enforcement in different countries, types of devices and their use in Belgium, attitudes on speed and policy of users and non-users, the use of these apps/navigation systems for other purposes, impact on speed and safety. The report consists of five chapters, each dealing with a specific topic (Figure 1).

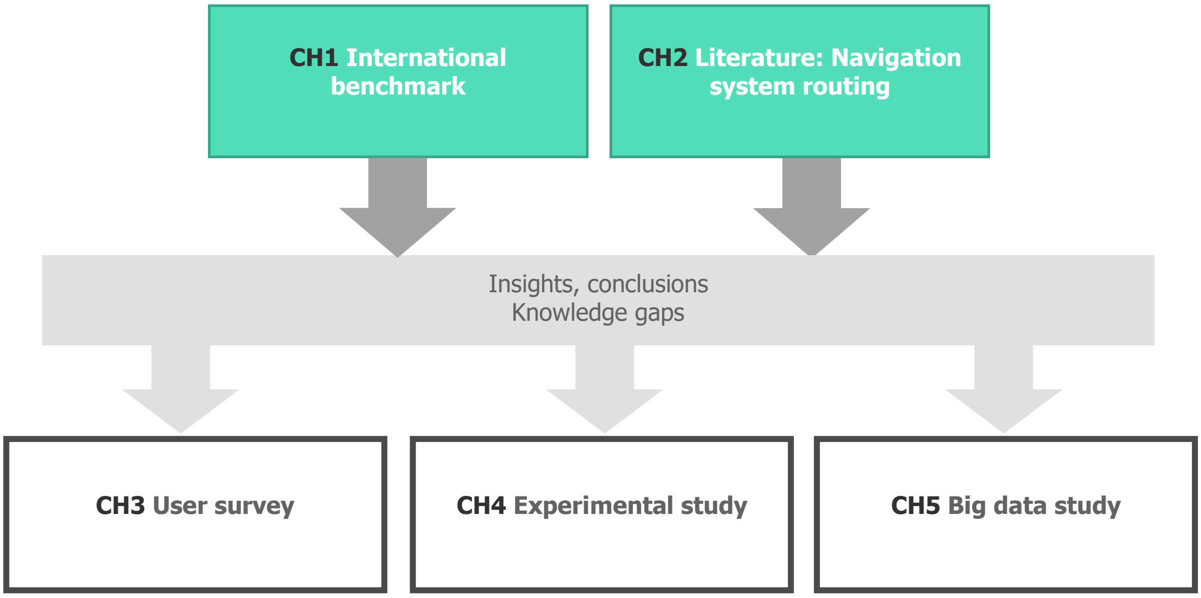

Figure 1 Overview of the study in different chapters.

The main research question that we would like to answer with this project is whether the current legislation in Belgium on in-vehicle warning systems for speed cameras should be adapted. Would prohibiting the use of all speed camera warning systems (devices or applications) improve road safety and can it be enforced? Several additional questions were formulated to get an integrated view of the issue.

1 International benchmark of the legislation on speed camera warning systems

1.1 Introduction

1.1.1 Research questions

To prevent the use of devices or applications that indicate the location of speed cameras or police controls, various countries, including Belgium, have introduced regulations. However, different regulations exist in different countries.

Over time, new technologies appeared. Nowadays, many smartphones are equipped with a navigation system, and these often include speed camera warnings (visual or auditory). No purpose-designed devices are thus needed anymore for risky or unaware drivers that want to escape speeding tickets. Some but not all countries include these new technologies in their regulations.

In this chapter, we would like to answer the following questions:

- What regulations exist in the various countries concerning navigation systems with speed camera warnings?
- With regulations in place, how are they enforced?
- Is the law under discussion and does it need to be revised, or is there satisfaction with the current rules?
- Are there regional differences or different rules for subgroups?
- In addition, we would also like to take stock of whether restrictions are imposed on providers of navigation systems on the functions they offer to users, or the routes they recommend (e.g. to limit cut-through traffic). If so, what form do these restrictions take?

1.1.2 Legislation in Belgium

In Belgium, the use of radar jammers and radar detectors to be alerted for the presence of speed cameras, or even to disturb the signal, is prohibited, as specified in Article 62bis of the Highway Code (see excerpt below). Moreover, having such a device installed in your car is illegal. Also producing, importing, owning, offering for sale, selling, or offering for free, devices to detect or interfere with radar signals used by the police for enforcement are illegal. Advertising this equipment, as well as offering assistance or advice on how to assemble them are also prohibited.

Excerpt from the legislation in Belgium (with English translation)

Artikel 62bis. Onverminderd de bepalingen van de wet van 30 juli 1979 betreffende de radioberichtgeving is het verboden elke uitrusting die of elk ander middel dat de vaststelling van overtredingen van deze wet en van de reglementen betreffende de politie over het wegverkeer, bemoeilijkt of verhindert of automatisch werkende toestellen bedoeld in artikel 62 opspoort, bij zich te hebben.

Article 62bis. Without prejudice to the provisions of the Law of 30 July 1979 on radio communications, it is prohibited to carry any equipment or any other means of hindering or preventing the detection of infringements of this Law and the regulations by the police or to use automatic devices as referred to in Article 62.

Only radar detectors and radar jammers are covered by this ban. Other speed camera warning systems (e.g. navigation systems with fixed speed cameras or smartphone apps) are not covered by this legislation because they are not capable of actively detecting or interfering with radars. These systems only indicate fixed speed cameras that have been registered in advance in a database, or mobile speed cameras that have been shared through a user community. Based on the current legislation, they are therefore allowed.

In case of violation of Article 62bis, a radar detector is confiscated and destroyed. A fine of €800 to €8000 or imprisonment from fifteen days to three months may be imposed. Furthermore, the driving licence may be immediately withdrawn for not less than eight days and not more than five years.

No specific legislation is in place for navigation system providers on the functions they offer.

1.2 Methods

In 2014, Touring[1] compiled an overview of existing regulations on speed camera warning systems in European countries. This was before the breakthrough of smartphone apps such as Waze, sometimes with a user community that can also report mobile speed cameras. In addition, for example in Germany, the legislation around these systems was recently changed. An update of this list is therefore appropriate. We also want to inquire about enforcement, whether the law is controversial, or divergent for subgroups.

Speed camera warning systems are often included in navigation systems. Navigation systems are regularly used to avoid traffic jams and to find the fastest route in real-time, causing cut-through traffic on local low-capacity roads. Whereas some see this phenomenon as endangering the liveability and road safety on local roads, others see these systems as ensuring an ideal redistribution of traffic so that network capacity is used optimally and fuel consumption and travel time are minimised (De Baets et al., 2014; Ericsson et al., 2006). It is technically possible for navigation system providers to limit cut-through traffic by adjusting their algorithms - this could also be imposed by the legislator. One potentially interesting target group for this is freight traffic (De Baets et al., 2014). It is unclear how governments and legislators deal with this in different European countries.

To get an overview of existing regulations on the use of speed camera warning systems and other regulations related to navigation systems in general in countries other than Belgium, we contacted a selection of international experts directly through email. Specifically, members of the "International Traffic Safety Data and Analysis Group" of the International Transport Forum at the OECD were contacted in March 2021. In this working group, over 40 countries from all over the world are represented. It consists of road safety experts from national road administrations, road safety research institutes, International Organisations, automobile associations, insurance companies, car manufacturers and others.

A short survey was presented to the experts (Appendix 1: Expert survey). The length of the survey was limited to increase the response rate; we, therefore, focused on some main questions. The survey consisted of two parts. The legislation concerning the use of warning systems for speed cameras forms the first part of the questionnaire. The second part of the questionnaire deals with the problem of cut-through traffic caused by the use of navigation systems, and possible legislation on this issue. Sixteen countries responded to the survey.

Through structured interviews and a further desk study, the main questions from the survey were examined in greater depth. This more detailed assessment was performed for countries that are of special interest to Belgium. The primary focus is on France and Germany; both are near Belgium, but, interestingly, they also have different legislations. We enquire about the reasons for and the chronology of their legislation, communication with providers of navigation systems, research that has already been carried out (e.g. profiling users, impact assessments), enforcement and fines, etc. Other countries are also discussed in so far as they are relevant to Belgium (the Netherlands) or have diverging legislations (Switzerland) (secondary focus).

[1] https://www.touring.be/nl/artikel/zijn-radarverklikkers-nu-wel-niet-toegelaten (21 oktober 2014)

1.3 Results

1.3.1 Expert survey

1.3.1.1 Speed camera warning systems

In the survey, we defined four types of speed camera warning systems and queried which ones were allowed in each country:

1. **Radar detectors:** Radio receivers tuned to the frequency range of police radars. This is a separate device.
2. **Radar jammers/scramblers:** Radar detectors that additionally distort the radar signal making their vehicles invisible to police radars.
3. **Speed camera alerts without user community:** Navigation system, purpose-built device, smartphone app, or similar, indicating the location of a speed camera. The location of the speed camera is provided with digital maps. Generally, these are the well-known visible speed cameras present for a long time, possibly even indicated on the road with a traffic sign. These systems cannot alert for temporary and hidden speed checks by the police.
4. **Speed camera alerts with user community:** Same as number 3, but in addition, it is possible for a user to indicate the location of a new speed camera and share it with a user community, or to be notified of a speed camera that was entered by another user in real-time.

A radar jammer (system 2) appeared to be forbidden in all the countries surveyed. A radar detector (system 1) is also forbidden in many countries. Both systems are forbidden in Belgium. On the other hand, speed camera warning systems with or without user communities (systems 3 and 4) are allowed in most countries. Exceptions to this are Germany, Switzerland and Greece. Table 2 gives an overview by country.

France uses a system in which the exact location of a speed camera cannot be indicated; however, a danger zone that could have a speed camera can be indicated. For companies that voluntarily sign the AFFTAC protocol (Association Française des Fournisseurs et utilisateurs de Technologies d'Aide à la Conduite), this zone must be at least 4 kilometres on motorways, 2 kilometres outside built-up areas and 300 metres inside built-up areas, within the limits of technical constraints. Companies that did not sign the protocol are free to define the danger zones as they wish.

In the United States, the use of radar detectors is not permitted for commercial vehicles, and in two states, Virginia and the District of Columbia, radar detectors are prohibited for all vehicles. In several countries, there are exceptions to the legislation for special vehicles (e.g. in Poland for the army and police), or when a licence has been granted (Greece, Japan, Austria). It is worth noting that in Chile, enforcement with speed cameras by the police is illegal, except for the use of 'speed guns'. It is therefore not an issue to try to evade speed controls by using a warning system.

In several countries, the legislation is somewhat controversial. Several countries (Germany, Italy, and Sweden) indicate that the police themselves report where speed cameras will be placed, but that radar detectors or warning systems are prohibited. In Germany, users of popular smartphone navigation apps such as Waze must disable the speed camera notification function, although it is allowed to check it in advance or for passengers to view it in the car (but they cannot warn the driver). In Switzerland, having a smartphone app with speed camera warnings installed on your smartphone, is illegal, even when the app is not in use.

Table 2 Regulations on speed camera warning systems by country.

Country	Radar detectors	Radar jammers	Warning system without user community	Warning system with user community
Belgium	Forbidden	Forbidden	Permitted	Permitted
Austria	Forbidden	Forbidden	Permitted	Permitted
Chile	Permitted	Permitted	Permitted	Permitted
Czech Republic	Permitted	Forbidden	Permitted	Permitted
Finland	Forbidden	Forbidden	Permitted	Permitted
France	Forbidden	Forbidden	Permitted	Permitted
Germany	Forbidden	Forbidden	Forbidden	Forbidden

Greece	Forbidden	Forbidden	Forbidden	Forbidden
Hungary	Permitted	Forbidden	Permitted	Permitted
Italy	Forbidden	Forbidden	Permitted	Permitted
Japan	Forbidden	Forbidden	Permitted	Permitted
Netherlands	Forbidden	Forbidden	Permitted	Permitted
Poland	Forbidden	Forbidden	Permitted	Permitted
Slovenia	Permitted	Forbidden	Permitted	Permitted
Sweden	Forbidden	Forbidden	Permitted	Permitted
Switzerland	Forbidden	Forbidden	Forbidden	Forbidden
United States	Permitted	Forbidden	Permitted	Permitted

All countries report that prohibited devices are confiscated and destroyed in case of violation of the legislation. In addition, a fine ranging from €15 (Hungary) to €8000 (Belgium) is imposed (Table 3). In some countries, the driving licence may be withdrawn (Belgium, France, Greece, Czech Republic), or demerit points may be gained (France, Germany). Belgium, Japan and Sweden may also impose a prison sentence.

Most countries do not report specific control activities. In the Netherlands, some police vehicles are equipped with a device that can detect radar jammers. In the Czech Republic, enforcement is difficult because police forces must be able to prove that the radar jammer was in use and effectively disrupted police signals. They indicate that enforcement would be easier if penalties could be imposed on possession rather than use.

Table 3 Fines for violating the law on speed camera warning systems, and enforcement, by country (local currency converted to euro).

Country	Fine in €	Imprisonment	Withdrawal of driving licence/demerit points	Enforcement
Belgium	800€ - 8000€	15 days – 3 months	8 days to 5 years	
Austria	Up to 5000€			
Czech Republic	200€ -400€		4 to 6 months	
Finland	20 days fine (linked to the income of the offender)			
France	Up to 1500€		6 points / up to 3 years	
Germany	75€		1 point	
Greece	2000€		30 days (+ 60 days withdrawal of vehicle registration)	
Hungary	~15€ - 400€			
Italy	800€ - 3212€			Control by traffic police
Japan	3800€	3 years		
Netherlands	430€			Police vehicles can detect radar jammers.
Poland	110€ - 1100€			Control by traffic police or car inspection
Slovenia	400€ - 1000€			
Sweden	200€	Up to 6 months		
Switzerland	3-180 days fine (linked to the income of the offender)			

1.3.1.2 Navigation systems for route planning

From the expert survey, it appeared that about half of the countries have problems with undesired cut-through traffic on local streets caused by navigation systems. Several countries receive complaints about this regularly (Germany, France, Slovenia, United States). In Austria, there are occasional discussions between experts. No restrictions are imposed on navigation system providers anywhere, for example on the routing algorithm. Of course, navigation systems must comply with the highway code.

Various authorities are trying to set up consultations with private navigation system providers. For example, a pilot project (Socrates 2.0[2]) is being conducted in Munich, Germany: When major events take place in the Allianz Arena or the Messe München, the authorities propose preferential routes and parking zones, which are then integrated into navigation systems. In the Netherlands and France, the main problem is freight traffic on the local road network. In the Netherlands, in consultation with navigation system providers specifically for trucks, it was agreed that trucks will now be guided around some village centres instead of through them. In France, mayors can restrict access to certain roads for traffic that endangers public peace. In the United States, attempts have been made in the past to impose local restrictions on providers of navigation systems, but without much success. The focus is now on working with the private sector, namely by developing processes for two-way communication about which roads are closed (e.g. because of floods or work zones) or to which restrictions apply (e.g. restrictions on the size or height of trucks). This does not solve the problem of diversion to shortcuts, but it does help with some forms of undesired and unsafe routing.

Some countries additionally note that attention should be paid to the safe use of a navigation system. Since 2018, all practical driving tests in the Netherlands should be conducted with the driver following a route on a navigation system to evaluate its safe use. Reference was also made to a recently published meta-analysis that studied the effect of in-vehicle information systems (IVIS) on road accidents and showed that 1.66% of all accidents are caused by operating such systems while driving (Ziakopoulos et al., 2019).

1.3.2 In-depth assessment: Regulations on speed camera warning systems

1.3.2.1 Germany

Legislation: According to §23 (1c) of the German Road Traffic Act (StVO), a driver may not operate or carry any technical device that is intended to indicate or disrupt traffic monitoring measures[3].

Excerpt from the legislation in Germany (with English translation)

(1c) [1]Wer ein Fahrzeug führt, darf ein technisches Gerät nicht betreiben oder betriebsbereit mitführen, das dafür bestimmt ist, Verkehrsüberwachungsmaßnahmen anzuzeigen oder zu stören. [2]Das gilt insbesondere für Geräte zur Störung oder Anzeige von Geschwindigkeitsmessungen (Radarwarn- oder Laserstörgeräte). 3Bei anderen technischen Geräten, die neben anderen Nutzungszwecken auch zur Anzeige oder Störung von Verkehrsüberwachungsmaßnahmen verwendet werden können, dürfen die entsprechenden Gerätefunktionen nicht verwendet werden.

(1c) [1]Anyone who drives a vehicle may not operate or carry a technical device with them that is ready for operation, which is intended to display or disrupt traffic monitoring measures. [2]This applies in particular to devices for interfering with or displaying speed measurements (radar warning or laser interfering devices). [3]In the case of other technical devices which, in addition to other purposes of use, can also be used to display or interfere with traffic control measures, the corresponding device functions must not be used.

Not only technical devices with the main purpose of displaying or disrupting speed cameras such as radar detectors and laser jammers are covered by the regulation, but also other technical solutions that achieve a comparable effect. This applies in particular to linking locations of fixed speed cameras with navigation systems because these devices also provide the warning in an automated and location-based manner.

Chronology: The original paragraph (articles 1 and 2) was included in the law for the first time in November 2001; from October 2017 it was included unchanged in section 23 paragraph 1c of the German Road Traffic Act (StVO). On 28 April 2020, Article 3 was added as a clarification. The amendment serves to clarify the language and does not change the regulatory content of the regulation. Navigation devices that have the

[2] https://socrates2.org/
[3] https://www.juris.de/jportal/cms/remote_media/media/jurisde/pdf/leseproben/leseprobe_juris_pk_sstrverkr_eggert.pdf

function of displaying speed cameras have already been covered by the regulation before; article 2 only contains an exemplary list. Indeed, the (main) purpose of navigation devices is primarily route guidance to the destination. However, devices with the aforementioned function (albeit as a secondary function) are at least also intended to display speed cameras and are thus covered by the regulation. This does not change even if the function is deactivated, because it is sufficient if the device is carried along ready for operation (not broken). The same applies to mobile phones on which so-called speed camera apps are installed (it's still a point of discussion among German lawyers what this means exactly for smartphone apps: installed or in use).

Enforcement: In the interest of enforcement, not only the actual operation but also the carrying "ready for operation" is prohibited (grey zone what this means for smartphone apps: installed or in use[4]). Otherwise, it would have to be proven in each individual case that the device was actually operated in order to prove a violation; this would not be practicable. The restriction to carrying the equipment "ready for operation" also distinguishes it from the commercial transport of such equipment, e.g. in cross-border goods traffic, which shall not be prohibited. During a police check, officers are allowed to ask for the smartphone only if they suspect that a speed camera warning app is being used. If there is any initial suspicion, they are entitled to check the smartphone and even delete apps. Drivers do not have to reveal a lock code, but the police can confiscate the device in return. Since police officers are normally not allowed to search a driver's smartphone, unless there is any initial suspicion, the discovery of speed camera warning apps is rather rare.

There are no dedicated controls for such devices but when a device (or app on a smartphone) is detected and it can be proven that it has been activated or ready for operation (by the police as a witness, by photographs,…) the driver will be fined and receive one demerit point. One example from a court case in 2015 where a driver was fined: The police had stopped him because of another offence and had taken photographs. One of the photographs showed a smartphone in a smartphone mount with a warning app clearly in operation mode. The same would apply to navigation devices.

Fines: A fine of €75 and one demerit point can be imposed for a violation. If the driver has the smartphone in their hand or if a police officer has seen it there shortly before, it becomes more expensive because smartphones cannot be operated while driving. In this case, the offence is punished with a fine of €100 and one demerit point.

In 2019, 659 cases of using an illegal device have been registered as an administrative offence in the central German driving licence register. Keeping in mind that there are about 4.5 million cases of administrative offences per year in total (3 million being speed violations) this is not really considered a priority in Germany.

Bypassing the law: Speed camera warning systems are allowed to be bought and owned in Germany, but they cannot be operated while driving (or carried ready to operate). Navigation devices and apps like Blitzer.de, Radarbot or Waze are on the market. In this case, the function/app may not be used. E.g. from the navigation device TomTom it is known that it gives you the information that the speed camera warning function is illegal when you activate it. In Waze, the function is available for the driver but at his/her own risk[5] – the driver can check speed cameras before he or she leaves, or for passengers to check along the way – the function/app on the smartphone of the driver should be deactivated while driving.

Legal options would be to:

- Drivers can look at their route before they leave, and remember the location of any fixed or mobile speed cameras;
- The locations of speed cameras can be printed out;
- Drivers can listen to the speed camera warning information on the radio (however, contrary to technical devices, the information about the location is not very precisely formulated (on purpose), so the actual location of the radar is not clear. Usually, only a road name and direction or a proximity is announced. Thus, the possibility is high that drivers reduce the speed to the legal limit for a longer road stretch and as a result, this can increase road safety);

[4] The current interpretation is that apps such as Waze can be installed and used, but the option to alert for speed cameras should be disabled.

[5] In contrast to Switzerland where Waze cannot offer the speed camera warnings to users and had to remove its database with speed camera locations.

- Passengers might use an app but they are not allowed to inform the driver about a radar (but they can ask the driver to slow down)[6].

Cooperation with system providers: The Federal Highway Research Institute (BASt) is not aware of any cooperation.

The map provider Google Maps has equipped its free navigation program with speed camera alerts in several countries; however, the function is not activated in Germany.

Speed cameras announced in other ways: Yes, under certain circumstances they are, e.g.:

- On the radio (usually mobile speed cameras);
- Area-wide radar campaigns on dedicated days are distributed through various media channels (e.g. the yearly "speed camera marathon" which is coordinated by the European traffic police network 'ROADPOL');
- On motorways within work zones through traffic signs.

There are various options and types of mobile speed cameras. E.g. tripod cameras mounted next to the road, radar pistols, and speed cameras in unmarked police cars. Most often the speed camera can be detected (if you look for it) but the associated police car is normally out of sight (not clearly visible).

Change behaviour of drivers? Impact on traffic safety? The Federal Highway Research Institute (BASt) is not aware of any evaluation studies.

1.3.2.2 France

In France, according to the governmental website on road safety[7], automatic speed cameras are installed primarily in dangerous areas where crashes due to excessive speed occur. Dangerous areas meet several criteria: the presence of signs indicating a danger (bends, intersections, steep slopes, etc.), a speed limit that is lower than the standard limit for the type of road concerned, the traffic, or a higher crash rate in the area. This "dangerous" qualification can also be temporary, for example in case of bad weather conditions.

Speed cameras are then prioritized in areas where increased vigilance is required. However, a zone of increased vigilance is not necessarily equipped with a speed camera. When a section of road is set up as a dangerous route, the probability of being controlled there is high, whether by means of autonomous, fixed, or mobile speed cameras. A sign indicates to the drivers that they are entering an automated speed control route. The difference with a traditional control announcement is the association of a second sign indicating the number of kilometres remaining before the end of the route. However, these signs do not indicate the proximity of a speed camera, but rather that the probability of a speed control is increased on the road section. Autonomous speed cameras can be installed randomly at several predefined locations. They are moved from one to three times a month. The installation of autonomous speed cameras in the areas is therefore very random so that motorists can sometimes encounter several speed cameras, sometimes none.

The legislation in France forbids the use of radar detectors and radars jammers/scramblers but authorizes the use of speed camera alerts under certain conditions, namely not showing the exact location. The possession and transport of radar detectors and jammers/scramblers are punished by a contravention of the 5th class. Article R. 413-15 from the Highway Code sets the regulatory framework for the use of these devices[8].

A fifth-class offence implies a fine of up to €1,500, but the actual amount is set by the Police Court at the time of the judgment, which is also competent to judge class 5 offences with regard to the fine, a potential suspension of license, confiscation of the vehicle or the obligation to do a road safety awareness course. In case of recidivism, the amount of the fine can go up to €3,000[9].

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[6] In February 2023, there has been a court case in which a passenger used a speed camera warning system and was fined for this. The driver in question refused to pay it and appealed. However, the judge at the Karlsruhe District Court ruled that other occupants were also not allowed to use the app. For them too, using a speed camera app is illegal. So the fine had to be paid.

[7] https://www.securite-routiere.gouv.fr/

[8] https://www.legifrance.gouv.fr/codes/id/LEGIARTI000025111528/2012-01-05

[9] https://www.legipermis.com/infractions/contravention-5eme-classe.html

Excerpt from the legislation in France (with English translation)

I. - Le fait de détenir ou de transporter un appareil, dispositif ou produit de nature ou présenté comme étant de nature à déceler la présence ou perturber le fonctionnement d'appareils, instruments ou systèmes servant à la constatation des infractions à la législation ou à la réglementation de la circulation routière ou de permettre de se soustraire à la constatation desdites infractions est puni de l'amende prévue pour les contraventions de la cinquième classe.

Le fait de faire usage d'un appareil, dispositif ou produit de même nature est puni des mêmes peines.

II. - Cet appareil, ce dispositif ou ce produit est saisi. Lorsque l'appareil, le dispositif ou le produit est placé, adapté ou appliqué sur un véhicule, ce véhicule peut également être saisi.

III. - Toute personne coupable de l'infraction prévue au présent article encourt également les peines complémentaires suivantes :

1° La peine complémentaire de suspension, pour une durée de trois ans au plus, du permis de conduire, cette suspension pouvant être limitée à la conduite en dehors de l'activité professionnelle ;

2° La confiscation du véhicule, lorsque le dispositif qui a servi ou était destiné à commettre l'infraction est placé, adapté ou appliqué sur un véhicule.

Toute condamnation donne lieu de plein droit à la confiscation du dispositif qui a servi ou était destiné à commettre l'infraction.

IV. - Cette contravention donne lieu de plein droit à la réduction de six points du permis de conduire.

V. - Les dispositions du présent article sont également applicables aux dispositifs ou produits visant à avertir ou informer de la localisation d'appareils, instruments ou systèmes servant à la constatation des infractions à la législation ou à la réglementation de la circulation routière.

I. - The fact of holding or transporting an apparatus, device or specific product to detect the presence or disrupt the operation of apparatus, instruments or systems used to establish offences against road traffic legislation or regulations, or to enable the evasion of the establishment of the said offences, is punishable by a fine laid down for fifth class offences.

The use of a similar device or product is punishable by the same penalties.

II. - The apparatus, device or product shall be seized. Where the apparatus, device or product is placed, adapted or applied to a vehicle, the vehicle may also be seized.

III. - Any person guilty of the offence provided for in this article shall also be liable to the following additional penalties

1° The complementary penalty of suspension of the driving licence for a period of up to three years, this suspension may be limited to driving outside of professional activity;

2° Confiscation of the vehicle, when the device that was used or intended to commit the offence is placed, adapted or applied to a vehicle.

Any conviction shall automatically give rise to the confiscation of the device that was used or intended to commit the offence.

IV. - This offence shall automatically result in a reduction of six points on the driving licence.

V. - The provisions of this article shall also apply to devices or products designed to warn or inform of the location of devices, instruments or systems used to detect violations of road traffic legislation or regulations.

In France and since 2011, the exact location of a speed camera cannot be indicated by any in-vehicle system (at least by operators that signed the AFFTAC protocol and receive certification), and systems can only inform about “danger zones” (with or without radars). In this case, the legislator considers the speed camera warning system as a driver assistance system. Navigation system operators who did not sign the AFFTAC protocol (French association of providers and users of driving assistance technologies) were free to define danger zone as they wish. Those who signed it committed, within the limits of technical constraints, to signal the dangerous sections of road representing a section of at least 4 kilometres on the motorway network, at least 2 kilometres outside built-up areas and at least 300 meters in built-up areas.

Articles L130-11 and L130-12 have been added to the Highway Code following the law of 24 December 2019 on the orientation of mobility. These additions apply to any operator of an electronic service that assists driving or navigation by geolocation since November 1st 2021. The aim here is to give the ability to an administrative authority, in the context of certain roadside checks for alcohol or drugs or checks provided for in the code of criminal procedure or for speed cameras, to request a ban on the retransmission via this service of any message or indication emitted by users that could enable other users to evade a check. This ban on retransmission should be limited in time and space: Depending on the situation, the duration of the ban would vary (2 hours for alcohol/substance tests, 12 hours for any other operation). Road locations concerned will be designated by the competent authority and may not extend beyond a certain radius around the roadside checkpoint (10 km when outside a built-up area and 2 km when located in a built-up area). Police roadside checks (times and locations) are communicated to navigation system providers beforehand through a dedicated information channel that ensures confidentiality, providers should confirm receipt of the information, and the information should be deleted as soon as the ban on redistribution has expired. In November 2021, the legislation was challenged in a lawsuit. Before November 2021, a different approach was in force for national roads and local or regional roads; the Constitutional Court decided that there is no ground for this discrimination.

Although the legislation in its current form is in force since November 2021, there are still unclarities associated with the operationalization of the law. The law is technically difficult to implement for navigation system providers, and there is uncertainty about the legal interpretation. For example: Can a traffic jam that originates from a police roadside check be indicated (combined with the information about a police roadside check in a larger zone, this could lead to the identification of the exact spot)?

In summary, the French law is somewhat ambiguous and has been amended several times. This creates confusion in all parties involved. Companies operating in France, such as Coyote and Waze, have already had to adapt their software several times.

1.3.2.3 The Netherlands

An official publication[10] by the Minister of Transport in the Netherlands in 2000 discusses the options for prohibiting the use of *radar detectors* (including radar jammers, laser detectors and laser shields) before any legislation was in force. A ban would be most effective if it is as broad as possible. That is to say, not only "having" such equipment in the vehicle should be prohibited, but also "offering for sale" (including advertising), "stockpiling" and "delivery". Enforcing a sales ban is relatively simple, in contrast to proving the presence of the equipment in a vehicle which often requires fairly extensive actions by the police. Recommendations were put into law in January 2004 and included in 'Besluit voertuigen' in May 2009[11].

Excerpt from the legislation in the Netherlands (with English translation)

Art. 2, lid 1 Het is verboden om radarontvangstapparaten die geschikt zijn om de aanwezigheid aan te tonen van een apparaat dat tot doel heeft om een overschrijding van de maximumsnelheid vast te stellen, in te voeren, te koop aan te bieden, in voorraad te hebben of af te leveren.

Art. 2, lid 2 Het eerste lid geldt niet voor de apparaten die in Nederland worden ingevoerd en waarvan door middel van handelsbescheiden wordt aangetoond dat de apparaten aansluitend worden uitgevoerd naar een andere lidstaat van de Europese Unie.

Art 3 Het is de bestuurder van een motorrijtuig verboden met dat motorrijtuig te rijden en de eigenaar of houder van een motorrijtuig verboden met dat motorrijtuig te laten rijden, indien in of aan het motorrijtuig een radarontvangstapparaat aanwezig is als bedoeld in artikel 2, eerste lid.

[10] https://zoek.officielebekendmakingen.nl/kst-26115-22.html
[11] https://wetten.overheid.nl/BWBR0025554/2021-01-01

Art. 2, lid 1 It is forbidden to import, offer for sale, stock or deliver radar receiving devices which are suitable for demonstrating the presence of a device whose purpose is to detect the exceeding of a maximum speed limit.

Art. 2, lid 2 Subsection 1 shall not apply to appliances imported into the Netherlands for which it is demonstrated by means of commercial documents that the appliances are subsequently exported to another Member State of the European Union.

Art 3 The driver of a motor vehicle is prohibited from driving that motor vehicle, and the owner or holder of a motor vehicle is prohibited from allowing a motor vehicle to be driven if a radar receiver is present in or on the motor vehicle as referred to in section 2, subsection 1.

More recently, in 2015, there was a court decision on the interpretation of the law[12]. Points dealt with in the discussions:

- A radar detector should not be in use or ready for instant use, in order to be covered by the legislation. In a specific case, a radar detector was installed in a vehicle, but the software was not downloaded.
- Detecting radars should not necessarily be the only or main function of the device in order to be covered by the legislation. The reason for this is that a distinction between main and secondary functions is not workable in practice for enforcement purposes.

In 2020, the minister of Justice and Safety declared that he will wait for an evaluation of the new ban on smartphone apps indicating the location of speed cameras in Germany. If such a ban has a positive impact on traffic safety, it could lead to a ban in the Netherlands as well.

1.3.2.4 Switzerland

In Switzerland, all speed camera warning systems are banned[13]. Whether installed in GPS units or in apps downloaded to smartphones, Switzerland strongly sanctions the use of this technology as well as its possession. Even if your navigation system with speed camera warnings is switched off or your app is not open, the mere fact of carrying a device that warns of danger zones exposes its user to a strong penalty: confiscation of the device and a fine (multifunctional devices are not seized, confiscated and destroyed). This regulation came into force on January 1st 2013. Smartphone apps with speed camera warnings that operate in several countries, like Waze, removed all speed cameras from their databases on Swiss territory, but the app can still be used for example for route guidance.

Excerpt from the legislation in Switzerland (with English translation)

[1] Est puni de l’amende quiconque:

a. importe, promeut, transmet, vend, remet ou cède sous une autre forme, installe, emporte dans un véhicule, fixe sur celui-ci ou utilise de quelque manière que ce soit des appareils ou des dispositifs conçus pour compliquer, perturber, voire rendre inefficace le contrôle officiel du trafic routier;

b. prête assistance à l’auteur des actes visés à la let. a (art. 25 du code pénal).

[2] Les organes de contrôle mettent ces appareils ou dispositifs en lieu sûr. Le juge ordonne leur confiscation et leur destruction.

[3] Est puni de l’amende quiconque:

a. adresse des avertissements publics aux usagers de la route concernant les contrôles officiels du trafic;

b. fournit à titre onéreux un service avertissant de tels contrôles;

[12] Besluit Hoge Raad 2015 https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:PHR:2015:2398
[13] Loi fédérale sur la circulation routière Art. 98a: https://www.fedlex.admin.ch/eli/cc/1959/679_705_685/fr#art_98_a

c. utilise, aux fins mentionnées, des appareils ou des dispositifs qui ne sont pas destinés à avertir de contrôles officiels du trafic.

[4] Dans les cas graves, la peine est une peine pécuniaire de 180 jours-amende au plus.

[1] A fine shall be imposed on anyone who

a. imports, promotes, transmits, sells, hands over or otherwise transfers, installs, carries in a vehicle, attaches to it or uses in any way whatsoever equipment or devices designed to complicate, disrupt or render ineffective official road traffic control;

b. assists the perpetrator of the acts referred to in subparagraph a (Article 25 of the Criminal Code).

[2] The control bodies shall keep these devices in a safe place. The judge shall order their confiscation and destruction.

[3] A fine shall be imposed on anyone who

a. issues public warnings to road users concerning official traffic controls;

b. provides a service warning of such controls for a fee;

c. uses equipment or devices for the aforementioned purposes that are not intended to warn for official traffic controls.

[4] In serious cases, the penalty shall be a fine of up to 180 days.

There are still many mobile radar detectors for smartphones on the market. As an alternative to the speed camera app, there are some SMS services, but these are also not permitted. Disseminating warnings on social media is also prohibited. Since 2013, the ban has applied to any type of public information about the current locations of speed cameras.

2 Literature review on navigation systems

2.1 Introduction

This report mainly focusses on different speed camera warning systems, their use, and their effect on traffic safety. In this chapter, we broaden the scope to the use of (navigation) systems for other purposes than warning for speed cameras. The use of navigation systems for (real-time) route planning can have an impact on global road safety. Navigation systems facilitate the use of alternative routes in case of incidents or traffic jams. Diverted traffic, i.e. cut-through traffic, can increase congestion on local roads or near schools, and thus negatively affect liveability and road safety. Moreover, in-vehicle screens may increase distraction. Through a literature study, we want to find out which research questions have already been studied and answered in the international literature, which conclusions we can draw for Belgium and which knowledge gaps still exist.

2.2 Methods

To get an overview as complete as possible of the state of the art, several sources were consulted. The academic database Web of Science, the Transport Research International Documentation (TRID), grey literature, and references in references were checked. On top of that, documents referred to by the external experts contacted for the international benchmark were included.

Search terms used for the desk literature review were: "cut-through/cut-thru/through-truck traffic", "navigation", "rerouting", "traffic app", "congestion", "rat-running", "Waze", sometimes combined with other search terms.

2.3 Results

2.3.1 What do we mean by navigation systems for route planning?

Navigation systems can be grouped according to functionality and form. Functionally, we can distinguish two types of systems: static and dynamic navigation systems. Static systems help the driver to find the shortest or fastest route between an origin and a destination based on historical data stored in a digital road map ("offline system"). Dynamic navigation systems also use real-time traffic information ("online system"). Both systems exist built into the dashboard of a vehicle (integrated system), in the form of a portable device where route navigation is the main function (separate non-integrated or nomadic system), or as a smartphone/tablet application (Figure 2). Nowadays there are also hybrid systems where the route navigation app of the smartphone can be displayed on the dashboard of the car (Apple CarPlay, Android Auto), or even on a smartwatch.

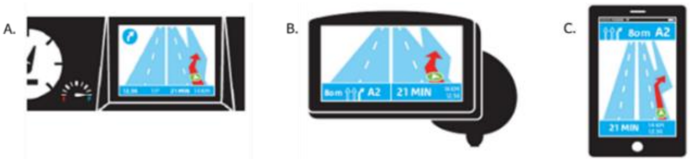


Figure 2 Navigation systems are available as built-in systems (A), as portable systems where route navigation is the main function (B), or as smartphone/tablet applications (C).
Source: (Schaap et al., 2017)

Navigation systems together with route guidance via dynamic text signs (Variable Message Signs) belong to the Advanced Traveller Information Systems (ATIS). This is the general name for all systems that collect, analyse and offer route information to individual road users (van Essen et al., 2016).

Real-time traffic information in navigation systems is often used to avoid traffic jams. Before starting a journey, drivers can check current traffic conditions and choose the optimal route. However, by using a navigation system connected to the internet, drivers can also re-evaluate their route in real-time and decide to take a different route along the way. Systems such as Coyote, Waze, or Google Maps continuously collect anonymous location data from smartphones of drivers and passengers (floating car data), and analyse this data to calculate travel times and possibly offer an alternative route taking into account the traffic conditions at the time (Yamsaengsung & Papasratorn, 2018). Drivers can thus follow the fastest route for them (decision based on full information about alternative routes).

To calculate the fastest or shortest route, route planners use a routing algorithm. This algorithm uses all available data to advise on a route: a digital road network enriched with additional attributes such as speed limit (static systems), as well as real-time information on travel times and driven speeds on the road network (in the case of a dynamic system) (De Baets et al., 2014). Each navigation system provider uses its own data and its own proprietary algorithm - different systems may therefore recommend a different route at the same time.

In many cases, navigation systems offer additional functions on top of route planning. Static systems may provide information about the location of fixed speed cameras, speed limits, and POIs. Dynamic navigation systems are marketed as 'safety systems' that warn of upcoming traffic jams and delays, stationary vehicles, wrong-way drivers or other dangers on the road. The most controversial function is to warn for mobile speed cameras or police checks (alcohol, drugs, vehicle documents).

2.3.2Prevalence in Belgium and characteristics of users

The 2016 MONITOR study[14] surveyed the *ownership* of navigation systems in Belgium. In Belgium, 37% of drivers own an integrated navigation system; in addition, 40% of drivers in Belgium report owning a separate non-integrated navigation system. In total, 73% of the drivers have a separate and/or integrated navigation system (Brussels 72%; Flanders 75%; Wallonia 71%). Men in particular own a navigation system: 79% compared to 68% for women. Figure 3 shows ownership by age and gender. It is mainly the 35 to 64-year-olds who have an integrated navigation system, partly because these systems are more often found in company cars. The figures from MONITOR are probably an underestimation because there is no explicit reference to smartphone navigation apps. Little is known at present about the *use* of navigation systems in Belgium.

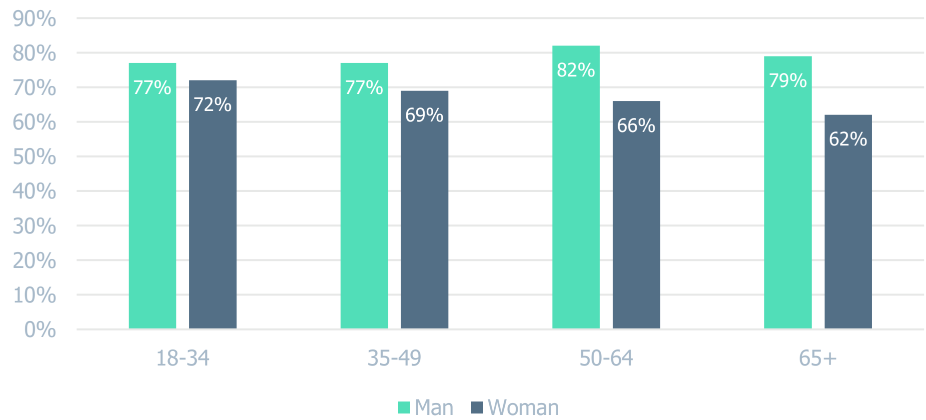


Figure 3 Percentage of drivers with a navigation system by age group and gender (figure based on MONITOR data, 2016).

[14] https://mobility.vias.be/nl/monitor/

There are many brands of navigation systems on the market. Popular systems in Belgium are Waze, Google Maps, and Coyote, but there are also Apple Maps, TomTom, Garmin, Flitsmeister, INRIX, and other smartphone-based navigation tools. The use of dynamic navigation systems with real-time routing (mainly via smartphone) is increasing (Schaap et al., 2017). Real-time route information is an important factor in attracting new users (Khoo & Asitha, 2016). There are indications that before, navigation systems were mainly used to drive to an unknown destination, whereas nowadays the systems are also used more often for daily trips (Guin et al., 2021).

Many drivers use multiple systems. The MONITOR study in Belgium showed that almost 5% of drivers own both an integrated and a separate non-integrated system (MONITOR, 2016, own calculation, no navigation apps surveyed). A Dutch study also found that more than one type of navigation system can be found in 34% of households (Schaap et al., 2017). A recent study in the United States shows that almost 1/3rd of users use multiple navigation apps (Guin et al., 2021).

It is difficult to accurately estimate the proportion of drivers on a road section with dynamic route instructions switched on, without having access to data from the app providers (Thai et al., 2016). In this context, it would be useful to literally map the problem of cut-through traffic when an incident appears on a major road. According to a recent study in the United States based on detector data, 4 to 22% of traffic on a highway with delayed traffic would detour onto local low-capacity roads, depending on the severity of an incident (duration), the number of lanes blocked, and the time of day (Guin et al., 2021). A questionnaire showed that 25% of the drivers followed route instructions blindly, and another 47% followed the route of the navigation system in 80 to 99% of the cases (Guin et al., 2021). A three to five-minute time gain was needed for drivers to accept a new route from the app (Guin et al., 2021).

2.3.3 What is the effect of navigation systems on road safety?

The use of (dynamic) route navigation has an impact on road safety. There are effects on the driver, but also on other road users.

Few experimental or observational studies have been carried out which would show that users of a navigation system have a higher crash risk than drivers without a navigation system. An early study by Perez et al. (1996) compared the number of crashes in test vehicles equipped with and without TravTek, the first modern navigation system in vehicles; no difference in the number of crashes was found between the two groups. Van Rooijen et al. (2008) compared the number of accidents in >100 000 leased vehicles with and without a built-in navigation system in the Netherlands. Drivers with a navigation system were found to report fewer claims than drivers without: 9.14 per million kilometres compared to 10.24 claims per million kilometres. A meta-analysis on a limited number of studies shows that the use of 'in-vehicle information systems' (IVIS; this includes navigation systems, but also others such as eco-driving systems, email interfaces, vehicle diagnosis systems, lane departure warnings) cause 1.66% of all traffic crashes - however, the number of studies is limited with a large variation in the type of IVIS (Ziakopoulos et al., 2019). It is important to take confounding factors into account in these studies: drivers with a dynamic navigation system may have a different profile (less risk-averse, younger, male) than non-users and this may distort the results.

Various simulations have been carried out to evaluate the effects of a navigation system on road safety. Some studies found no effect on the number of crashes (Perez et al., 1996; Stoneman, 1992), others found a higher number of crashes (Abdulhai & Look, 2003), or a lower number of crashes with an increase in the proportion of dynamic route navigation users (Chatterjee & McDonald, 1999; Kiec et al., 2020).

The results of the different studies are not consistent; moreover, many studies are outdated and do not use navigation systems as they exist today (mainly smartphone apps). It is therefore difficult to draw final conclusions about the impact of (dynamic) navigation systems on road safety. In the following paragraphs, we, therefore, look more closely at individual risk factors that may influence the number or severity of crashes. We consider both the impact on the driver with and without a navigation system *ceteris paribus*, and the effect of an alternative route that differs from the original route in terms of travel time, road type, etc.

2.3.3.1 More traffic on local roads

To estimate the impact of navigation systems with real-time traffic information on the total travel time and mileage of all drivers, we must first understand the complex theory behind it. Selfish routing is a phenomenon in which users of a navigation system travel from an origin to a destination along a path that minimises their individual cost function, without considering other entities on the network (Lazarus et al., 2018; van Essen et al., 2016). Such behaviour can be studied using a game-theoretic approach in which the resulting traffic flows represent a Nash equilibrium: when congestion occurs on a route, a faster alternative route will be chosen (Cabannes et al., 2018). In a Nash equilibrium (also called a Wardrop equilibrium in traffic science), no driver can still improve his cost function by unilaterally choosing another path. Nash equilibria have been studied extensively in economics and have been shown to be suboptimal for society. A system-optimal routing would ensure that the *average* travel time for all road users is minimal; theoretically, this could lead to a 10-30% reduction in total travel time (Wilmink et al., 2017).

Specifically for navigation systems with dynamic routing, users have all the information to choose the route with the lowest cost function for them. Before, this was not possible because their knowledge was always incomplete: not all alternative roads are known, there may be delays on alternative roads, etc. Whereas before there was 'bounded rationality in decision making', now with quasi-complete information one can choose a route that minimises one's cost function (Thai et al., 2016; van Essen et al., 2016). In case of congestion on the main road network, local roads will therefore be chosen very quickly and lead faster to the destination. When (almost) all vehicles are equipped with dynamic route navigation, the network thus quickly enters a suboptimal Wardrop equilibrium (with the assumption that drivers will effectively follow the proposed route) (Bonsall, 1992; Festa & Goatin, 2019).

A second phenomenon that comes into play is that of 'induced demand': the space freed up on the main roads will be taken up by new traffic. The reason for this is that the traffic on a road during rush hour often does not cover the full demand, because congestion has caused potential trips to be cancelled, diverted, replaced with other transport modes, or postponed. In the longer term, this will not lead to shorter journey times for everyone.

A consequence of both phenomena is additional traffic on local low-capacity roads and intersections that are not equipped for it. A simulation by Thai et al. (2016) for Los Angeles showed that selfish routing enabled by navigation systems can lead to a 300% increase in vehicle kilometres on local roads, depending on the percentage of users, and only a 10% decrease in vehicle kilometres on main roads (Figure 4). Thus, the increase in traffic on local roads did not lead to a significant decrease in congestion on motorways (due to weaving behaviour and congestion on exits which also led to delays further down the motorway, in combination with induced demand). Also, Festa et al. (2019) showed with a simulation that traffic on local roads increases when the number of drivers with dynamic route navigation increases. When saturation of local roads occurs, the travel time from origin to destination will become similar on all roads; and (new) cut-through drivers will no longer be tempted to use the shortcut (Cabannes et al., 2018).

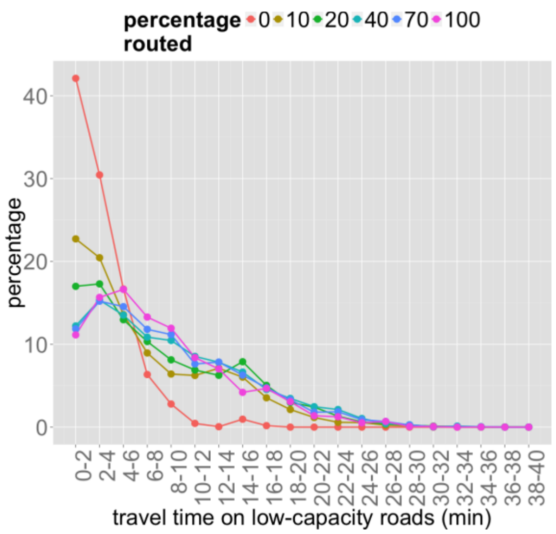


Figure 4 An increase in the proportion of users of navigation systems with dynamic routing causes a notable increase in travel time on local roads (simulation for Los Angeles, USA).
Source: (Thai et al., 2016)

The risk of a crash per kilometre driven is higher on local roads and roads with more level crossings (e.g. Flanders: https://www.vlaanderen.be/statistiek-vlaanderen/mobiliteit/verkeersongevallen). The increase in vehicle kilometres on local roads is therefore expected to lead to more crashes. In a study on cut-through driving using navigation systems in Japan, no less than 49.8% of the drivers who took a shortcut reported that the alternative route was too narrow and that it was difficult to pass cars or make turns; only 11.5% of the drivers had never experienced a dangerous situation on an alternative route (Kojima et al., 2015). In addition to the impact on road safety, there is also a significant impact on liveability: neighbourhoods that suffer from high levels of cut-through traffic suffer from increased traffic and congestion, noise pollution, air pollution, damage to infrastructure, and reduced quality of life, among other things (Lazarus et al., 2018).

2.3.3.2 Change in total vehicle kilometres

The change in total vehicle kilometres due to dynamic route navigation is less pronounced on all roads combined than on local roads only. On the one hand navigation systems provide knowledge of the entire road network so that the shortest and/or fastest route will be chosen more often. Navigation systems reduce searching behaviour when driving to unknown destinations; this results in fewer kilometres driven (Lee & Cheng, 2008; Vaa et al., 2007; Van Rooijen et al., 2008). On the other hand, with a navigation system, drivers may choose new destinations or routes that they did not dare to visit before (Vaa et al., 2007). Under the influence of congestion, it is also likely that dynamic route navigation will opt for a longer but faster route. The overall impact is thus uncertain.

2.3.3.3 Change in driving speed

Changes in traffic flow also lead to changes in driving speeds. Vehicles that leave the motorway to take a shortcut proposed by dynamic route navigation, do so because they want to reach their destination faster. A higher speed will lead to more serious crashes (Elvik, 2005; Hussain et al., 2019). In the STRIDE study in the United States, drivers reported that the use of smartphone apps for navigation increased the speed of other drivers on local roads; in contrast, they reported no change in their own speed, possibly biased by the presence of 'social desirability' (Guin et al., 2021). In a study by Knapper et al. (2016), no difference was found in the percentage of time when the speed limit was violated between trips with and without a navigation system (in the same drivers).

Navigation systems often include additional functions that warn of various dangers on the road. These systems aim to improve road safety by increasing the driver's alertness or by recommending an appropriate speed. An experimental study in 24 motorists who used a navigation system with 'curve speed warnings' found an 8-10% decrease in speed in bends (Davis et al., 2019). In the Netherlands, ProRail compared speed data near unguarded railway crossings before and after the introduction of a warning in the Flitsmeister navigation app[15]. The test showed that motorists reached their lowest speed 25 metres earlier on average, and speed was up to 5 km/h lower.

2.3.3.4 Manoeuvres

When a driver receives an instruction for an alternative route or a warning for a dangerous situation on the road, he will immediately change his behaviour, for example by changing lanes or by slowing down; this may lead to an increased risk of a crash (Abdulhai & Look, 2003; Erke et al., 2007). The new route, which, as shown above, more often runs along local roads, will expose the driver to potentially dangerous situations: more conflicting traffic movements, including those with pedestrians and cyclists, unsecured turns at intersections, unsuitable local roads, and so on. Newspapers regularly report on trucks getting stuck on narrow roads or under low bridges [16], vehicles driving towards wildfires [17] or getting stuck on muddy farm roads [18] by blindly following their navigation systems.

2.3.3.5 Distraction and stress

A navigation system can reduce stress when driving to an unknown destination; it reduces the workload and errors made by drivers, which will lead to increased road safety (Van Rooijen et al., 2008). It avoids known

[15] https://www.prorail.nl/nieuws/proef-prorail-en-flitsmeister-maakt-automobilisten-bewuster-van-overweg
[16] https://www.nieuwsblad.be/cnt/blbpr_03016084
[17] https://eu.usatoday.com/story/tech/news/2017/12/07/california-fires-navigation-apps-like-waze-sent-commuters-into-flames-drivers/930904001/
[18] https://www.npr.org/2019/06/27/736572732/google-maps-leads-about-100-drivers-into-a-muddy-mess-in-colorado

risk factors for crashes like 'Searching for a street name' and 'Looking at a map' (Vaa et al., 2007). The accuracy with which the time of arrival is estimated reduces uncertainty and stress.

However, all things not directly related to driving the vehicle can distract the driver from the driving task (Schaap et al., 2017). When drivers receive new information about delays or an alternative route, this causes immediate distraction, which can be expressed in terms of reaction speed, the degree to which the environment is still correctly perceived and interpreted, the so-called 'Situational Awareness', and driving behaviours such as distance to the car in front or the degree of swerving on the road (Schaap et al., 2017). Distraction usually increases the risk of a crash (Vaa et al., 2007; Ziakopoulos et al., 2019). Behavioural change can occur concretely because drivers need time to read ('eyes off the road') and understand the new information, or to consider an alternative route. A good user interface for the navigation system is crucial and can reduce distraction (Dingus et al., 1997). In a survey of navigation system users in the Netherlands, 70% did not agree with the statement that a navigation system distracts them (Van Rooijen et al., 2008). Moreover, 67% of the drivers said that they experience less stress because of the system than before, and they feel more in control (78% agreed) and more alert (45% agreed) (Van Rooijen et al., 2008). On the other hand, in a Japanese study a significant proportion of detourers, 17.8%, stated that they did not see a person walking on the road in time or missed a traffic sign because they were looking at their navigation system at that very moment (Kojima et al., 2015).

A navigation system also needs to be operated. This happens mainly at the start of a journey: about 40% of the interaction with the system takes place in the first 10% of the journey (Knapper et al., 2016). About 35% of the interaction occurs when the vehicle is stationary or travelling at a low speed (up to 10 km/h) (Knapper et al., 2016). Metz et al. (2014) observed that drivers lower their speed when operating a navigation system and that the following distance increases. However, drivers also regularly use a navigation system at moments when this is risky. According to a British study, one of the most dangerous distracting driving tasks that leads to crashes is entering the destination in a navigation system: 2% of the respondents reported ever having had an accident while performing this task (Lansdown, 2012). In a European survey (Fondation Vinci, Baromètre de la Conduite Responsable 2021), 55% of Belgian drivers said they set their navigation system while driving, compared to a European average of 43%.

In certain situations, a proposed route may be different from what a driver expects. An alternative route may be perceived as slower than a known route, which increases stress and frustration, and it may also lead drivers not to follow the proposed route (Bonsall, 1992; Yamsaengsung & Papasratorn, 2018). This will again require more interaction with the navigation system (checking the route, looking at alternatives), it will cause distraction and will not improve road safety.

We already showed that the use of a navigation system leads to more traffic on local roads. Driving on local roads is more complex: right of way, changing speed limits, and mixed traffic, which causes more stress for the driver (Ringhand & Vollrath, 2019).

All kinds of warnings offered in navigation systems can increase a driver's alertness (Van Rooijen et al., 2008). But imposing additional information in certain demanding situations can also have a negative effect on road safety. On the other hand, the lack of information where it is needed also causes a high workload and possible negative effects (Schaap et al., 2017). When providing information, a balance must therefore be carefully sought between too much and too little.

Some in-vehicle warning or navigation systems also request real-time feedback from drivers. This concerns all kinds of new warnings that can be entered by a user, or existing warnings that can be confirmed or indicated that it is not there anymore. There is a long list of events that a driver can indicate or confirm, depending on the specific app: traffic jams, stopped vehicles, speed cameras, minor or major crashes, roadworks, slippery roads, road closures, etc. This is a relatively new source of distraction and more research is needed for this specific activity. The US Department of Transportation states that tasks where you look away from the forward roadway for more than 2 seconds at a time, or briefly several times with a total duration of 12 seconds, should not be allowed while driving and are associated with an increased risk of a crash or near crash (NHTSA, 2016). Again, the user interface is crucial in limiting or not the degree of distraction.

2.3.4What measures can be taken to prevent cut-through traffic?

In this section, we discuss measures to reduce the negative consequences of cut-through traffic induced by the use of navigation systems.

2.3.4.1 Traffic calming: Slowing down motorised traffic on local roads

Shortcuts become less attractive when travel time increases. Reducing speed can be done by lowering the speed limit with traffic signs (signs C43, F4a). Other legislative options for slowing down motorised traffic include introducing right-of-way and adding stop signs (signs B1, B5, B17). One can also intervene in the infrastructure: constructing speed bumps, narrowing the road (visually), and reducing the road capacity (e.g. reducing the number of lanes, adding a cycle path or green spaces). Generally speaking, the aim should be to bring the road layout in line with the road categorisation as determined in regional and local mobility plans (De Baets et al., 2014). This process can be accelerated so that the use of the road will more quickly correspond to the use for which it is intended. A lower speed increases road safety, both through a reduction in the number of crashes and in the severity of crashes (Elvik, 2005; Hussain et al., 2019).

2.3.4.2 Access restrictions

Navigation systems have to follow the highway code as imposed by the road authority when planning a route. The use of cut-through roads is not prohibited, so these roads are offered to users. Restricting access to streets or areas will ensure that motorised through-traffic is banned; however, some of the measures also affect residents (and related service vehicles/deliveries). Possibilities for restricting access include introducing one-way traffic, prohibiting access except for local traffic, turn restrictions, establishing car-free or restricted access zones, road blocks or partial closures. Circulation plans can be drawn up to prevent structural cut-through traffic on a road network, for instance by dividing cities into zones or loopholes, and cutting through traffic axes. The aim is almost always to ban non-residents from areas prone to cut-through traffic. An effective way to limit cut-through traffic on local roads due to incidents or congestion on motorways is to change the timing of traffic signals on exit ramps (Guin et al., 2021). Access can be limited in time, for example only during rush hours.

2.3.4.3 Road pricing

Economic incentives, road pricing, congestion charging, or cordon tolling can make motorists prefer to avoid certain roads or times of day (Li et al., 2021). Introducing a charge for the use of local roads, with prices rising during rush hours, discourages cut-through traffic. To enable correct pricing, the external costs caused by dynamic navigation systems on local roads should be properly mapped (Lazarus et al., 2018). The costs can be charged to the drivers themselves or to navigation system providers. In contrast, drivers can be rewarded for choosing a slightly longer route that does, however, strive for a system-optimal distribution of traffic.

2.3.4.4 Adjusting the digital road network or the routing algorithm

By adjusting the digital road network or the routing algorithm, cut-through traffic induced by navigation systems can be limited. These adjustments must be made by the providers of the navigation systems, but in theory, they can be imposed by the government.

Possible adaptations are for instance digitally removing or making inaccessible certain streets from the road network, adaptations that avoid the use of local roads at a great distance from the destination, or giving higher weights to roads of a lower category (De Baets et al., 2014). An interesting study in this respect is by De Baets et al. (2014). They simulated a route between two locations in Flanders with the help of several online route planners. They compared these suggested routes with the desired route based on the road categorisation in Flanders, which takes into account criteria related to liveability and traffic safety. The different road categories were assigned a weight. Results show that commercial route planners more often chose local roads of the lowest category than is socially desired, and that usually a socially more desirable alternative was available that did not increase travel time and distance excessively. It is therefore desirable in this case to prefer the most sustainable and socially-desirable route over the shortest or fastest route.

Some navigation systems already make use to a greater or lesser extent of a modified algorithm that tries to avoid local roads more often. The app Flitsmeister tries to convince drivers of a socially more desirable (often longer) route by tempting them with extra options (temporary PRO license)[19]. From a societal point of view, a system-optimal distribution of traffic could be chosen that ensures that the travel time for all traffic participants together is minimal and that in addition the external costs of motorised traffic are limited as much as possible. This is in contrast to selfish routing with a Nash equilibrium. This desired state can be achieved with the help of an adapted algorithm - an important precondition for this is that all navigation system providers (including smartphone apps and open source systems) cooperate in this.

2.3.4.5 Spatial planning and road network

Cut-through traffic is not always a problem. In urban regions that are structured as a grid with no real road hierarchy, traffic can be evenly distributed across the road network; if there is a traffic jam on a particular route, deviated drivers will spread out over the many parallel roads in the wider region.

The reason for congestion is often delays on the main road network. This can be prevented by designing cities differently, with residents living closer to destinations, and where they can use active transport modes and public transport.

2.3.5 Traffic management via navigation systems: Public-private partnerships

Dynamic navigation systems can be an innovative and smart means of managing traffic in real-time. They create opportunities for businesses, cost-effective traffic management for governments, and better service for road users. Services can focus on smart routing advice, but also alert for incidents or dangerous situations, parking guidance, and speed advice, or it can be integrated into MaaS systems.

At present, collaborations between governments and the various companies that market navigation systems are rare and hesitant. Both parties often have conflicting interests (Lazarus et al., 2018). Developers of navigation systems have no interest in suggesting a slower route - if they do not suggest the fastest route, their customers will choose another app (Kröller et al., 2021). Governments aim for a system-optimal distribution of traffic, with sustainable routes and minimal external costs. Nevertheless, recently some interesting pilot projects have been set up that exchange all kinds of traffic information between public and private parties resulting in a win-win situation. From these pilot projects, one can learn how to organise cooperation, what elements are needed to make it successful and how to scale up the solutions. In what follows, we discuss several *good practices* that have been applied worldwide.

In the **Socrates 2.0**[20] project, European governments worked together with companies such as Waze, TomTom, Be-Mobile and others to achieve more structural cooperation, for example through new standards for sharing traffic information. The project ran from 2017 to 2021. As part of the project, Kröller and colleagues (2021) investigated the willingness of TomTom users to choose a longer, but socially more desirable route proposed by the road authority. They found that users were very interested in receiving such route suggestions, but drivers did not want their routes to be automatically adjusted. Users were more inclined to change their route if there was a personal benefit for them in doing so, e.g. avoiding a potentially dangerous situation or if an incentive was offered. The willingness to take a longer route decreased as detour time increased. In Socrates 2.0, several pilot studies were also set up in four European cities, always in cooperation between public and private parties (Table 4). Based on the pilot projects, a number of success factors were identified:

- Cooperation framework between road authority(ies) and service providers, including protocols, standardisation of data exchange formats, division of tasks, etc;
- Win-win-win (for the road authority, private parties, and the user);
- Scalability of the solutions (the same application can be used in different places to justify the initial investment).

[19] https://www.flitsmeister.nl/
[20] https://www.ndw.nu/onderwerpen/socrates

Table 4 Pilot projects within Socrates 2.0.

Smart route advice in Antwerp, BE	In case of heavy traffic in the Kennedy tunnel, drivers who participate in the study are offered to drive toll-free along the Liefkenshoek tunnel. The pilot project is a cooperation between the Flemish Traffic Centre, the German car manufacturer BMW, the Dutch MAPtm, and the Ghent traffic data company Be-Mobile (Flitsmeister app). The pilot took place in 2020. The road authority notified BMW and BE-Mobile when drivers could be diverted; push messages were sent to affected drivers via geofencing, and if they were willing to take the route via the Liefkenshoek tunnel, they received a QR code to use the toll tunnel free of charge. About 50% of the drivers who were eligible to use the alternative route, actually used it (impact rate = 47%).
Preventing traffic jams by re-routing in Amsterdam, NL	Traffic jams on the main road network are prevented by predicting them in advance and offering alternative routes to users of a smartphone app (Flitsmeister) who are about to be part of the traffic jam. In 2020, the pilot was rolled out near Amsterdam. The alternative route usually proved longer, so drivers were offered compensation in the form of credits for a pro-licence. About 6000 drivers participated, with an impact rate of 38%.
Route guidance for events in Munich, DE	At major events in the Allianz Arena or the Messe München, the authorities suggest preferential routes and parking zones, which are then integrated into navigation systems. A planned pilot project was cancelled due to the cancellation of major events because of the Corona crisis.
Managing car traffic in the city of Copenhagen, DK	Alternative routes are proposed to motorised traffic by navigation systems in different situations: (1) cars are rerouted to avoid intersections with bicycle traffic jams; (2) cars are rerouted to avoid places with poor air quality or low emission zones; (3) cars are routed via preferred routes and to park-and-ride zones at events. Planned pilot projects were cancelled due to the cancellation of major events because of Corona; traffic rerouting was unnecessary due to the large reduction in the number of cars on the road by lockdown measures.

Another example of an existing collaboration between governments and private parties is '**Waze for cities**' [21] where Waze passes crowdsourced incident reports from their drivers to governments, and governments pass information about planned events, roadworks, or road network modifications to Waze. Public authorities or private road operators can apply to exchange data with Waze; there are already more than 3000 such collaborations worldwide (Table 5).

In the Netherlands, road authorities, the government (Rijkswaterstaat, Nationaal Dataportaal Wegverkeer) and map providers are collaborating in an extensive trial where navigation apps warn drivers for children travelling in school neighbourhoods during school hours or even propose an alternative route[22]. Among others, the apps Flitsmeister and Waze participate in the trial.

Table 5 Examples of collaborations within 'Waze for cities'.

Ghent, BE	In 2017, the city of Ghent introduced a new circulation plan. Through cooperation with Waze, correct route instructions were given to Waze drivers from day 1.
Antwerp, BE	Data on road works and events in Antwerp is shared with Waze. The city of Antwerp gains access to the real-time data Waze collects about the situation on the roads, the so-called 'floating car data'.
Brussels, BE	With the introduction of "Ville 30/Stad 30" on 1 January 2021, the speed limit was reduced to 30 km/h on local roads in Brussels. Brussels Mobility made the map available to Waze in advance so that the correct speed was shown in the app from day 1.
Budapest, HU	Accident reports from Waze were used to measure the impact on road safety of reducing speed on a major road.
Israel, IL	Accident reports from Waze are reported directly to emergency services, leading to a 10-15% faster response time compared to reports from other sources.
Boston, USA	Traffic jam alerts from Waze were used to evaluate new traffic signal timings to ease chronic traffic jams.
Versailles / Paris, FR	Closed roads due to an annual running event are reported in the Waze app. In addition, Waze sends push messages to local users to inform them about the temporary traffic situation.
Kentucky, USA	In the event of stormy weather, Waze users were called upon via Twitter and other channels to report fallen trees and flooded streets via Waze. This gave the road authorities a fast and accurate overview (on a map) of the locations where they needed to take action.

[21] https://www.waze.com/nl/wazeforcities
[22] https://fietsberaad.nl/kennisbank/schoolzones-opgenomen-in-navigatiesystemen

During the COVID-19 pandemic, green and blue spaces became popular destinations in many countries. When becoming too busy, governments spread messages to avoid those areas as safe physical distances could not be maintained or car parks were saturated. These messages were usually communicated through classical media, however, in the Netherlands, these messages were also spread through navigation systems[23]. The original message of the governmental institution (just an alert that it is too busy, or including suggestions of using a nearby P+R facility) was transformed into a technical format and then pushed in real-time to Waze, Google Maps and Flitsmeister to offer it to their users.

Nowadays, public parties worldwide are looking for ways to institutionalise temporary ad hoc collaborations and make them more permanent. One of the most promising applications in this respect is **keeping the digital road network** used by navigation systems **up to date**. For example, in recent years cities and towns have been strongly committed to reducing the speed limit near schools – if navigation systems can take this 'new' speed into account, part of the traffic will no longer take the quickest route past the school. Keeping the digital road network up to date is a task for the service providers, but local authorities have every interest in ensuring that this information is up-to-date and correct - after all, it is this information that is used widely by citizens. New information can flow from local governments to the various providers of digital road networks in different ways:

- TN-ITS[24]: A European platform that sets out the information flow from data coming from the road authority to up-to-date information on the navigation system of the European user. This includes the development of technical specifications for the data exchange flow.
- The company Localyse offers the 'Improve Google Maps' service in Belgium and the Netherlands[25]. The company plays an intermediary role in which cities and municipalities can pass on desired adjustments to the Google Maps digital road network, and Localyse ensures that these adjustments are smoothly incorporated into the navigation systems. These can be adjustments to the speed limit, temporary roadworks, repeated closures of a road for school zones, adding new roads, changing street names, and so on.
- In the United States, several states, through their Department of Transportation, work with providers of digital road networks to keep them up to date[26]. In practice, a Department of Transportation employee is in close contact with the various map providers to report changes (via e-mail, via an API, or via other information channels that are picked up directly by the private parties, for example, a Twitter feed).

Smooth cooperation to keep digital road networks up to date is important for both public and private parties: cities and towns can avoid undesirable behaviour of drivers with navigation systems, and providers of navigation systems can offer a product with correct information to their customers. At present, however, there is no final protocol for communication between the parties, and local authorities in particular do not know who to turn to with problems related to navigation systems. In practice, various providers of digital road networks work with volunteers to implement adjustments to the maps (e.g. Waze, OpenStreetMap, HERE).

It should be mentioned that in the case of chronic traffic jams and cut-through traffic, a municipality can make adjustments to the maximum speed or report a reduced speed to the map providers, but this will likely push the problem to parallel streets or other residential neighbourhoods. While this does not solve the problems associated with cut-through traffic, it can ease some forms of unwanted and unsafe routing. Cities should also consider reducing motorised traffic and traffic jams, eliminating bottlenecks, and investing in a modal shift to active transport modes (walking, cycling, e-bikes) or public transport.

In summary, there is no structural cooperation between private and public parties yet; however promising pilots are paving the way for future collaborations. Currently, the cooperation focuses primarily on keeping the digital road network up-to-date through the exchange of data between parties.

[23] https://www.nm-magazine.nl/artikelen/nieuwe-open-data-toepassing-in-car-meldingen-over-drukke-locaties/
[24] https://tn-its.eu/
[25] https://localyse.eu/improve-maps/
[26] https://transportationops.org/ondemand-learning/adventures-crowdsourcing-engaging-navigation-providers-edc5-webinar-series

2.3.6 Special case: Freight traffic

Navigation systems are not always adapted to the specific characteristics of heavy goods vehicles. Route planning for trucks must take into account the physical characteristics of the vehicle (width, height) and the road, as well as local access restrictions for trucks (tonnage, access times, etc.). All too often, lorries get stuck or cause serious nuisance to local residents when blindly following their navigation system.

For example, in Google Maps or Waze, some of the most widely used route planners, there is no option to select 'truck' as the means of transport. For light trucks and vans, this is usually not a problem, but for heavy trucks, it can greatly reduce the reliability of the suggested route.

The use of unsuitable navigation systems by heavy goods vehicles leads to problems for the logistics companies themselves, for local residents and for the road authorities.

- It is difficult for truck drivers to manoeuvre in a city centre or residential area. They lose time and money when they get stuck in traffic (congestion) or on a one-way street. Roads that are not suitable for a large number of trucks become congested, leading to further time losses.
- For local residents, who have seen the number of heavy trucks in their street increase, this has a significant impact on road safety, it leads to more noise pollution and higher emissions, but also vibrations and longer traffic jams. The liveability of village centres and residential areas is reduced and the health of the people living in the neighbourhood suffers.
- For the road authority, more heavy traffic on roads that are not designed for it means that the road surface will wear out more quickly and incur higher costs in the medium term. Local authorities regularly receive complaints from residents about the liveability of their neighbourhood or village.

There are, however, navigation systems specifically for freight traffic[27]. These systems usually take into account the type of vehicle, size, weight, load and speed. As with passenger cars, there are built-in systems, nomadic systems, and smartphone apps. Embedded systems are often part of an integrated fleet management system that allows transport planners to remotely monitor vehicles or communicate with the driver. Some systems provide real-time traffic information, often for a fee. In practice, truck drivers sometimes use two systems: a static system specifically for trucks, combined with a (free) app such as Waze that can warn of incidents and suggest an alternative route. Waze, however, does not offer specific support for trucks, and then problems, as indicated above, can occur.

A comparison in the Netherlands of the driving parameters of trucks without and with a navigation system showed a higher average speed (+ 5.1 km/h) and a shorter distance (-2.7 km per trip) for trucks equipped with a navigation system (Arentze et al., 2012). Also striking was the reduction in the use of local roads and motorways, and an increase in the use of regional roads (Arentze et al., 2012). Trucks also regularly deviate from a route suggested by a navigation system. For drivers of heavy trucks, the accessibility of a route is of the utmost importance; for lighter trucks, the speed of the route is a major consideration (Arentze et al., 2012).

[27] Examples are TomTom GO Professional, Garmin, Sygic Truck Navigation app.

Insights, intermediate conclusions, knowledge gaps

The legislation on speed camera warning systems differs by country. The use of radar detectors and radar jammers that actively detect police signals is prohibited in almost all countries. Other systems are allowed in most countries, including Belgium, but sometimes with limitations. For example, in France, navigation systems and apps cannot indicate the exact location of a speed camera, but they can indicate a zone with an increased risk for speed cameras. Speed camera warning systems cannot be used in Germany, however, enforcement is difficult and there are grey zones in the law. For international travellers, it's not easy to know local regulations. In France, the law was changed in 2021 to include certain other police roadside checks, like for alcohol or drugs, or in the framework of a criminal investigation.

A key question is whether there is an impact of different legislations on speed behaviour or crash risk near fixed and mobile speed cameras. Comparing countries with different legislations would be an interesting approach to answer this question.

Nowadays, speed camera warnings are often integrated into navigation systems. These devices or smartphone apps also warn of other dangers on the road, like road works, rail crossings, dangerous curves, or nearby schools. Several countries receive regular complaints about cut-through traffic on local roads induced by navigation systems. In none of the countries, however, there have been legal actions, for example by imposing restrictions on the routing algorithm of navigation system providers.

There are few numbers about the ownership and use of speed camera warning systems in Belgian drivers. This holds for navigation systems, and especially navigation apps. It would be useful to gain insight into the attitudes of drivers concerning speed in relation to using certain systems, and to investigate public support for adapting the legislation on speed camera warning systems. This will be investigated in chapter 3.

More research questions on navigation systems could be defined, like the safety impact of different types of alerts, or the amount of rat-running in freight traffic or delivery vans. However, chapters 4 and 5 will focus on the impact of speed camera warning systems on driven speed and safety.

3 User survey

3.1 Introduction

3.1.1 What do we know already? Evidence from Belgium

In 2016, the Belgian MONITOR study surveyed >8000 individuals on travel behaviour that included a question on ownership of radar detectors and navigation systems (FOD Mobiliteit en Vervoer, 2016). About 9% of the respondents indicated that their vehicle was equipped with a radar detector (Brussels 13%; Flanders 6%; Wallonia 14%). 73% of the car drivers owned a nomadic or integrated navigation system (Brussels 72%; Flanders 75%; Wallonia 71%). Drivers of vehicles equipped with a radar detector received on average 0.15 fines for speeding per 10,000 kilometres, compared to 0.13 in drivers without such a system. It should be stressed that 'radar detector' was not defined in detail for the respondent, and was referred to as 'radarverklikker' in Dutch and 'avertisseur de radars' in French which may have led to some misclassification.

Also in 2016, the Agence Wallonne pour la Sécurité Routière preformed a survey on attitudes related to speed in 1000 adults with a driving licence and living in Wallonia (Riguelle, 2016). They found that 16.4% of drivers regularly use a speed camera warning system, of which 10% pay for such a system. 5% of drivers use an illegal system (radar detector or radar jammer). Men are three times more likely than women to use a speed camera warning system; also younger age groups (18-34y compared to 55-69y) are more likely to use such systems. More than a quarter of all drivers with high annual mileages (>20,000 kilometre per year) uses a speed camera warning system, compared to ~10% of drivers with <10,000 kilometres per year.

The survey, 'Nationale verkeersonveiligheidsenquête / Enquête nationale d'insécurité routière', conducted annually in Belgium with 6000 respondents includes a question on support for a policy that would prohibit the use of radar detectors (Vias institute, 2021). In 2021, 43% of the respondents were in favour; 33% were against this; the others were indecisive. In Flanders, the number of people in favour of a ban was somewhat higher: 46%. One year earlier, in 2020, 38% of Belgians were in favour of a ban; in 2019 30% were in favour. It thus looks like the support for a ban on 'Systems that indicate police checks via other drivers (i.e. radar detectors)' is growing.

In 2022, Coyote Systems Benelux questioned over 22,000 of its users[28]. The aim was to assess and better understand the motivations for using a Coyote and the effects of its use. The survey showed that a Coyote device evolved from a simple speed camera warning system into a complete driver assistant with real-time information. 75% of the users reported that they drive slower since using a Coyote, and 90% of motorists reported to not accelerate after passing a speed camera.

3.1.2 Recent developments

Increasing amounts of route information have become available in recent years. Notably, real-time info on traffic jams or mobile speed cameras can now reach the driver along his way. While this brings new opportunities to drivers, private companies, and road authorities, these developments may also severely impact travel behaviour and traffic safety negatively.

Radar jammers and detectors are illegal in Belgium, moreover, nowadays the radar (or lidar) signal can be disturbed by other in-car safety systems, making radar jammers and detectors less attractive and less reliable as speed camera locator devices. Many integrated and nomadic navigation systems warn for fixed speed cameras and red-light cameras already for several years, but mobile speed cameras could not be detected with these systems and you could still be caught while speeding. Popular smartphone apps with large user communities, such as Waze, Coyote or Flitsmeister, fill this gap and now also map community-reported mobile speed cameras. Because of the large and growing community, alerts for speed cameras are rather reliable, even for temporary mobile ones. While radar jammers and detectors could be quite costly, various navigation systems with speed camera warnings are now available at no cost.

[28] https://www.ccimag.be/2022/06/09/enquete-evaluation-de-limpact-du-coyote-sur-la-conduite-automobile/

These developments likely lead to a changed profile of users of speed camera warning systems. Where before notable speeders with many fines for speeding could benefit from buying a radar detector or jammer ("If you never exceed speed limits, why would you pay for a radar detector?"), many more drivers now receive information on speed camera locations. For many of the users, being alerted of speed cameras is not the main reason for using these smartphone apps – they use them for navigation and route planning, to get an estimate about the time of arrival, or to escape traffic jams. Though if you feel like being warned about all speed cameras, it may invite drivers to exceed speed limits at other locations.

Getting current travel information from a navigation system will also alter the usage. Before, navigation systems were mainly used for route planning and guidance when travelling to an unknown destination. Nowadays, navigation systems serve as integral safety systems, with real-time location-aware alerts for crashes, wrong-way drivers, dangerous curves, traffic jams, speed cameras, etc. Where there was 'bounded rationality' in route choice, the fastest route for you at that time now becomes within reach by avoiding traffic jams and delays, leading to selfish routing, and a suboptimal result for society. It is unclear, however, where we are at this point ("How many drivers always follow their optimal route?"), and to what extent cut-through traffic is a systematic societal problem.

3.1.3Research questions

The main objective of the survey is to *profile* owners and users of (1) speed camera warning systems, (2) navigation systems.

In this process, an answer is sought to several additional questions:

- What are the reasons for ownership/use; what is the frequency of use; which systems and functionalities are popular?
- How many are potential rat runners/diverters? How likely are drivers to follow cut-throughs suggested by navigation apps?
- Can the usage of different systems be related to attitudes on speed, cut-through traffic, safety, or to actual speed violations or crashes?
- What is the public support for a ban on speed camera warning systems? What type of policy do people prefer (total ban; indicative location rather than exact spot)? Will this improve safety?

3.2 Methods

To provide answers to the research questions, an online survey was developed, implemented and analysed.

A representative sample of 2000 adults (+17y) living in Belgium was targeted. Participants belonged to the panel of the polling agency iVOX – they govern an internal online research panel of 150,000 individuals in Belgium. A stratified random sample was drawn from this panel taking into account age and gender (interlaced); soft quotas were educational level and region (Brussels Capital Region, Flanders, Wallonia). Further inclusion criteria were defined as having a temporary or permanent driving licence for a car (permit B), and regularly driving a car or van (at least 1-3 days per month). The polling agency uses an incentives scheme in which respondents to the questionnaire receive points that can eventually be exchanged for gifts.

Respondents that do not own a navigation system, or do not use speed camera warnings were included in the survey. Their information is important to derive penetration rates of these systems in regular drivers and to gain insights into the characteristics of users and non-users. For non-users, the irrelevant questions were skipped automatically in the online questionnaire.

Professional drivers (road transport of passengers or goods) were asked to complete the questionnaire as if they were driving for their job. Although this group was anticipated to be relatively small – we did not oversample them or include recruitment quota – the analysis could provide some initial insights into how often and for what reasons these drivers use speed camera warning systems or navigation systems. All other regular drivers were asked to complete the survey for their car trips, even though they might be using a navigation system on their bicycles, motorbikes, etc.

The online survey was conducted in August and September 2021. During this time, habitual travel behaviour could be impacted by the COVID-19 pandemic with some restrictions in place. Therefore, respondents to the survey were instructed to think about their normal habitual behaviour, and if in doubt they could think about the period before the COVID-19 pandemic (i.e. a period without lockdowns or restrictions to contain the virus).

The questionnaire was made available in Dutch and French and could be completed in the preferred language of the respondent. The survey platform used a responsive web design with questionnaires that could be filled out across a wide range of devices (from mobile phones and tablets to desktop computers). To increase the quality of the data, questionnaires contained skip logic, instructive illustrations, different question types with constraints (e.g. ranges for numerical questions, multiple choice and Likert-scale questions, frequency of use questions), and randomization of items in grid questions. Initial cleaning was done by the polling agency (straight lining, completed too fast, etc.), and an additional screener question was added to identify false responses. Completing the questionnaire was anticipated to take about 15 minutes.

The content of the questionnaire was developed by Vias institute for the project. In view of comparability, the questionnaire was inspired by multiple previous surveys, in Belgium and abroad.

- (Riguelle, 2016): Survey from AWSR (Agence Wallonne pour la Sécurité Routière) among 1000 car drivers in Wallonia, Belgium, on attitudes toward speed. Attitudes on speed and speed limit violations were related to the use of a radar detector.
- (Schaap et al., 2017): Survey in the Netherlands among almost 4000 car drivers in 2014/2015. The survey focused on existing and new sources of travel information, including navigation systems, and how they are being used.
- (Guin et al., 2021): Survey in the framework of the STRIDE project in the USA with >500 respondents. They studied the usage of navigation apps and the potential of trip re-routing.

Research questions can be grouped according to two main topics: (1) speed camera warning systems, (2) navigation systems. Asking people for the number of crashes and speeding tickets, along with questions on the use of (il)legal speed camera warning systems, may be prone to biases in responses. To limit biases, several preventive actions were taken. Firstly, the questionnaire was framed as a study into navigation systems and apps; not mentioning speed camera warning systems in the title or introduction. Secondly, the order of questions was carefully considered: questions on speeding tickets were asked in the beginning, and a question on the usage of speed camera warning systems followed only later on. Thirdly, a social desirability scale question was included and was used to evaluate any remaining bias (Stober, 2001). Finally, questionnaire responses were anonymous: the identity of the respondent was not transferred to the data processor (and this was communicated as such to the respondent).

Given the above considerations, a multitude of variables was collected in the survey. The full questionnaire is available in Appendix 2: Questionnaire (Dutch) and Appendix 3: Questionnaire (French).

- **Socio-demographic information:** gender, year of birth, household income, education, postcode of residence & other frequent location, job, household composition, driving licence?
- **Stated travel behaviour:** frequency of transport mode use, mileage per year, professional driver, company car, frequency of traffic jams, frequency of use of different road categories
- **Ownership & usage of systems:** ownership and usage of smartphones (with navigation apps), speed camera warning systems and navigation systems, reasons for use, paid or free, with real-time info or static
- **Behaviour & attitudes:** speeding, fines for speeding and other traffic offences, crashes, attitudes on speed and speed cameras, attitudes on the safety of navigation systems, social desirability scale
- **Support for policy:** public support to ban speed camera warning systems, public support for legislation as used in other countries

Data analysis was conducted by Vias institute starting from the raw questionnaire data in R software, version 4.0.4 (R Core Team, 2021). All numbers presented in the report have been weighted to make the sample representative of the Belgian population unless stated otherwise. Sample weights were calculated with the variables diploma, age group, gender, and region, and had a maximum value of 3. Differences between groups were evaluated with the weighted Chi-square statistic from the R package 'weights'. The most important results and statistics are presented in this report – further analyses can be performed upon reasonable request.

3.3 Results & discussion

Results are presented in different sections, starting with a description of the survey sample. Next, results related to speed camera warning systems are presented, followed by an analysis of the results on navigation systems. Finally, professional drivers are discussed in a separate chapter.

3.3.1 Description of the sample

After the removal of participants with false responses and participants that were not eligible based on the initial screening questions, 2214 individuals successfully completed the full questionnaire. The characteristics of the sample are presented in Table 6.

Table 6 Participant characteristics (unweighted).

	Total (N=2214)
Gender	
Male	1082 (48.9%)
Female	1129 (51.0%)
Other	3 (0.1%)
Age group	
17-24 years	67 (3.0%)
25-34 years	321 (14.5%)
35-44 years	368 (16.6%)
45-54 years	558 (25.2%)
55-64 years	358 (16.2%)
Over 65 years	542 (24.5%)
Household	
Single, without children at home	465 (21.0%)
Single, with children at home	138 (6.2%)
Couple, without children at home	889 (40.2%)
Couple, with children at home	654 (29.5%)
Other	68 (3.1%)
Region	
Brussels	123 (5.6%)
Flanders	1411 (63.7%)
Wallonia	680 (30.7%)
Language	
Dutch	1413 (63.8%)
French	801 (36.2%)

	Total (N=2214)
Diploma	
Maximum secondary education	1113 (50.3%)
High school or university	1101 (49.7%)
Job	
Employee (clerk/officer)	1020 (46.1%)
Manual labourer	176 (7.9%)
Management	64 (2.9%)
Free profession	26 (1.2%)
Self-employed	61 (2.8%)
Entrepreneur	6 (0.3%)
No job	861 (38.9%)
Professional driver (road transport)	
Yes	52 (2.3%)
No	2162 (97.7%)
Income	
Less than 10,000 euro	43 (1.9%)
Between 10,000 and 25,000 euro	361 (16.3%)
Between 25,000 and 50,000 euro	772 (34.9%)
Between 50,000 and 75,000 euro	316 (14.3%)
Between 75,000 and 100,000 euro	93 (4.2%)
More than 100,000 euro	31 (1.4%)
No answer	598 (27.0%)
Frequency car driver	
Daily or almost daily	1295 (58.5%)
1-3 days per week	752 (34.0%)
1-3 days per month	167 (7.5%)

The Social Desirability Scale (SDS-17) developed by Stober was included in the questionnaire to assess the rate at which participants answered in a socially desirable and biased way (Stober, 2001). The SDS-17 is composed of 16 true–false items (item 17 on illegal drugs was removed). The scale has been validated extensively. With a weighted mean and standard deviation of 11.0 ± 2.8, the score is within the expected range with limited bias present. As a sensitivity analysis, the top 10% of respondents based on their SDS score were excluded, however, this did not meaningfully change the results (a high sum of SDS is thought of as giving socially more favourable answers; 'fake good'), therefore, the results from the full sample are presented.

3.3.2Speed camera warning systems & attitudes on speed

3.3.2.1 Ownership and use

In total, 37% of all drivers habitually use one or more systems to warn for speed cameras. Almost 29% of all drivers usually use a free smartphone application that warns of speed cameras during their trips; 7% use a paid smartphone application or device that warns of speed cameras (Figure 5). Illegal systems are less often used: 2.4% reported using a radar detector, and 0.6% uses a radar jammer. More drivers may own a speed camera warning system, however, if they only sporadically use it, this was not covered by this question. A built-in system is indirectly paid for by the driver, but this may not have been perceived in that way, so built-in systems may not have been fully included. 37% of all drivers habitually using a speed camera warning system is thus a conservative estimate.

Men are statistically significantly more likely to use any of the systems than women (Figure 6). The youngest age group is the most likely to use any system: 62% of drivers aged 17-24 years use a free system that warns about speed cameras; in the group over 65 years this is only 13%. Drivers with a company car are more often equipped with a speed camera warning system compared to drivers without a company car. In line with this: drivers with higher annual mileages have higher use of speed camera warning systems. All differences are statistically significant.

Compared to an earlier study from AWSR in 2016 (Riguelle, 2016), the share of Walloon drivers using at least one of the systems listed has increased considerably: from 23% to 39%. In Brussels, due to the younger population, especially the use of free smartphone apps is more popular compared to the other regions. Radar detectors and jammers are more often used in Wallonia: 3.7% use a radar detector and 1.2% a radar jammer. Some report the use of both a radar detector and jammer, resulting in 4.3% of the Walloon drivers using an illegal system – this is slightly lower than in the AWSR study of 2016 (5.0%). In the MONITOR survey in 2016, about 9% of the respondents indicated that their vehicle was equipped with a radar detector (Brussels 13%; Flanders 6%; Wallonia 14%). When compared to the numbers in the current study, it indeed looks like the different wording in both studies distorts the results.

Just over 10% of the participants regularly consult social media or online fora with locations of speed cameras. This behaviour is more frequent in Wallonia (16%; it was 11.3% in the AWSR study in 2016), compared to Flanders (7%) and Brussels (12%). Like the other systems, looking for speed camera locations on social media is more popular in younger age groups (27% in 17-24 years; 3% in +65 years). Drivers that pay for a speed camera warning system or drivers consulting social media before a trip probably more consciously use the warnings to evade speed cameras.

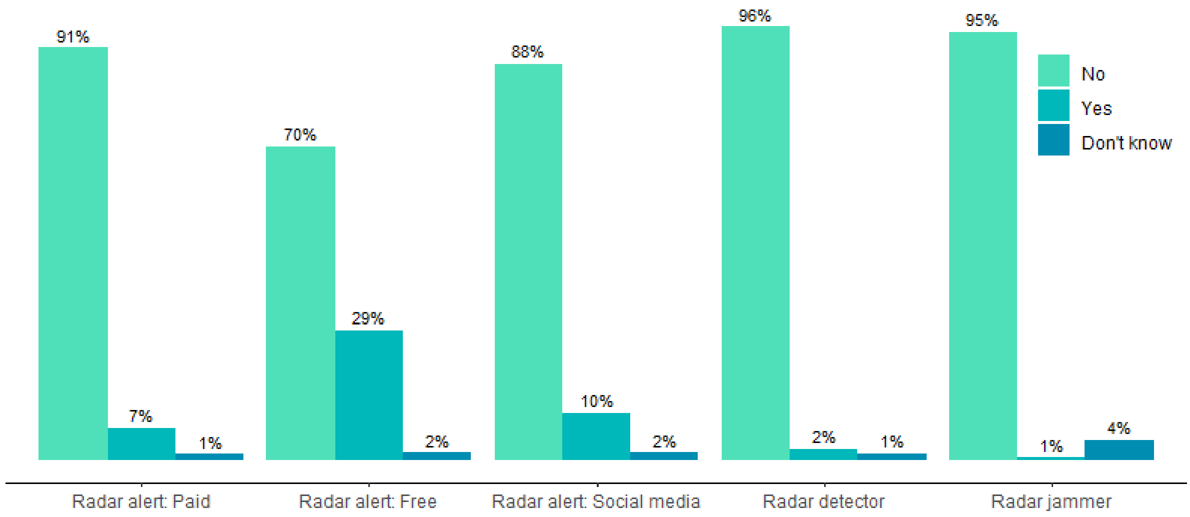


Figure 5 Use of speed camera warning systems in Belgium.

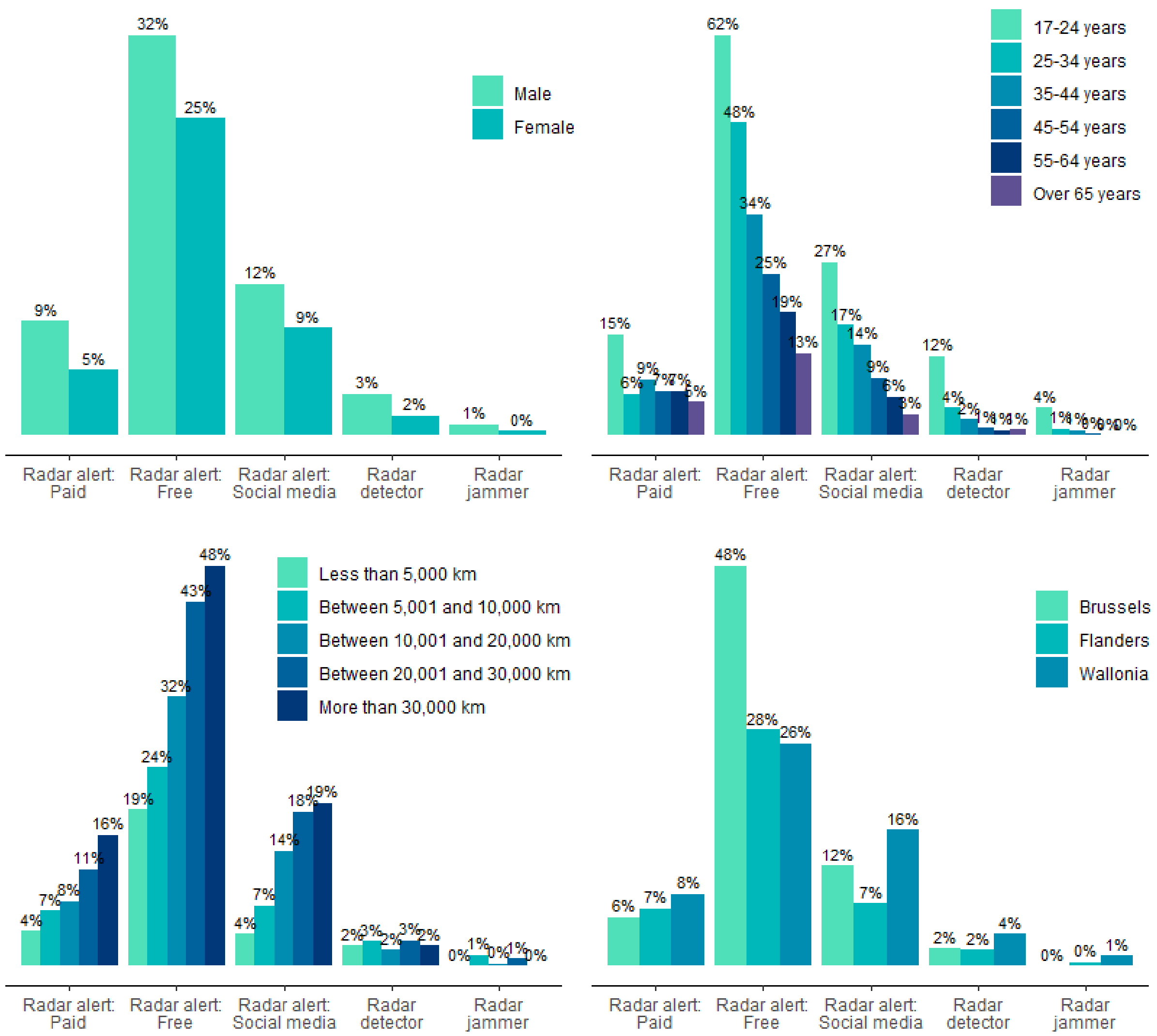


Figure 6 Use of speed camera warning systems in Belgium, divided by gender, age, annual mileage, and region of the residence.

3.3.2.2 Association with fines for speeding

Drivers with a warning system for speed cameras (free or paid system or application, warnings via social media, or radar detector or jammer) receive more speed fines than drivers without a warning system (Figure 7) – about the same numbers were reported in the Walloon study in 2016 (Riguelle, 2016). A part can be explained by the higher annual mileage of drivers with a speed camera warning system, however, when accounting for this, drivers with a warning system still have more fines per 10,000 kilometres driven than drivers without such a system. These results confirm earlier results from the MONITOR survey in Belgium (FOD Mobiliteit en Vervoer, 2016). The group with a paid radar alert has 0.43 speeding fines per 10,000 kilometres. The small subgroup of users of a radar detector or radar jammer has even higher values of 0.68 speeding fines per 10,000 kilometres.

This finding is counterintuitive because when approaching a speed camera and being warned about this, a driver could adjust his speed and avoid getting fined. This finding thus suggests that drivers with a speed camera warning system, more often than other drivers, violate the speed limit on roads on which they assume are no speed cameras present[29].

[29] Hidden and mobile speed cameras are often moved to other sites; when only just in place, it may not have been entered yet in apps like Waze or Flitsmeister. None of the systems can be considered 100% accurate and foolproof.

A similar trend can be observed when considering injury crashes: drivers with a speed camera warning system seem to report more injury crashes per 10,000 kilometres; however, given the small prevalence of crashes results have high uncertainty.

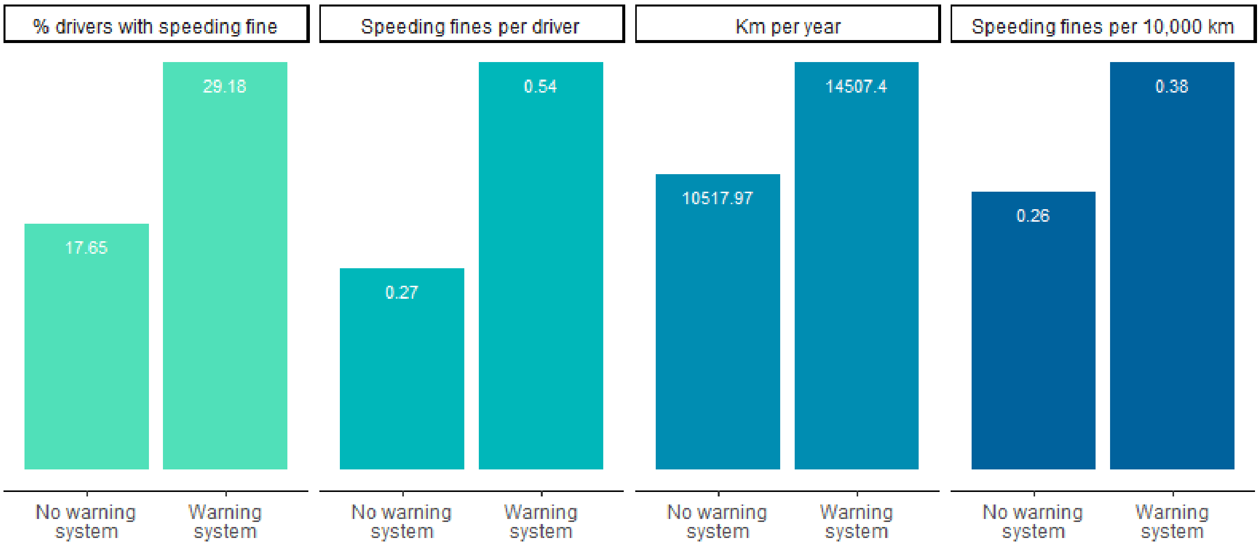


Figure 7 Percentage of drivers with a speeding fine in the last 12 months, the average number of speeding fines per driver per year, kilometres driver per year by the driver, and the average number of speeding fines per 10,000 kilometres travelled, for drivers with and without a speed camera warning system. Differences between groups are statistically significant.

3.3.2.3 Drivers' attitudes toward speed and speed cameras

Speed cameras are the main tool to enforce speed limits and contribute to road safety. A meta-analysis on the effect of speed cameras on crashes found that speed cameras reduce total crash numbers by about 20%; section control was found to have a greater crash-reducing effect (-30%) (Hoye, 2014). Further research also consistently shows that speed cameras are also an effective intervention in reducing road traffic casualties (Pilkington & Kinra, 2005).

In general, most drivers in the survey agree that speed cameras (fixed or mobile cameras, section control) are useful for road safety: only 12% disagrees with this statement. Drivers with a speed camera warning system are somewhat less convinced, but still, the majority agrees that speed cameras contribute to road safety (Figure 8). Compared to an earlier study in Wallonia in 2016 where only just over 50% agreed with this statement, drivers are now more convinced about the usefulness of speed cameras (Riguelle, 2016). It is also observed in other studies that over time the support for speed cameras grows (Retting et al., 2008). Opinions are more divided on the topic that speed cameras' only purpose is to raise money for the government: 31% agree, and 46% disagree. Users of speed camera warning systems believe more often that indeed the only purpose of speed cameras is to raise money (39% versus 26% of non-users). It is encouraging to note that also this number is lower than what has been observed previously: in 2016 51.5% of Walloon drivers agreed that the only purpose of speed cameras was raising money. Older drivers are more in favour of speed cameras and agree that they are useful for road safety; this is in line with earlier evidence (Retting et al., 2008).

Users of speed camera warning systems have somewhat less strict opinions about speed in general compared to non-users: 26% compared to 19% agree that it is safe to pass the speed limit when a road is deserted; 55% compared to 48% do not agree that there should be more 30 km/h zones in city centres. This confirms the hypothesis that indeed drivers with a speed camera warning system tend to speed more often in general and show a more risky driving behaviour. On average, male drivers agree more often than women with the statement "If a road is deserted, it is safe to exceed the speed limit" (25% compared to 18%). Older age groups are more in favour of 30 km/h zones than younger drivers.

On the question of whether changing driving speed when late for an appointment, 42% reported driving faster, and 57% reported no change. Of drivers with a speed camera warning system, 51% drive faster than usual.

No major differences were observed between regions.

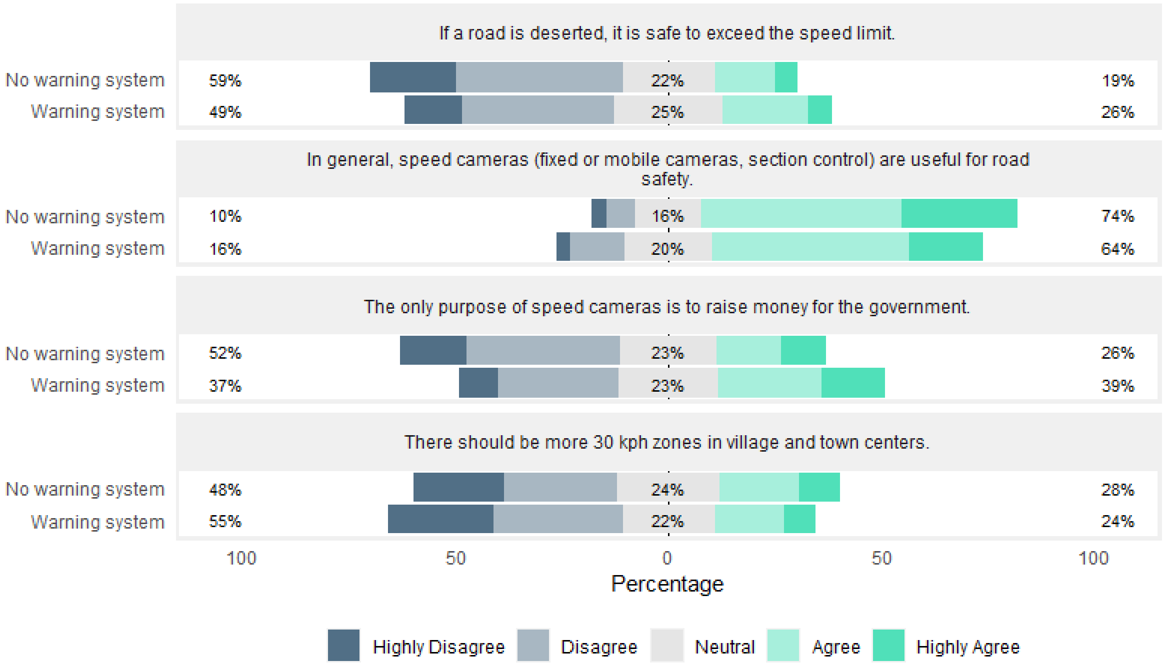


Figure 8 Drivers' attitudes toward speed and speed cameras for drivers with and without a speed camera warning system.

3.3.2.4 Self-reported speed near speed cameras

Research in the United States has shown that the presence of a speed camera warning system in a vehicle contributes to non-compliance with speed limits: 58% of radar detector users said they drove faster than they would without a radar detector and 75% of the users said that the radar detector saved them from at least one speeding ticket (Rudin-Brown & Cornelissen, 2012). In the current survey, 14% of all drivers reported driving faster when they know for sure that there is no speed camera nearby; in drivers with a speed camera warning system, this was 21% (Figure 9). This percentage is even higher in drivers with a warning system that received a speeding fine in the last year (28%) – It seems that having received a speeding fine was not enough to change speed behaviour. More drivers lower their speed when they see an announcement of a speed camera, than when they actually see the speed camera. This difference is more pronounced in users of a speed camera warning system. This seems to suggest that drivers with a speed camera warning system reduce speed right at the moment when they get the alert, rather than looking for the actual speed camera and lowering speed later on. The majority of drivers does not, or does not have to, change speed.

A large majority of drivers agree that speed cameras cause sudden braking and rapid acceleration. Users of speed camera warning systems, likely from their own experience, agree even more than non-users (75% compared to 66%). So-called kangaroo driving near speed cameras has been observed before, in Belgium and abroad. Observations on two motorways in Belgium showed that speeds decreased on average by 6.4 km/h near camera locations; also the odds of drivers exceeding the speed limit of 120 km/h decreased significantly by 80% (De Pauw et al., 2014). However, further upstream and downstream of the speed cameras the speed hardly changed, suggesting abrupt braking and acceleration close to the camera (De Pauw et al., 2014). It is unclear to what extent these abrupt speed changes increase the risk of crashes: in a meta-analysis, no adverse effects on crashes were found (Hoye, 2014).

Users of radar detectors in Australia and the UK believe that they are safer drivers when using a speed camera warning system as they are more aware of speed limits (Rudin-Brown & Cornelissen, 2012). However, the researchers also state that non-users are naturally more aware of their speed than users. Moreover, it is hypothesized that the latter group is aware of their own speed on all roads, while users of speed camera warning systems are only confronted with their speed when there is a speed camera, and not on other stretches of the road network.

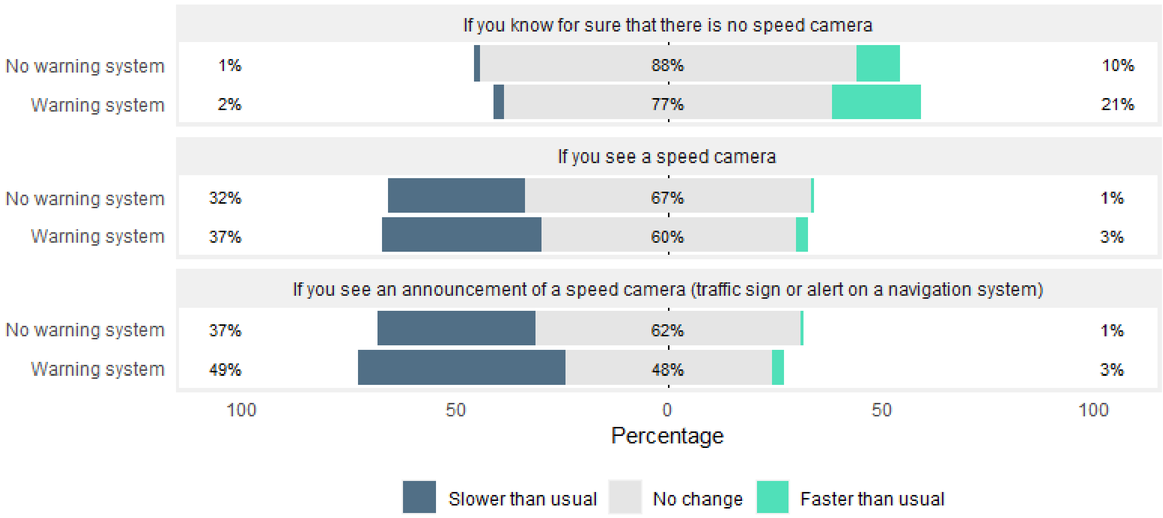


Figure 9 Intention to drive slower or faster or not change the usual behaviour under certain circumstances for drivers with and without a speed camera warning system.

3.3.2.5 Support for policies

Firstly, 40% of Belgian drivers agree that speed camera warning systems in their current form (i.e. pointing to the exact location of a speed camera) harm road safety. The share is significantly higher in non-users (51%) than in current users (23%) of those systems (Figure 10).

Drivers do not agree on whether speed camera warning systems in their current form should be banned: 40% disagree, 36% agree, and 25% are neutral. The majority of current users do not favour a ban, while non-users are rather positive about a ban. Older age groups are significantly more in favour of a ban (over 65 years: 49% agree; 17-24 years: 21% agree).

In contrast, most drivers believe that it would be a good idea to announce a zone with a speed camera, rather than the exact location: 66% of all drivers agree. 75% of the current users of a speed camera warning system would be happy with such a system.

In France, it was recently announced that starting from November 2021 navigation systems and apps can no longer announce the location of police checks on alcohol, drugs, or car documents. The new law does not concern speed cameras. In our Belgian sample, 46% of the drivers agree with such an approach, but 33% disagree. Again, it is mainly the current users of such systems that oppose this statement.

There are no marked differences between genders, or in the three regions. Also, if a distinction is made between users of a free and a paid speed camera warning system, opinions are not very different. Overall, users of a paid system are somewhat more convinced about their opinion, so they more often 'Highly disagree', but in total the same share of drivers disagrees or agrees.

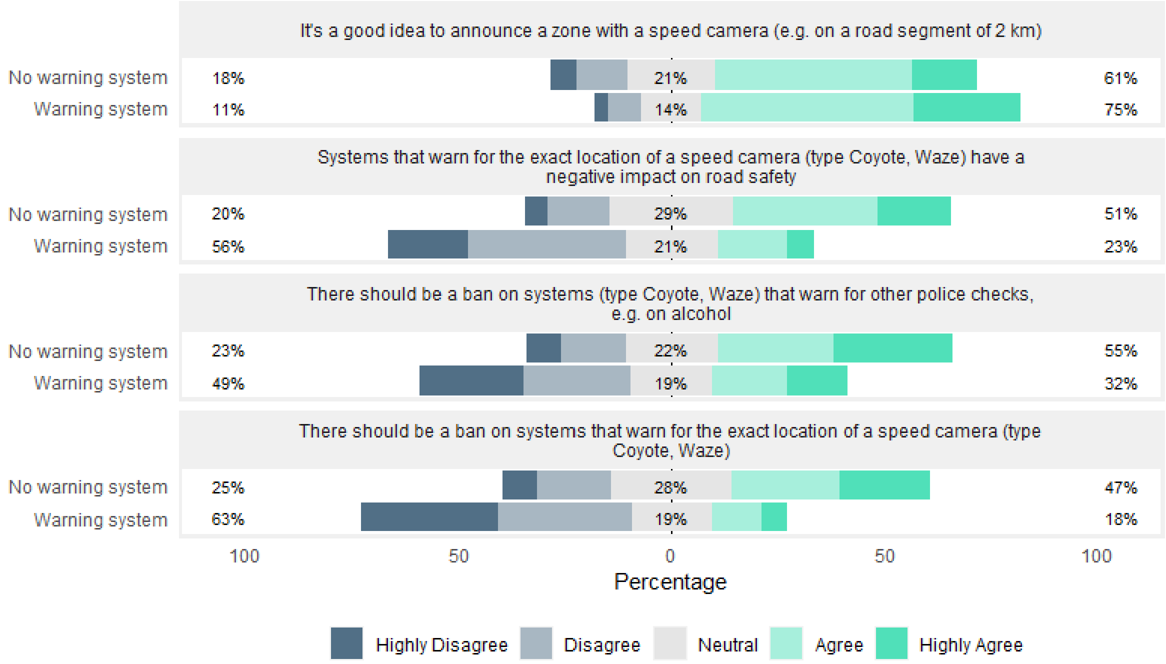


Figure 10 Drivers' support for policy measures for drivers with and without a speed camera warning system.

3.3.3Navigation systems

In the questionnaire, different types of navigation systems were defined. Firstly, a navigation system can be built into the dashboard of a vehicle – also called an integrated system. Secondly, a navigation system for use in a vehicle can come in the form of a portable device where route guidance is the main function (a separate non-integrated or nomadic system, also called a TomTom after the popular brand). Further, many smartphone/tablet navigation apps are available – clearly, navigation was originally not the main purpose of these devices. Lastly, there are also hybrid systems where a smartphone application can be displayed on the dashboard of the car (Apple CarPlay, Android Auto).

Figure 11 Types of navigation systems (from top left to bottom right): a built-in navigation system, a nomadic navigation system, a smartphone with a navigation application, and an app displayed on the dashboard (Apple CarPlay, Android Auto).

3.3.3.1 Ownership and use

Only 7.4% of all frequent drivers (driving at least 1 to 3 days per month) do not own a navigation system; in addition, 1% answered that they do not know. Those who do own a navigation system, often have access to multiple systems (Figure 12). Over 60% of all drivers with a navigation system own a built-in navigation system; 41% have access to an app; almost one out of four has a nomadic system; and almost 9% have access to a navigation app that can be displayed on the dashboard (e.g. Apple CarPlay, Android Auto). Ownership of any navigation system is higher than reported in the MONITOR survey from 2016 in Belgium where 73% of the drivers report owning a navigation system (FOD Mobiliteit en Vervoer, 2016). It should be noted however that smartphone apps for navigation were not explicitly mentioned in that study which may explain the different results. Men were statistically significantly more likely to own a navigation system, but men and women were equally likely to own a nomadic system or a navigation app. Drivers over 65 are least likely to own a navigation system, only for nomadic systems, they have the highest ownership rate. There are no significant differences in ownership between Flanders, Wallonia, and Brussels; except for higher ownership of navigation apps and lower ownership of nomadic systems in Brussels.

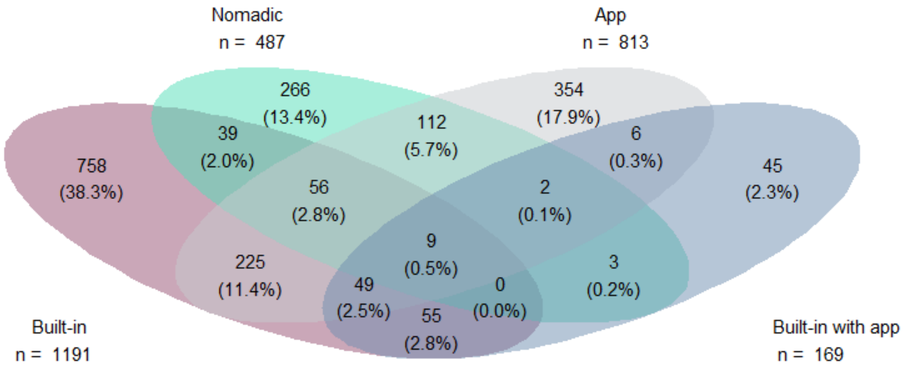


Figure 12 Ownership of different types of navigation systems.

In contrast to ownership of a navigation system, the use of different systems can be studied. A navigation system that is built-in into the vehicle is the most used type of system in Belgium (51%), followed by a smartphone navigation app (26%), a nomadic system (17%), and finally a navigation app that can be displayed on the dashboard of the vehicle (6%). For 83% of drivers that have a built-in navigation system in their vehicle, this is also the most used system, whereas a smartphone app for navigation is more often used as a secondary system.

22% of all drivers use a navigation system daily or almost daily. A quarter uses it on 1 to 3 days per week. This means that about half of the drivers that use a navigation system, use this system for 1 to 3 days per month or less. Men use a navigation system significantly more often. Also, younger drivers use a navigation system more often, while older drivers are more sporadic users. Regional differences in frequency of use are small, except for the larger share of drivers in Brussels that use a navigation system on 1 to 3 days per week. 41% of drivers with a company car use a navigation system daily or almost daily, and 75% of drivers with a company car use it at least 1 to 3 days per week. Similarly, drivers with high annual mileage use navigation systems more often on a daily basis.

About a third of the drivers have access to multiple types of navigation systems, and some others have access to multiple navigation apps. 21% of all drivers with a navigation system also declare to sometimes use multiple navigation systems or apps during the same trip. Especially the built-in systems are often combined with other systems. The prevalence of this behaviour is higher in younger drivers: 33% agree to at least sometimes use multiple navigation systems or apps during the same trip. There was no difference between genders. Respondents to the questionnaire further commented that sometimes the car passenger uses a different system than the driver during the same trip, or that they use a smartphone app when the built-in system has lost its way.

A built-in system is most popular when it comes to daily use (Figure 13). On a second place, Google Maps is used by many drivers, but less frequently – more drivers declare to use Google Maps on 1 to 3 days per month or even less. Worth mentioning is the smartphone app Waze[30]. It is the third most used system, and 39% of users, use it at least 1 to 3 days per week (unlike Google Maps where this share is only 26%). Waze is also the system that is most used on a daily basis in Brussels. The higher use of Waze in urban areas with dense motorized traffic is to be expected because one of the central themes in their branding is its usefulness to avoid traffic jams. Current statistics from Waze from several Belgium cities also point to higher usage and more incident reports during traffic peak hours[31]. Drivers sporadically mention other navigation systems, mostly apps, that were not listed beforehand, for instance HERE WeGo, Maps.me, ViaMichelin, and Sygic.

In the USA, 78% of respondents to a recent survey stated a smartphone as their main device for navigation; only 6% mentioned a built-in navigation system (Guin et al., 2021). As per our survey, Google Maps and Waze are the most popular navigation apps.

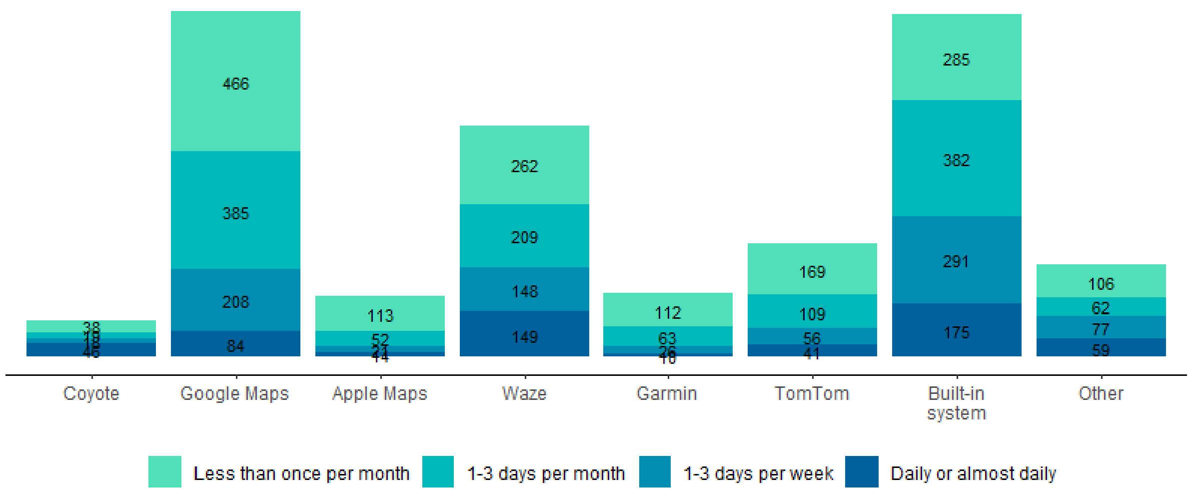


Figure 13 Absolute number of users of different navigation system brands by frequency of use (weighted sample). Mio, Flitsmeister, Wikango, and CamSam have smaller shares (in decreasing order) and are omitted from the figure. Wikango has ceased operations and support for its products in May 2021. Brands such as Coyote and TomTom are also frequently used as built-in systems; however, since most drivers cannot recall the brand of their built-in system, this was included under the tag 'Built-in system'.

3.3.3.2 Reasons for use

Initially, mainstream in-vehicle navigation systems were developed for route planning and guidance. This is currently also the primary reason for using a navigation system in Belgian drivers: 86% of the users of a navigation system mention route planning as the only or one of the reasons for use (Figure 14). About half of the users mention getting information on the road (speed limit, number of turning lanes, etc.) and getting an estimate of the time of arrival. A third of the users of a navigation system use it to avoid traffic jams. Getting alerts on the presence of speed cameras is mentioned by 15% of the drivers.

In the navigation system users that claim not to use their navigation system for route planning (for example, users that know their way around and rarely visit unknown places), most would use it to get information on the road (64%), to get an estimate of the time of arrival (46%), to avoid traffic jams (37%), to get safety alerts (23%), or to receive speed camera warnings (15%).

[30] The community-driven navigation app Waze was acquired by Google in 2013.
[31] https://www.wazebelgium.be/stat/city.php

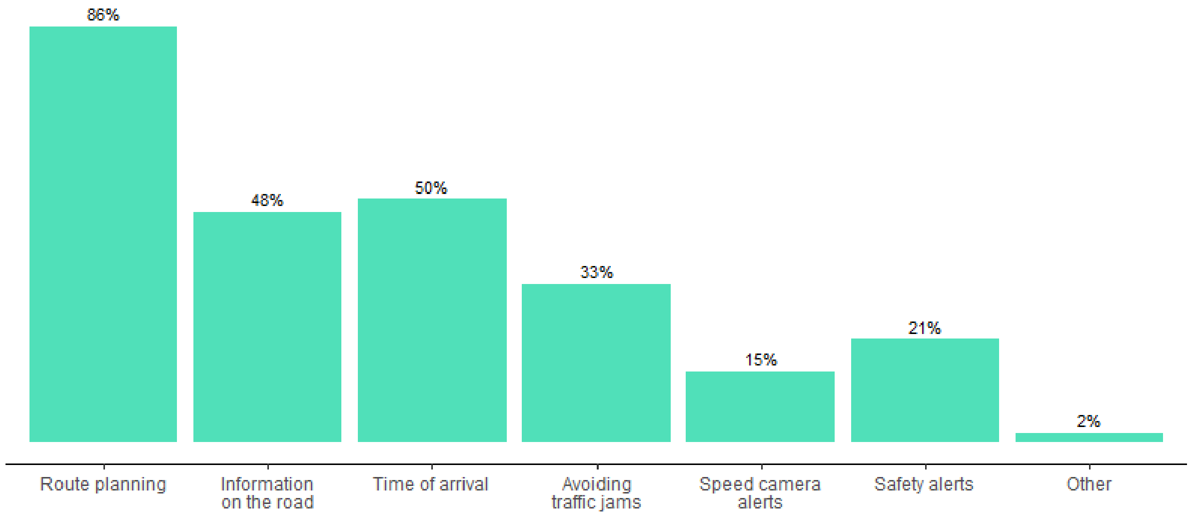


Figure 14 Reasons for using a navigation system.

Drivers use a navigation system especially when they visit locations that they do not often visit (Figure 15). 86% use it at least regularly for a day out (e.g. to an amusement park, to the coast), and 92% for a trip that is longer than 150 km. For daily habitual trips, to go to work or to run daily errands, use is much less frequent, although still 24% at least regularly use a navigation system to drive to work, of which 9% always has their navigation system switched on when driving to work. Younger drivers are somewhat more likely to use a navigation system for all trip purposes. There is only a very small difference between male and female drivers. Recent numbers from the USA indicate that almost half (46%) of the regular commute trips by car make use of navigation apps (Guin et al., 2021).

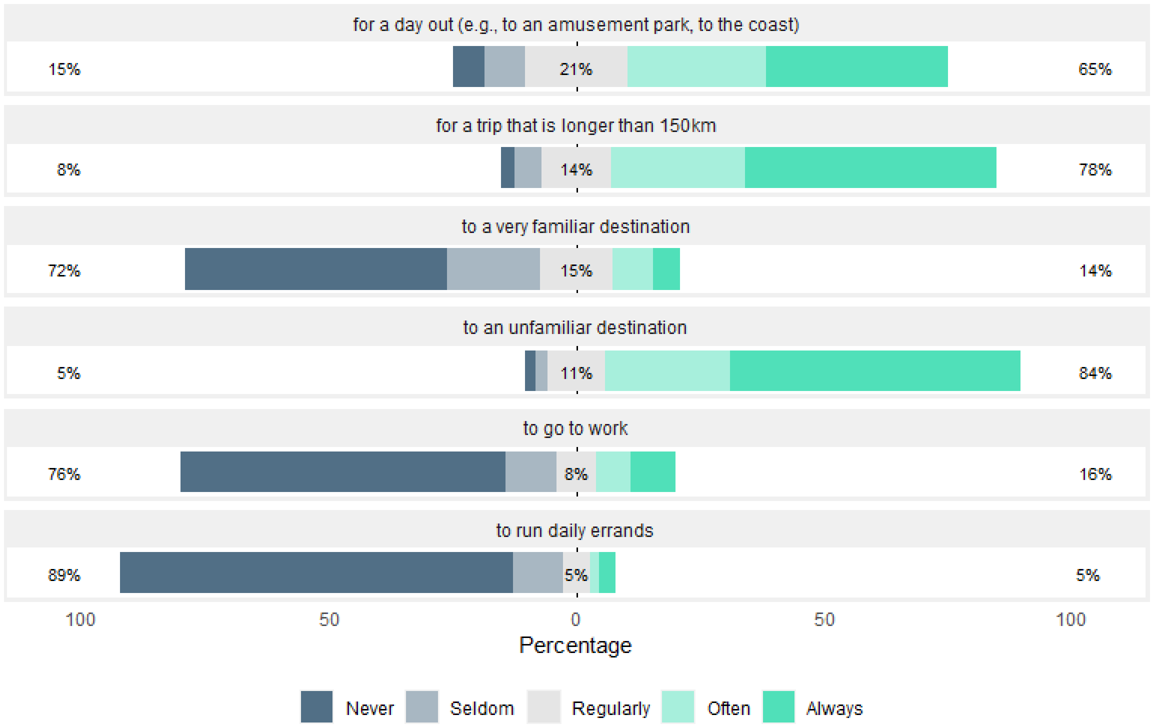


Figure 15 Frequency of using a navigation system for different types of trips.

3.3.3.3 Reliability and understandability

Reliability of travel information is highly valued by drivers, for many drivers, this is even more important than cost, comfort, or ease (Bates et al., 2001). 68% of the Belgian drivers agree that the information provided by a navigation system is reliable; 10% disagree (Figure 16). A previous study in the Netherlands found that mainly built-in navigation systems are valued as less reliable; a possible explanation is the less frequent updates of these systems (Schaap et al., 2017). In the current study, it is mainly the navigation apps that are thought to be more reliable, built-in systems and nomadic systems are valued as equally reliable. As a side note, too high reliance on a navigation system may lead to safety concerns. Drivers that blindly follow the route suggested by their navigation system might end up in streets that are too narrow for their vehicle, or drive straight into floods or insufficient roads.

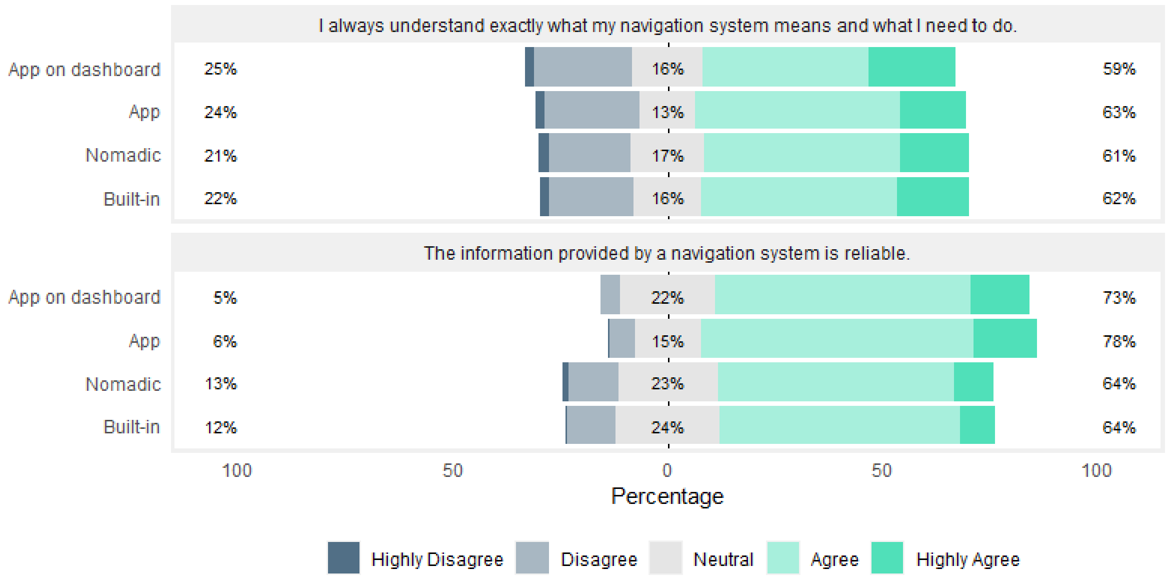


Figure 16 Understandability and perceived reliability of navigation systems for different types of navigation systems.

An important factor in determining the reliability of a navigation system is thus the frequency of system and map updates. Road infrastructure, and also navigation systems themselves, develop quite rapidly but drivers do not always update their systems at the same pace to get the latest maps. One out of five users of a navigation system does not know when their system was last updated; 18% report that it has never been updated or that it was more than three years ago (Figure 17). Most smartphone apps come with automatic updates, which should lead to more up-to-date maps and more reliable routing.

Reliability is likely to be perceived as higher with timely and current traffic information. Almost 60% of users of a navigation system have a system that provides real-time information, for instance, live information about traffic jams or traffic crashes. Those systems have to be connected to the internet or get traffic information through TMC (Traffic Message Channel). 61% of all built-in systems get real-time traffic information, 72% of all navigation apps (some smartphone apps offer offline maps), and 86% of the navigation apps that are shown on the dashboard. Nomadic navigation systems only show real-time traffic info in 27% of the users. A relatively high share of users (14%) could not answer this question and doesn't know whether their system gives real-time information or not. Younger drivers have more often access to real-time info, while older age groups are more often unaware of having access or not.

Next to perceived reliability, the understandability of a navigation system may also impact its use. 23% disagree with the statement "I always understand exactly what my navigation system means and what I need to do", 62% agree, and 15% neither agree nor disagree. The type of system has only a very minor impact on this rating (Figure 16). More women admit to not always understanding their navigation system as compared to male drivers (29% compared to 17%). There is no difference between age groups.

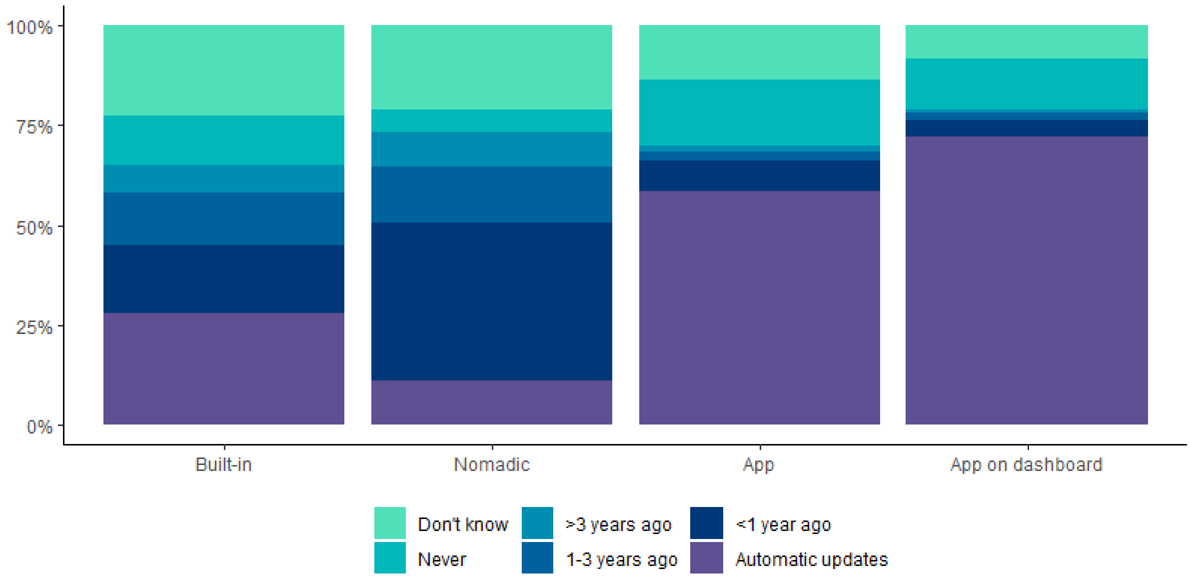


Figure 17 Self-reported frequency of updating a navigation system for different types of navigation systems.

A proxy variable for the revealed reliability and understandability of a navigation system is the extent to which drivers follow the route suggested by their system. Only 16% always follow the route recommended by the navigation system. A previous study from the Netherlands indicated that women are less likely to deviate from their route than male drivers (Schaap et al., 2017); however, this was not observed in the current study. Reasons for non-compliance are, most importantly, because drivers know that the suggested route is not faster (50% of navigation system users). This means that many drivers don't trust their system that is programmed, in most cases, to indicate the fastest route. Also, drivers often have a preference for their usual route and don't like to be deviated (37%). Other less important reasons include "Time gain is too little", "I don't want to drive through residential areas or along smaller roads", and "The suggested route is too difficult". Previous research also found that drivers have a higher tendency to divert to alternate routes if they are more familiar with the suggested route (Khoo & Asitha, 2016).

Since some respondents mention that the time benefit needs to be bigger in order to deviate from the original route, it was asked how much the time gain should be to convince the driver to divert. This appeared to be a difficult question, with one respondent out of five being unable to answer this. Having said that, 30% would require a time gain of more than 10 minutes to be convinced about taking a different route; only 7% would immediately follow a new route when this route appears to be 0 to 2 minutes faster. Compared to a recent study in the USA, Belgians appear to be more reluctant to deviate from a planned route, and they would require a larger time gain before accepting a new route while travelling (in the USA, 11% would require a time gain of >10 minutes; 26% follow a new route when it is 0 to 2 minutes faster) (Guin et al., 2021).

3.3.3.4 Potential for rat-running

An important topic in mobility research and liveability is the problem of cut-through traffic. Although cut-through traffic, or traffic avoiding incidents or traffic jams on main roads via smaller roads, exists already much longer than navigation systems, navigation systems definitely make it easier for drivers to divert.

Quantifying the amount of rat-running is difficult, and drivers will often not admit this socially non-desirable behaviour. Only 6% of all frequent drivers seem highly likely to be rat-runner (Figure 18). Some drivers may not even realise their unwanted behaviour – they blindly follow the guidance of the navigation system. However, up to 41% of all frequent drivers are potential rat-runners; they have all the tools: they receive real-time traffic information and use a navigation system when possibly facing traffic jams.

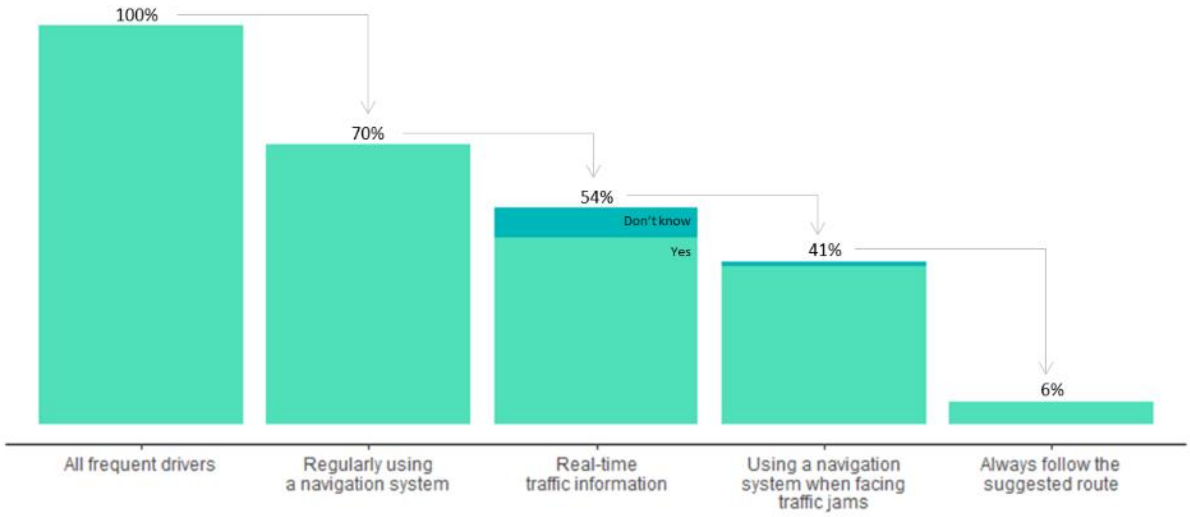


Figure 18 Derived potential for rat-running in Belgium.

3.3.3.5 Self-reported impact on safety

Experimental and observational studies and various simulation studies have studied the impact of navigation systems on road safety. However, results have been inconsistent and several factors may contribute to the overall effect.

An important factor is distraction. Only 11% of the users of a navigation system agree with the statement that the system distracts them, and 72% disagree (Figure 19). These numbers are very similar to a previous study in the Netherlands (Van Rooijen et al., 2008). Users of different types of navigation systems report the same levels of distraction, with just slightly lower levels of distraction with built-in systems. A potentially important factor in using a smartphone for navigation is apps, ads or messages popping up on the screen or beeping while driving, which could easily increase distraction – however, this was not visible in our self-reported results. Distraction may also originate from operating the navigation system, particularly entering the destination (Ziakopoulos et al., 2019). In a UK study, 2% of the respondents reported having had an accident while entering a new destination in a route guidance system in the last 5 years – it is one of the most dangerous behaviours that may lead to a crash (Lansdown, 2012). Of Belgian drivers, 77% state that they always enter their destination before they leave, whereas 15% disagree with this statement (Figure 19). Mainly users of a built-in system sometimes enter a new destination while travelling.

When driving on a road that is unknown to the driver, 50% of drivers state that they drive slower than usual, and the other half report no change in speed. When following the directions from a navigation system, 32% state that they drive slower than usual, and the others report no change. This suggests that, at least for some drivers, a navigation system can reduce the mental workload when driving in a new environment. Previous evidence is in line with this hypothesis: Van Rooijen et al. (Van Rooijen et al., 2008) found that subjects in an experimental study drove slightly faster with a navigation system than with conventional navigation aids (like a paper map) when navigating to an unknown location. Also, the observed and self-reported workload of the participants was lower when using a navigation system (Van Rooijen et al., 2008).

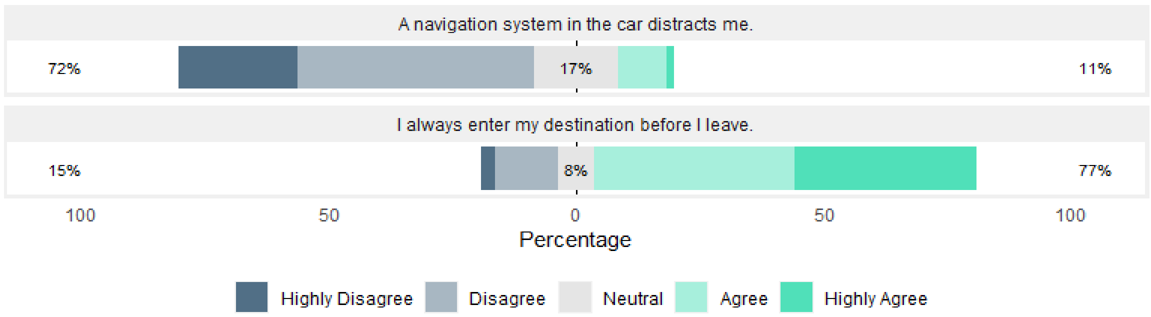


Figure 19 Distraction from a navigation system in Belgian drivers (self-reported).

Another, more indirect, factor that likely impacts traffic safety is the increase of traffic on local roads because of the use of navigation systems. Driving on local roads brings about more manoeuvres and there are more potential conflicts, resulting in a higher mental workload. Of Belgian drivers, 22% agree that since using a navigation system, they drive more often on local roads; 43% disagree (Figure 20). It is more often the users of navigation apps who confirm to drive more on local roads (28% of app users agree, and 18% of users of built-in systems agree). Daily highway users agree somewhat more that since using a navigation system, they drive more often on local roads (25% agree, compared to 20% of drivers that use a highway less than once per month). In the USA, 53% of drivers observed an increase in the time spent driving on residential roads since using a navigation system (Guin et al., 2021). A majority of 69% responded that traffic did not become busier because of drivers with navigation systems near where they live. No differences among gender and age groups were observed.

Additionally, answers about driving on local roads were compared for people living in different degrees of urbanization. The residential location was linked to the European DEGURBA[32] measure categorizing villages into three levels. Differences between drivers living in different degrees of urbanization were non-significant, however, some trends are visible. Drivers living in cities agree more that they drive more on local roads since using a navigation system. Also, with increasing levels of urbanization, more drivers agree that traffic near where they live has become busier because of drivers with navigation systems.

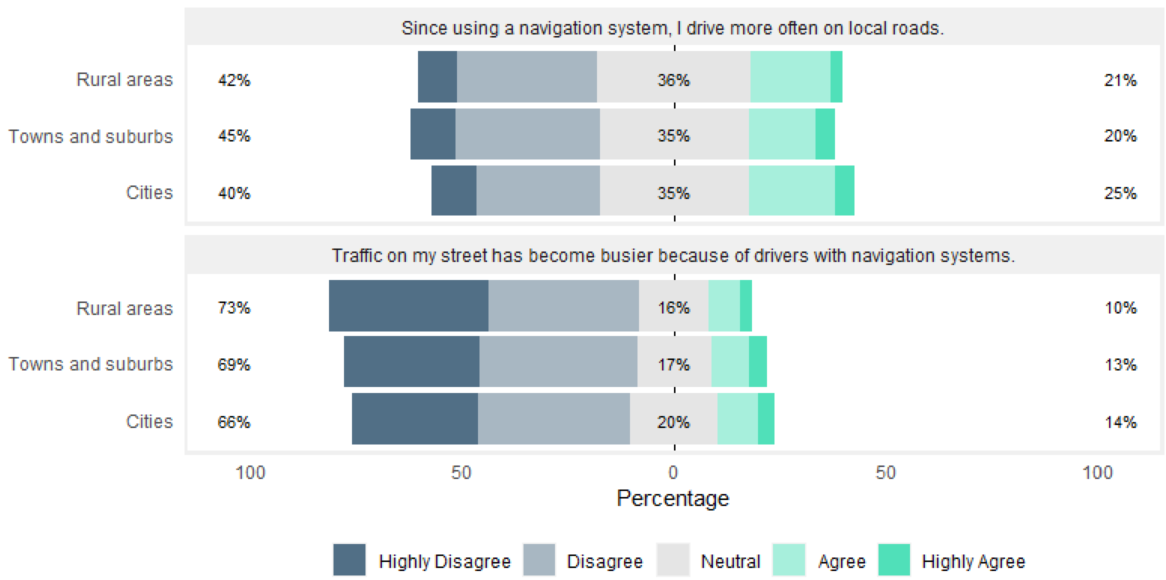


Figure 20 Opinion about the traffic on local roads because of navigation systems for drivers living in different degrees of urbanization (European DEGURBA classification).

32 https://ec.europa.eu/eurostat/web/degree-of-urbanisation/background

3.3.3.6 Community alerts

21% of the users of a navigation system state that they sometimes report incidents, traffic jams or speed camera locations via their navigation system, smartphone app, or on social media. As could be expected this share is higher for users of a smartphone app (34% of drivers with a smartphone app; 63% of drivers with a navigation app displayed on the dashboard of the vehicle). Men are somewhat more likely to report incidents, and also younger people are more inclined to do so. In Brussels, 38% of users of a navigation system sometimes create alerts. Of the daily Waze users, 74% state that they sometimes report incidents, traffic jams or speed camera locations.

3.3.3.7 Privacy

Geographical data from users' trajectories is highly sensitive data. Nevertheless, only 12% of the users of a navigation system are concerned about their privacy, 71% are not concerned, and the others are indecisive. Younger users are a little more concerned. There is no difference between users of different types of navigation systems.

The fact that many drivers are not really concerned about their privacy may stem from unawareness about the data kept by navigation system providers. Key questions include: "What data is kept and what is the spatial and temporal resolution?", "Who is the owner of the data?", "How long is the data kept?", "Who has access to the data?".

3.3.3.8 Drivers without a navigation system

As discussed before, only 7.4% of all regular drivers do not own a navigation system. These drivers are more likely to be female (10% compared to 5% in males), and are generally older (increasing shares in non-ownership with age; up to 13% non-owners in drivers 65 years and older). There is no statistically significant difference in non-ownership between regions.

Drivers that don't own or use a navigation system gather information about their route through other channels. The most popular channel is the internet (52%). To a lesser extent, drivers also consult signposts (36%), a paper map (27%), instructions from family, friends or colleagues (22%), the radio (19%), or dynamic route information panels (13%). 8% of the drivers without a navigation system never visit new or unknown places.

3.3.4 Professional drivers

A small share of drivers in the survey was a professional driver (road transport): 26 in passenger transport, and 26 in goods transport. These drivers were asked to complete the questionnaire as if travelling for their job, by bus, taxi, van or lorry. Professional drivers were excluded from the general analysis presented above. Given the small sample size, results should not be interpreted in absolute numbers, and rather serve as a first exploratory analysis. In the future, a dedicated survey towards professional drivers could be performed to confirm the results.

3.3.4.1 Speed camera warning systems

Professional drivers have higher use of speed camera warning systems than the general population of drivers: 66% of all professional drivers habitually use one or more speed camera warning system. 32% report using an illegal system, a radar detector or a radar jammer. Similarly, as in the private fleet, professional drivers with a speed camera warning system receive more speeding fines per 10,000 kilometres than non-users.

3.3.4.2 Navigation systems

15% report not having any navigation system in their vehicle; the others own at least one system. Whereas built-in systems are the most owned type of navigation system in the private fleet, in professional drivers nomadic systems are most prevalent, closely followed by built-in systems and navigation apps. Google Maps is the most popular brand, but also TomTom and Waze are often used. Professional drivers use their system more frequently than the general population: 49% use their navigation system on a daily or almost daily basis, and another 29% use it on 1 to 3 days per week. Half of the drivers sometimes use multiple navigation systems or apps during the same trip.

80% of professional drivers use a navigation system for route planning and guidance, 49% to get an estimate about the time of arrival, 45% to get information on the road, and 43% to help them avoid traffic jams. The majority, almost 7 professional drivers out of 10, have access to real-time traffic information. The two most important reasons for not following a suggested route are "I know that the suggested route is not faster" (57%), and "I don't want to drive through residential areas or along smaller roads" (34%). Interestingly, and much higher than in the general population of Belgian drivers, 41% use a navigation system to travel to a destination they know very well. About a third of the professional drivers agree that since using a navigation system, they drive more often on local roads, a third disagree, and another third neither agree nor disagree.

3.4 Conclusions

3.4.1Speed camera warning systems

- The majority of drivers do not use any speed camera warning system; 37% habitually use one or multiple systems. The prevalence of illegal systems is low, systems available at no cost are the most popular. The share of users is remarkably higher in younger drivers.
- Drivers with a speed camera warning system get more speeding tickets per 10,000 kilometres.
- Users of a speed camera warning system have less strict opinions about speed, for example, they are less in favour of 30 km/h zones, they more often agree that exceeding the speed limit is safe when a road is deserted, they more often than others drive faster when they know for sure that there is no speed camera nearby.
- An announcement for a speed camera triggers more drivers to reduce speed than the actual speed camera.
- A majority of non-users believe that speed camera warning systems in their current form harm road safety and should be banned; the majority of current users disagree. Conversely, most drivers favour the use of 'risk zones' where speed cameras could be present.

3.4.2Navigation systems

- Ownership of different types of navigation systems: built-in system > navigation app > nomadic system > navigation app connected to the built-in system (Android Auto, Apple CarPlay). 7.4% of regular drivers do not own a navigation system.
- 22% of owners use it (almost) daily, also to travel to familiar destinations (24% use it at least regularly to go to work).
- 1 in 3 drivers owns multiple types of navigation systems or multiple apps, and 21% state to sometimes use different systems or apps during the same trip. A built-in system then usually acts as the primary system, while navigation apps are more often used as a secondary system.
- Most perceive the information from a navigation system as reliable. Navigation apps are the most frequently updated and considered the most reliable.
- Where in the early days of navigation systems everyone was presented with the same static info, now almost 60% get location-aware and real-time traffic information.
- Most drivers do not blindly follow a new route and time gain is not the only factor.
- Not all drivers are as likely to be rat-runners pushed by their use of a navigation system: either because they do not have all the tools available (e.g. real-time traffic info) or because they are not willing to divert. Between 6% and 41% of regular drivers might sometimes use cut-through routes. Some may use cut-through routes unintentionally.
- Distraction is a real risk, however, the majority (72%) disagree that a navigation system distracts them while driving.

- 22% of drivers agree that they drive more on local roads since using a navigation system; this share is higher in users of navigation apps and in cities.
- 21% of drivers with a navigation system sometimes report incidents, traffic jams, or speed cameras. In daily Waze users, this number is 74%.
- 71% are not concerned about their privacy.

3.4.3 Professional drivers

Professional drivers have a higher use of speed camera warning systems (also illegal systems) and they more frequently use navigation systems.

4 Experimental study

4.1 Introduction

Little research has been done on the impact of speed camera alerts on speeds. Usually, producers from warning systems are not very keen on investigating this question since it might lead to the conclusion that speed camera warning systems are not beneficial for road safety. It is often hypothesized that drivers who receive alerts rather speed on roads without alerts: they use the system to avoid fines, but the absence of an alert may be a free pass to drive too fast. And speed contributes to the number and severity of crashes.

Police officers occasionally consult speed camera warning systems as well and notice that their hidden speed camera is discovered on apps such as Waze. Persistent speeders avoid a fine by using the app. The police sometimes respond to this by moving more quickly to another location to still spot the real speeders.

However, is there really an impact of these systems on the average speed and the number of speed violations? When speed camera warnings would be prohibited by the government, would this have a noticeable impact on speed and traffic safety?

In this chapter, we report on an analysis that associates speed camera alerts (for temporary speed checks) with speeds measured by the Belgian police at times with and without an active alert. Moreover, in a survey, it was checked whether the presence of speed camera alerts in those apps leads to a higher subjective chance of being caught while driving too fast.

The following research questions were defined:

- Are there more speed violations before an alert is entered in a speed camera warning system? Can we observe changes in speed over time (with and without an active Waze alert)?
- How long does it take for a mobile speed camera to be included in speed camera warning systems? How long does it take before it is removed? Do some remain undiscovered?
- What is the positional accuracy of the alerts?
- Do drivers experience a higher chance of being caught speeding when using speed camera warning systems?
- Is the awareness about one's speed different in drivers with speed camera warning systems compared to non-users? This may tell us something about their behaviour when speed camera warning systems would be banned (they may not act like other drivers).

4.2 Methods

To be able to answer the research questions, three data collection efforts were set up. First, speed data from the police registered during a mobile speed control were retrieved. Complementary to this, speed camera alerts from the app Waze were collected. Our survey (chapter 3) showed that Waze is the second most popular navigation app in Belgium, particularly for daily users who want to be warned about traffic jams and speed cameras in real-time. Thirdly, three short questions were asked via an online questionnaire in a representative sample of ~2000 drivers in Belgium.

4.2.1 Mobile speed control & Waze alerts

The exact speeds of all passing vehicles[33] were measured by the police at two locations in the province of Limburg during several speed enforcement sessions. Speeds were measured with a mobile speed camera rear-facing, i.e. a vehicle fitted with speed camera equipment which can park on the side of the road to monitor the speed of passing traffic driving away. In addition to the speed in kilometres per hour and the exact time

[33] It is estimated that 95 to 98% of all traffic is included when the speed camera is on the central median (as was the case in our study).

of each passing vehicle, an estimate of the type of vehicle (car or truck) and the lane (first or second lane) was also provided. The two locations were both on two-lane highways with a speed limit of 120 km/h in the Province of Limburg: E313 (Bilzen, direction of Antwerp) and E314 (Lummen, direction of the Netherlands). These sites were chosen to have a sufficiently high traffic intensity but without congestion, while also having as little as possible other factors impacting driving speed (e.g. intersections, road narrowing). This was necessary to observe the pure impact of the presence or absence of a Waze alert on speed, with few biases. Mobile speed enforcement is not announced in any other way to drivers, and the anonymous car is hidden (however it may be spotted last minute by drivers, but we assume that it is too late to significantly adjust speed on highways).

Alerts on speed cameras from the popular navigation app Waze were retrieved for the approximate location and time of the mobile speed control. It provides among others information about the start and end time of an alert, the geographical coordinates, and the number of 'Thumbs up' that an alert received. Waze users get a pop-up when driving by a location with an active alert. A user can enter a new alert, confirm an active alert with a 'Thumbs up' if the report has been useful, or push the 'Not there' icon to report that the speed camera is gone. An alert stays active or disappears depending on the number of drivers that tap each of those buttons. For each mobile speed control several individual alerts may be present, either at the same time (but in different locations – not all alerts are spatially accurate) or entered sequentially as an alert might have disappeared while the speed control was still there.

For the analysis, speed measurements were merged with the Waze alerts and broken down in time intervals with and without alerts. 'Thumbs up' were summed by session. Since the speed of each passing vehicle was measured, the sum of the number of vehicles is the traffic volume over a time period.

4.2.2 Online survey in drivers

Next to the long survey performed for chapter 3, we added three short questions to a monthly online mobility survey organized by Vias institute. The questions were added to the questionnaire in December 2021 and January 2022. Each questionnaire was answered by 1000 non-overlapping respondents (from which only car drivers got the following questions). The questions were translated into Dutch and French.

- How often do you use a device or application in your vehicle (as a driver) that alerts you to the presence of fixed and/or mobile speed cameras? (Waze, Coyote, TomTom, etc.)
- In your opinion (as a driver), how likely are you to be checked for speeding by the police during a typical drive (including checks by a police car with a camera, fixed cameras, mobile cameras, and section controls)?
- Please indicate to what extent the following statement applies to you: "I sometimes only realise afterwards that I was driving too fast."

4.3 Results & discussion

4.3.1 Mobile speed control & Waze alerts

4.3.1.1 Sample description: Mobile speed cameras

Valid data are available for 22 speed enforcement sessions with a mobile speed camera, 11 sessions on the E313 highway and 11 sessions on the E314 highway (Table 7). The average duration of one session is 2.96±1.10 hours (mean±sd). The shortest session lasted for 39 minutes, the longest session was 5 hours and 40 minutes. The first session included in our analysis was on March 2nd 2022 and the last one was on August 26th 2022.

The E314 highway generally had a higher traffic intensity, but the E313 had a higher share of trucks. Average traffic intensity was 982±137 vehicles per hour (two lanes combined) on the E313 and 1744±409 vehicles per hour (two lanes combined) on the E314, both well below the maximum capacity.

Table 7 Session characteristics.

Session	Location	Day	Start time	End time	Duration [minutes]	Total vehicles	Volume per hour
1	E313	Wednesday	02/03/2022 13:36	02/03/2022 15:56	139	2400	1032
2	E313	Monday	07/03/2022 15:29	07/03/2022 18:21	172	2928	1023
3	E313	Sunday	20/03/2022 16:02	20/03/2022 18:13	130	2153	991
4	E314	Wednesday	23/03/2022 07:07	23/03/2022 11:22	254	8192	1935
5	E313	Wednesday	23/03/2022 08:17	23/03/2022 11:55	218	3253	896
6	E314	Saturday	02/04/2022 07:15	02/04/2022 11:06	231	5158	1340
7	E314	Tuesday	12/04/2022 07:20	12/04/2022 09:40	139	4988	2153
8	E313	Wednesday	13/04/2022 07:31	13/04/2022 10:39	187	2728	873
9	E313	Monday	18/04/2022 10:03	18/04/2022 13:12	188	3000	957
10	E314	Monday	18/04/2022 16:30	18/04/2022 19:41	190	4725	1489
11	E313	Wednesday	20/04/2022 16:16	20/04/2022 18:17	121	2389	1189
12	E314	Tuesday	03/05/2022 08:02	03/05/2022 10:06	123	4561	2221
13	E314	Friday	06/05/2022 07:00	06/05/2022 09:46	166	6229	2257
14	E314	Wednesday	11/05/2022 09:04	11/05/2022 11:20	136	4133	1826
15	E313	Saturday	14/05/2022 08:18	14/05/2022 10:57	158	2309	877
16	E314	Saturday	14/05/2022 08:21	14/05/2022 12:39	257	6668	1556
17	E313	Saturday	14/05/2022 11:04	14/05/2022 12:33	89	1067	721
18	E313	Tuesday	17/05/2022 15:15	17/05/2022 18:00	165	3203	1165
19	E314	Sunday	29/05/2022 07:08	29/05/2022 11:26	258	4071	947
20	E313	Tuesday	31/05/2022 17:32	31/05/2022 18:12	39	707	1074
21	E314	Saturday	11/06/2022 06:51	11/06/2022 12:31	340	8701	1536
22	E314	Friday	26/08/2022 08:15	26/08/2022 11:38	202	6471	1922

4.3.1.2 Characteristics of the Waze speed camera alerts

A mobile speed camera deployment session got on average 267±211 'Thumbs up' (all individual alerts linked to the same session combined). All sessions were discovered by Waze users at some point.

How long does it take before a mobile speed enforcement session is entered in Waze?

- On the E314: The speed camera was always spotted before the actual speed measurements by the police started. Sometimes the Waze notification disappeared for a while, but it usually reappeared very quickly, within minutes.
- On the E313: Five sessions have not been spotted before the speed measurements by the police effectively started, six were already alerted in Waze.

It takes time to prepare and install a speed camera. Before the actual speed measurements start, the anonymous police car has been present on the spot for an estimated 10 to 15 minutes (estimate provided by the Wegpolitie Limburg).

Across all sessions, **93.7% of the time with actual speed measurements from the police, there is an active Waze alert** to notify other Waze users about the presence of a mobile speed camera. Only 6.3% of the time with a police check there is no active Waze alert. In our dataset, this translates into 82,531 vehicles that passed the mobile speed camera during an active Waze alert, and 7,503 vehicles that passed without an active alert.

In all cases, the Waze alert was still active after the speed measurements from the police were over. On average, the alert stayed active 19.6 minutes after the end of the speed measurements. Depending on the type of speed camera used, it takes 3 to 5 minutes or 5 to 7 minutes for the police to break down the camera and leave the location (estimate provided by the Wegpolitie Limburg).

The geographical accuracy of the Waze alerts was variable. The average distance from the location of a Waze alert to the real location of the speed camera was 177.6±167.2 metres in Bilzen and 171.0±139.4 metres in Lummen. Generally, alerts closer to the real location got more ‘Thumbs up’. Alerts were visible in both driving directions, this may have to do with the fact that the police car is in both cases parked on the central median and not on the side of the road (Figure 21).

Figure 21 Location of the mobile speed camera (red star) and the Waze alerts related to this camera (points coloured according to the number of ‘Thumbs up’ (low to medium to high = black to white to red)). The arrow indicates the direction of the speed camera. Left map: E313 Bilzen; right map: E314 Lummen.

4.3.1.3 Impact of a speed camera alert on speed

There is a difference in average speed at times with an active Waze alert versus times without an active alert. From an unpaired two-tailed t-test, it could be concluded that **at times with an active Waze alert, the average speed is significantly lower than at times without an active alert** ($p<0.05$, 95%CI [0.81; 1.43]).

- Without Waze alert: 111.6 km/h (cars only: 113.3 km/h)
- With Waze alert: 110.5 km/h (cars only: 112.6 km/h)

However, the presence of an alert may be related to the traffic intensity (more vehicles, a higher chance of a driver entering an alert, but also a higher chance of lower speeds due to the high traffic intensity). Therefore, a linear regression model was fitted that takes into account 1-minute traffic volumes. Indeed, 1-minute traffic volume is related to speed, however, also the presence of a Waze alert is a significant and independent predictor of measured speed. **When a Waze alert is active, the speed of vehicles (Waze users and non-users) lowers by 1.15 km/h** on those two sites on a highway in Limburg.

Until now, the focus was on average speed. However, it could be expected that it is mainly drivers driving above the speed limit that want to adjust their speed. Therefore, the distribution of the speeds of all vehicles was studied.

The plot in Figure 22 reveals a bimodal distribution with two peaks, one just below 90 km/h mainly from trucks, and one peak just below 120 km/h for cars. Vehicles travelling at speeds above the speed limit of 120 km/h are fewer at times with a Waze alert (indicated by the blue box in Figure 22). At the same time, more vehicles travel at speeds right below 120 km/h (pink box in Figure 22). In general, there is little change in driven speed in vehicles travelling between 100 and 115 km/h.

For trucks, the same phenomenon is visible, although at a smaller scale at speeds around 90 km/h (Figure 22). The police fines truck drivers that exceed the speed limit of 90 km/h; therefore, some trucks likely use

Waze to be alerted for speed cameras. It is unclear what caused the double peak at speeds below 90 km/h with an active Waze alert, mainly on the busier highway E314. We see several potential reasons, but they could not be confirmed with our data. A slightly slower-moving truck will have a line of fellow truck drivers trailing behind it due to the overtaking ban (traffic sign C39). Another possibility is that different speed regimes apply to double-trailer trucks and regular trucks in the EU, where in some countries and circumstances only 80 km/h is allowed. Apparently some transport companies configure the maximum speed of their trucks to 87 km/h instead of 90 km/h to avoid any potential speeding – this may also explain the double peak.

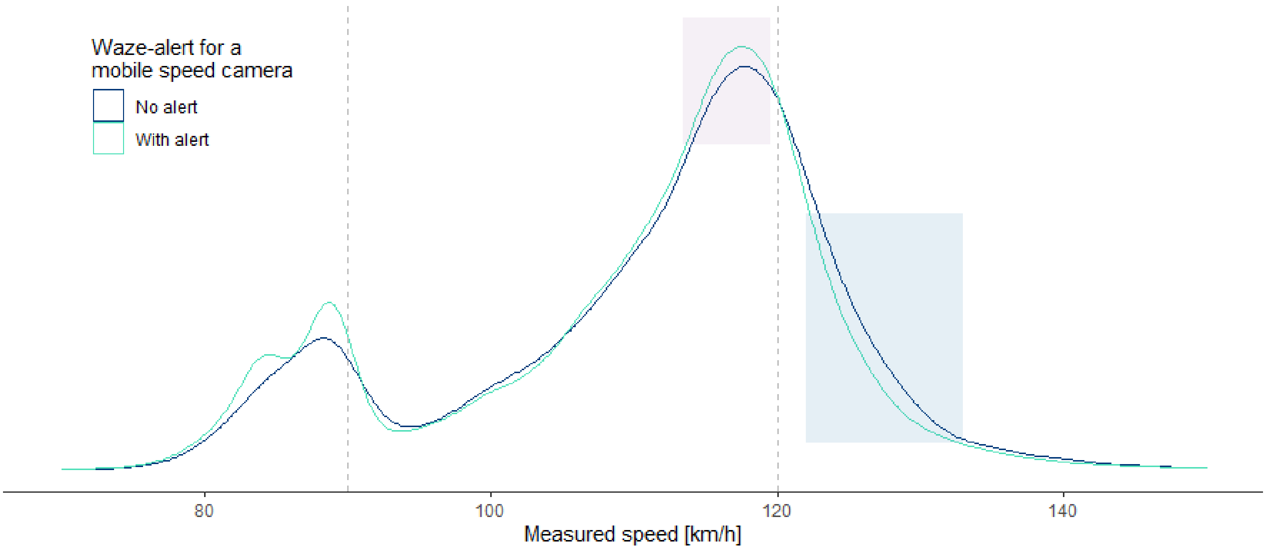


Figure 22 Speed distribution of 90,034 vehicles during 22 mobile speed enforcement sessions. The distribution is split up between times with a Waze alert for a speed camera and times without such notification.

Following the observation of a shift between cars travelling above 120 km/h to below 120 km/h, the number of speed violations was studied. In the full sample, 20.1% of the vehicles drove at a speed above 120 km/h. **At times without a Waze alert, 23.4% of the vehicles were speeding; at times with an active alert, 19.8% of the vehicles were above the speed limit**.

Details and results for each session separately can be found in Appendix 4: Impact of a speed camera alert on speed – results by session.

A limitation of the study design is that the speed measurements from the police cannot discriminate between drivers using the Waze application and non-users. Using speeds registered by Waze could be an alternative approach, but these speeds might be unreliable because they seem to be capped at the speed limit, and these speeds are spatially aggregated and not instantaneous speeds (as with speed cameras). We can assume that the same share of drivers uses the Waze app at times with an alert versus without an alert.

It would be interesting to estimate the speed adaptation in drivers with an alert versus the other drivers. Of course, we do not know which vehicles used a speed camera warning system from our experimental study. From Figure 22, it could be estimated that the speed of those car drivers who are aware of the speed camera lowers from 127 to 117 km/h (difference between the middle point of both rectangles); for trucks this difference is smaller. To the best of our knowledge, no similar studies were performed before. However, a study from Champness (Champness et al., 2005) evaluated the impact of a mobile visible speed camera and they concluded that the impact on the average speed was a reduction of 6 km/h (on a road with speed limit 100 km/h); the number of vehicles exceeding the speed limit fell from 53% to 16% immediately adjacent to the operational camera. After 1500m, the effect was completely gone, and when the speed camera itself was gone, the effect on speed was also immediately zero.

Only the impact of Waze alerts on speed was evaluated in this study, data from other speed camera warning systems were not available. However, our survey showed that the Waze app is very popular in Belgium. When an alert disappears, in most cases the alert reappears within minutes, also suggesting that this app is highly used. The number of 'Thumbs up' per session compared to the number of passing vehicles (from the speed measurement) gives a lower limit to the number of Waze users on the road, namely the road users that actively interact with the app. **From all the passing vehicles, 6.1±2.6% posted a 'Thumbs up' in Waze** (average over the 22 sessions), with a maximum of 11.2% for the session on Monday, April 18 during the evening peak hour. The lowest share of Waze users was on Saturday, June 11 in the morning. These numbers indicate that a good share of drivers on the sampled highways was distracted by Waze, either by entering the initial alert, or by confirming the presence of the speed camera. Before confirming the alert in the app, drivers likely also scan the roadway environment to spot the camera or police vehicle.

4.3.2 Online survey in drivers

Do drivers experience a higher chance of being caught speeding when using a speed camera warning system? Surely daily users of those systems get frequent reports of fixed and temporary speed enforcement actions by the police, more often than other drivers might notice them. Our results show no impact of the use of a speed camera warning system on the reported likeliness of being checked for speeding by the police during a typical drive (Figure 23). Maybe the high numbers of speeding fines in Belgium result in an already high subjective chance of being caught for speeding – being exposed to speed camera warnings through a navigation device or app does not add to that feeling.

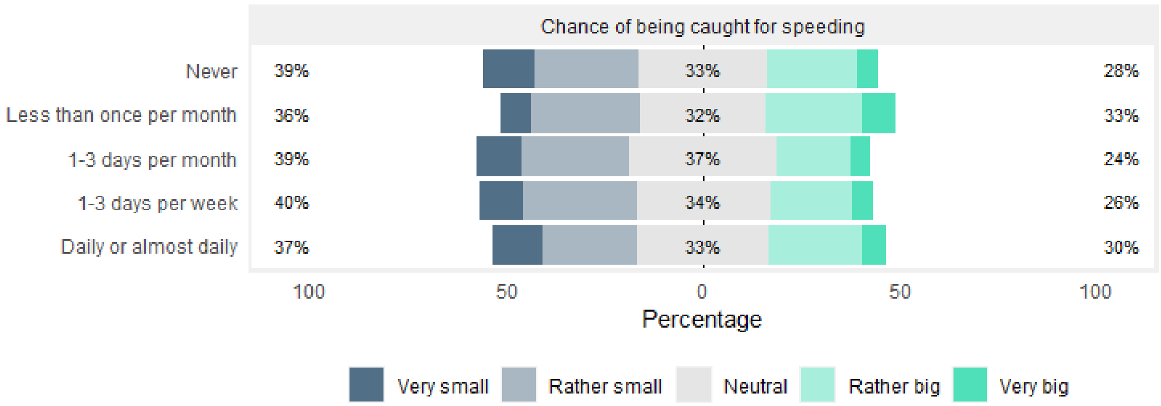


Figure 23 Frequency of using a speed camera warning system and reported likeliness of being checked for speeding by the police during a typical drive.

An additional analysis related the use of speed camera warning systems to awareness about one's speed. These systems often continuously present the speed limit on the screen, or at least when closing in on a speed camera. Contrary to what might be expected, frequent users of Coyote/Waze/etc. seem to be less aware of their speed (Figure 24). This trend is even more visible in daily users of speed camera warning systems. This implies that users of these systems might be more at risk of driving too fast (consciously or unconsciously). This may tell us something about their behaviour when speed camera warning systems would be banned: they may not act as current non-users.

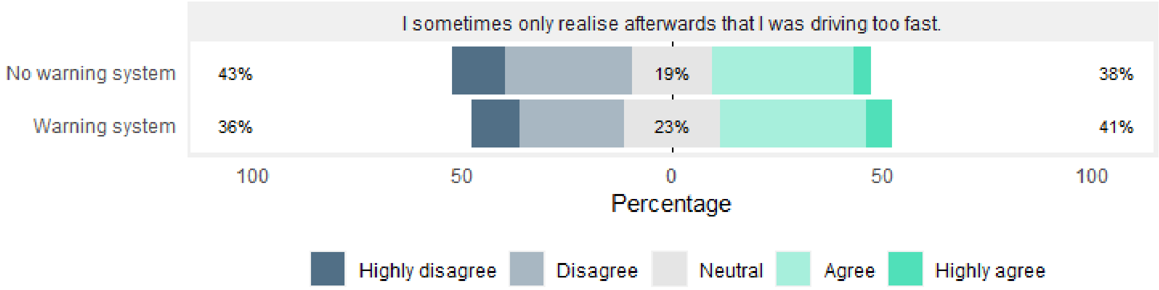


Figure 24 Drivers with and without a speed camera warning system and self-reported awareness of driving speed.

4.4 Conclusions

An important question remains: do warning systems have an impact on the speed driven outside the designated speed camera locations? Do drivers drive faster in those places (where there are no speed cameras) than a driver would if s/he did not have a speed camera warning system?

- There is no definite answer to this question because we did not measure speed outside the two locations with a temporary speed camera. Based on previous research on kangaroo jumps in the vicinity of speed cameras, one can expect the effect to be very local (De Pauw et al., 2014; Hoye, 2014).
- The speed of single drivers was not tracked over a longer distance. However, consciously tracking the speed of a driver while using Waze would likely have an impact on his driving behaviour. Retrieving this data from navigation system providers is extremely difficult because of privacy concerns.
- Our results do suggest that vehicles drive slower during an active alert (consistently across the two locations), approximately 1 km/h.

What if the legislation is adapted, e.g. what if no speed camera alerts would be allowed as in Germany? What do the results mean in this context?

- When no speed camera alerts could be broadcasted anymore, do former users then drive slower everywhere, or would they drive as fast as they do now at times without an alert?
- The short survey, reported in this chapter, shows that habitual users of a speed camera warning system are less aware of their speed and have a higher risk of speeding. From the first survey (reported in chapter 3), these drivers also appear to effectively get more fines for speeding. Likely, therefore, they will continue to drive (slightly) faster even without using such a system, they will just get more fines for their behaviour.

5 Big data study

5.1 Introduction

The legislation on speed camera warning systems differs between countries. Is there an impact of different legislations on speed behaviour near fixed speed cameras? As suggested earlier in this report, comparing countries with different legislations would be an interesting approach to answer this question.

Previous research has shown that the individual speed of vehicles with radar detectors (illegal device) decreased significantly when a speed camera was detected, while those of vehicles that were not equipped with radar detectors was not affected (Rudin-Brown & Cornelissen, 2012). After a few kilometres, though, the effect seems to diminish and the users are either back to their previous speed or to the speed of the traffic flow locally (Rudin-Brown & Cornelissen, 2012). This phenomenon is often referred to as kangaroo driving (braking and accelerating) (De Pauw et al., 2014; Hoye, 2014). When a speed camera is not discovered, no change in speed is expected.

The following research questions were defined:

- Do vehicles equipped with a speed camera warning system adjust their speed close by a speed camera? And do they drive faster further away from the camera?
- Do drivers with a speed camera warning system behave differently with respect to speed near a fixed speed camera in countries with different regulations on these warning systems? If they do, how do they behave differently? We compare three countries: Belgium (Warning system can indicate the exact location of a speed camera), France (Warning system can indicate a 'danger zone' with a possible speed camera), and Germany (Speed camera warning systems cannot be used by drivers).

5.2 Methods

A big data study was set up to answer these research questions: observational 'real-life' data from a large group of drivers is being studied. Therefore, driven speeds from Waze-users were collected nearby fixed speed cameras in three countries: Belgium, France and Germany.

5.2.1 Locations

In each of the three countries, Belgium, France and Germany, seven fixed speed cameras were selected (Figure 25). The neighbourhood of the speed camera needed to have as little elements as possible that may impact speed, e.g. intersections, steep sections, sharp curves (checked via aerial photography and street view pictures). With this in mind, the selection included only rural roads and highways. Speed limits on these roads differ between countries, however all three countries have roads with a speed limit of 70 km/h; on highways speed limits are 110, 120 and 130 km/h.

Environmental factors or road characteristics that might interfere with the driven speed were registered and included in the interpretation of the results. An example is the presence of a traffic sign that announces a speed camera and that is present on many of the sites on variable distances from the camera.

A detailed description of the 21 locations is provided in Appendix 5: Big data study: Speed camera locations.

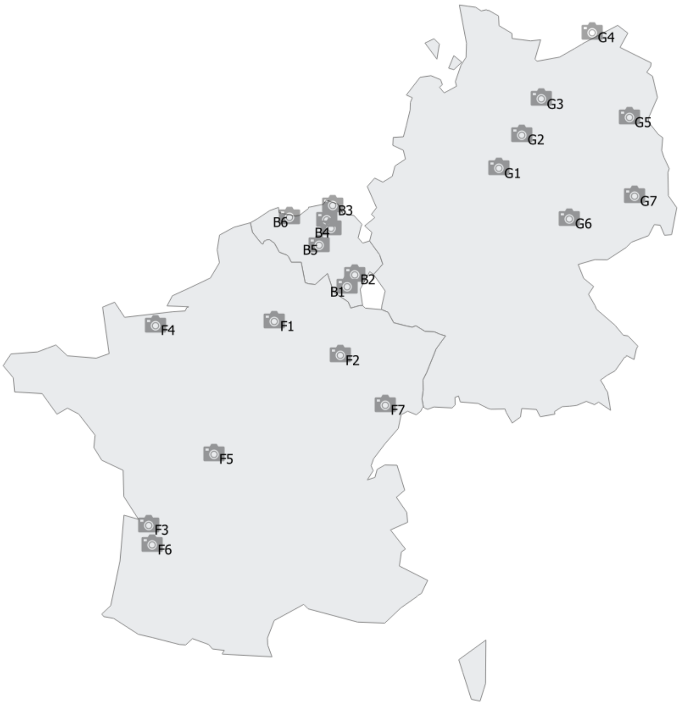


Figure 25 Locations of the fixed speed cameras studied in Belgium, France, and Germany. The number with the pin indicates the site name.

5.2.2Waze speed profiles

As one of the most popular apps in Belgium but also abroad, and an app that alerts drivers for fixed and mobile speed cameras, speed data from Waze nearby speed cameras would make a very good dataset to answer our research questions. Moreover, average speed data can be retrieved via the Waze for Cities program in real-time for the road sections of interest.

A trajectory from 2 kilometres before the speed camera to 2 kilometres after the speed camera along the same road was defined on rural roads, and 4 kilometres before and 4 kilometres after the speed camera for highway locations. This trajectory was split into segments bounded by waypoints or nodes from Waze. Waypoints usually correspond to intersections or changes in geometry. The average travel time (from all Waze users crossing the segment in a specific time interval) and the length of each segment were retrieved from Waze; the average segment speed could be calculated from this. The data was collected every 2 minutes in real-time for the month of April 2022[34], which we assume is representative of the longer term. Longitudinal speed profiles were constructed from this and speed behaviour close by and further away from the camera was studied in all 21 locations.

Theoretically and in ideal circumstances, it is expected that speed profiles in the three countries have distinct curves: a drop in average speed over a longer distance in France, a sudden drop in average speed and quick acceleration nearby the speed camera in Belgium, and no change in average speed in Germany (Figure 26). Of course, fixed speed cameras were probably in place for a longer time already and a certain proportion of drivers, Waze users or not, will already be familiar with their location and adapt their speed behaviour accordingly to avoid a fine.

Note: Despite the French legislation with risk zones rather than the exact location of a speed camera, which was under discussion at the time of the study, some apps never changed the way fixed speed cameras were announced, for example Flitsmeister (they always displayed exact locations, contrary to other systems that did adapt the way speed cameras were announced, like Coyote). Waze alerts about speed cameras in France in a similar way as a section control, but it seems like the camera is always right in the middle of the risk zone. Waze works in the same way in Germany as in Belgium (i.e. exact location), but drivers can be fined when speed camera alerts are active. Drivers in Germany should switch off the functionality (activated by default).

[34] Some data were missing for the 5th, 13th, 24th and 26th of April 2022.

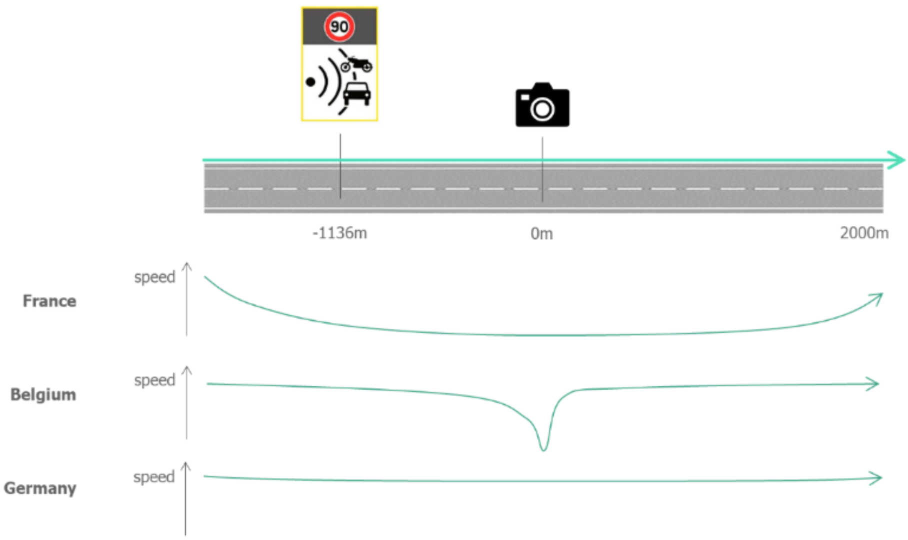


Figure 26 Theoretical speed profiles as expected in three countries in users of speed camera warning systems.

5.3 Results & discussion

Valid data were retrieved for all but one trajectory (Table 8). Fewer waypoints, and thus segments, were available for highway locations, despite the longer total length of the studied trajectories. Hence, for highways it was not possible to construct speed profiles with a sufficiently high spatial resolution.

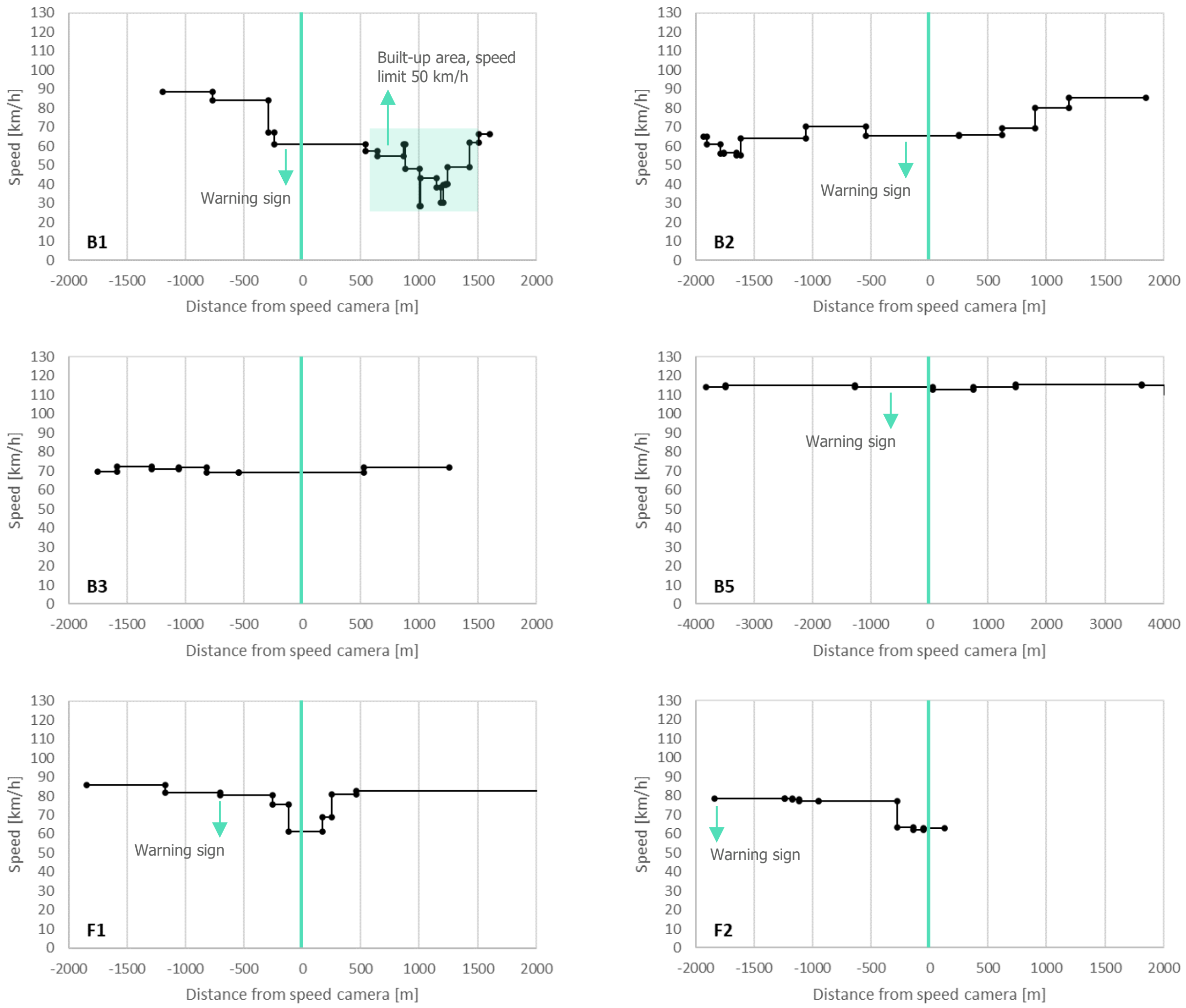
Table 8 Description of the 21 trajectories with a fixed speed camera in three countries.

Site name	Country	Highway / rural	Speed limit [km/h]	Average speed (April 2022)	# waypoints	Comments
B1	Belgium	Rural	70	66	19	
B2	Belgium	Rural	70	70	14	
B3	Belgium	Rural	70	71	9	
B4	Belgium	Highway	120	119	3	No speed profile
B5	Belgium	Highway	120	114	10	
B6	Belgium	Highway	120	111	4	No speed profile
B7	Belgium	Highway	120	114	5	No speed profile
F1	France	Rural	70	81	14	
F2	France	Rural	70	75	10	
F3	France	Rural	70	68	21	
F4	France	Highway	110	108	7	No speed profile
F5	France	Highway	130	119	5	No speed profile
F6	France	Highway	130	-	1	No speed profile
F7	France	Highway	130	119	6	No speed profile
G1	Germany	Rural	70	70	20	
G2	Germany	Rural	70	76	14	
G3	Germany	Rural	70	75	14	
G4	Germany	Rural	70	-	-	No data – technical issue during data collection
G5	Germany	Highway	120	121	3	No speed profile
G6	Germany	Highway	120	112	6	No speed profile
G7	Germany	Highway	120	118	5	No speed profile

The longitudinal speed profiles are presented in Figure 27. In total, 10 profiles could be constructed with a relatively high spatial resolution: 4 for Belgium, 3 for France and 3 for Germany. Nine speed profiles are for rural roads with a speed limit of 70 km/h, and only one speed profile for a highway could be made (site B5 in Belgium). Sudden drops in speed, not caused by the speed camera, are annotated where possible, e.g. a change in speed limit or the presence of an intersection. The location of a warning sign for a fixed speed camera is also indicated on the figures (when present), however, no direct effect of the sign could be identified. An earlier study in Belgium also found that an information sign leading to a speed camera has only little impact on the driven speed on motorways (-3% and -4%) (De Pauw et al., 2014).

In nearly all figures, a drop in speed right before the speed camera could be observed. In Belgium, the speed reduction is the smallest, but also the initial speed is lower (when drivers are not speeding, it is not necessary to lower speed near the camera) (Figure 28). In most cases, the speed increases again after the speed camera, i.e. kangaroo jumps (Figure 28).

Waze displays the exact location of a fixed speed camera in Belgium and a danger zone in France, so we could expect a difference in speed behaviour between Belgium and France. However, this does not seem to be the case and the drop in speed while nearing the speed camera starts at the same distance in France as in Belgium. In Germany, drivers are expected to switch off the functionality to alert for speed cameras, so we expect no big change in speed nearby speed cameras. In fact, also in Germany, kangaroo jumps are clearly visible, even though in-vehicle speed camera warning systems cannot be used by drivers (Figure 28). Presumably, drivers see the fixed speed camera on the side of the road and adjust their speed, especially those drivers that regularly pass the camera. Moreover, a proportion of (non-German) drivers may be unaware that they need to switch off the speed camera warnings – they will receive a warning anyway.



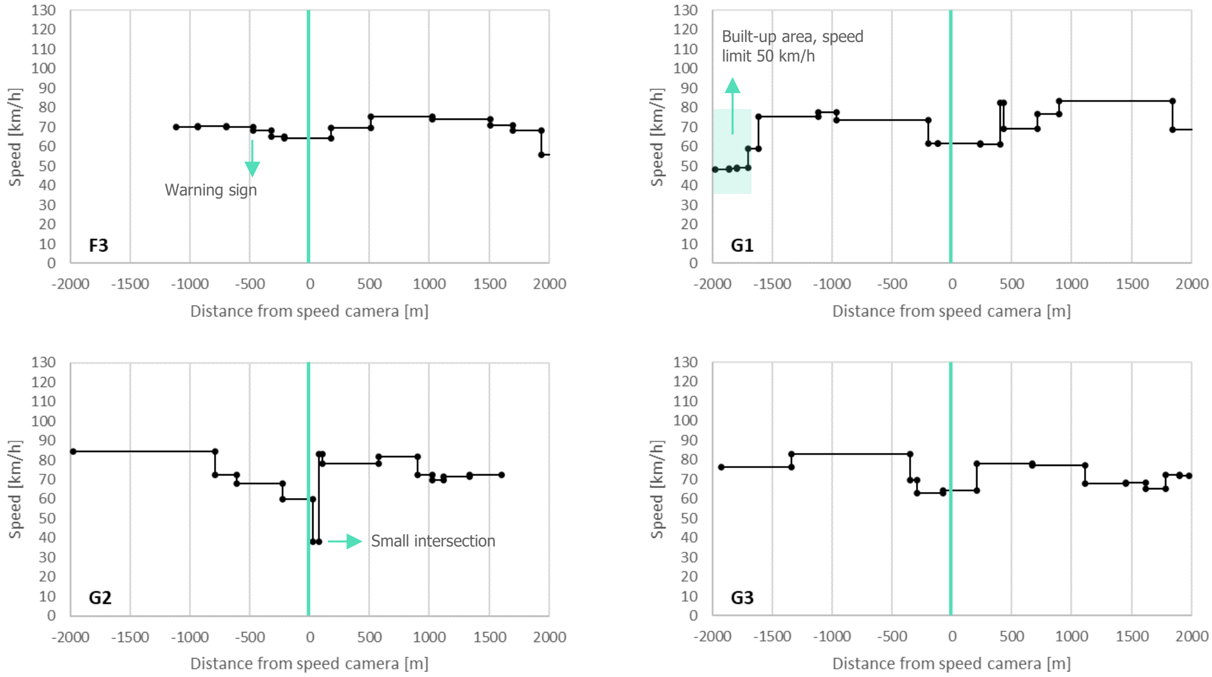


Figure 27 Longitudinal speed profiles with speed data collected from Waze for selected road segments. The fixed speed camera is located at distance zero.

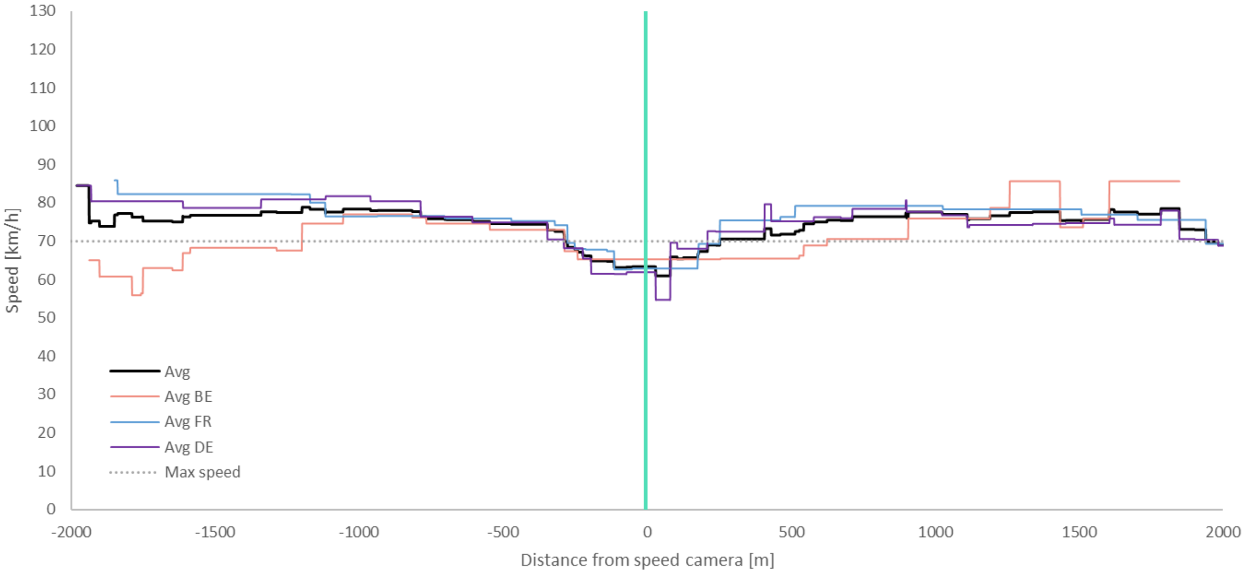


Figure 28 Longitudinal speed profiles with speed data collected from Waze summarized by country and over countries (locations B1 to B3, F1 to F3, and G1 to G3). Sections with a maximum speed different from 70 km/h were left out. The fixed speed camera is located at distance zero.

It is unknown on how many Waze users the average speeds are based. It is known that Waze has more users on highways than on local roads, because one of the main reasons for using Waze is avoiding traffic jams. The website www.wazestats.com provides an unofficial estimate of the number of Waze users in European capitals. The maximum number of daily users per 1 million citizen was highest in France (Paris: 55,875 users per 1M inhabitants on 21st February 2023), lower but still high in European rankings in Belgium (Brussels: 13,582 users per 1M inhabitants), and lowest in Germany (Berlin: 153 users per 1M inhabitants). This suggests that the uncertainty about the average speeds will be highest in Germany. Moreover, this also indicates that likely because of the current legislation, the Waze app is not often used in Germany.

5.4 Conclusions

From the limited number of (rural) sites in our analysis, it could not be concluded that Waze users behave differently nearby speed cameras in France or Germany, where the functionality to alert for speed cameras should indicate a zone or be switched off respectively. In this sense, it seems that the differences in legislation between countries do not really impact speed differently nearby fixed speed cameras (kangaroo jumps observed in all countries). We did find a much lower penetration ratio of the Waze app in Germany compared to Belgium and France, likely because of the restrictions in usage.

The speed data from Waze had some technical limitations: the use of waypoints or nodes limited the spatial resolution and interpretability of the longitudinal speed profiles, especially on highways; and the average speed is more uncertain at locations with fewer Waze users. Only average speeds could be retrieved from Waze; other measures that could have been interesting to study are speed percentiles (e.g. V85), percentage above the speed limit, or speed variance. On the other hand, the free availability of the dataset through Waze for Cities is an advantage and made our analyses possible. Moreover, Waze allowed us to extract data collected homogeneously for different countries.

Conclusions, legal options and recommendations

Conclusions of the study

Speed camera warning systems are **habitually used by 37% of Belgian drivers**. Illegal systems are used by 2.4% (radar detector) and 0.6% (radar jammer) of the drivers. Initial results show that professional drivers have a higher usage of speed camera warning systems, but this should be confirmed in further studies. Alerts for speed cameras are often a functionality included in navigation systems or smartphone apps and it is usually not the main function of these devices. In most systems, speed camera alert messages are projected on the screen, and include an audible tone or a voice informing about the type of alert. Some systems additionally provide the speed limit on all roads and optionally provide a speeding warning, irrespective of the presence of a speed camera. Despite the use of a speed camera warning system, those drivers report receiving more fines for speeding per 10,000 kilometres than drivers without such a system.

Users of speed camera warning systems differ from current non-users in their **attitudes towards speed**, as was found in chapter 3. Users of speed camera warning systems more often think that it is safe to exceed the speed limit if a road is deserted (26% compared to 19% in non-users). 39% of users believe that the only purpose of speed cameras is to raise money for the government, while this is only 26% in non-users. When the perceived risk for a speeding fine is small, then more drivers are tempted to speed: 21% of drivers with a speed camera warning system indicate that they drive faster when they know for sure that there is no speed camera nearby. No difference between users of a speed camera warning system and non-users was seen in the reported likeliness of being checked for speeding by the police during a typical drive, although in the literature it is generally considered that the exposure to enforcement increases when using warning systems. It also appeared that current users of a speed camera warning system are less aware of their speed. Therefore, it's likely that users will continue to drive (slightly) faster even without using such a system, they will just get more fines for their behaviour.

The **reliability of speed camera alerts** is variable. Fixed speed camera locations are drawn from general databases and accuracy is expected to be high. The accuracy of alerts for mobile temporary speed cameras is more difficult to assess. Accuracy depends on the number of users of a certain system. Our evaluation of the app Waze revealed that all mobile speed cameras on two highways in the province of Limburg were discovered quickly and an alert was active for 93.7% of the time with a camera in place; the average deviation from the actual location of the camera was ~175m (positional accuracy).

An active speed camera alert has an impact on speed. In chapter 4, it was shown that at times with an active Waze alert, the average speed is significantly lower (-1.15 km/h) than at times without an active alert in all drivers combined. At times without a Waze alert, 23.4% of the vehicles were speeding; at times with an active alert, 19.8% of the vehicles were above the speed limit. It seems that only those drivers above the speed limit lower their speed and not the ones that were already below the speed limit. It was estimated that car drivers who were speeding and using a speed camera warning system, lowered their speed by up to 10 km/h at the location of the camera. This shows that at a specific site (usually a site that is considered dangerous by the police) and at times with an active alert, speed camera warning systems lower speed, but this effect is temporary and may result in sudden braking and quick acceleration.

In some countries, stricter rules apply on the use of speed camera warning systems. In Germany and Switzerland, all systems are forbidden. In France, apps can be used, however, the exact location of a speed camera cannot be communicated (for companies that signed the AFFTAC protocol). Waze speed data was retrieved for April 2022, and speed camera alerts were indicated as a danger zone. In chapter 5, we have shown that **despite the differences in legislation between countries, there is no observed difference in speed behaviour** near fixed speed cameras: kangaroo jumps are observed in all three countries. An international meta-analysis concluded that kangaroo driving near speed cameras did not lead to adverse effects on crashes, and speed cameras were found to reduce total crash numbers by about 20%, even 30% for section controls (Hoye, 2014). Legislation did seem to lead to much lower usage of the Waze app in Germany.

In this study, the main focus was the impact of speed camera warning systems on speed, as a proxy for road safety. Speed camera warning systems can have other impacts on safety as well, for example, the visual and audio alert may lead to **distraction**. The alerts can interrupt drivers and encourage them to use their navigation system or mobile phone while driving, to report and/or confirm the location of the police enforcement (Oviedo-Trespalacios & Watson, 2021). Gamification of police reporting in apps such as Waze encourages drivers to interact with the screen, or to look out for speed cameras on the side of the road – in both cases the eyes of the driver are not on the road for several seconds. Moreover, advertising messages that pop up in some of the systems may cause further distraction. In chapter 2, we discussed the impact of in-vehicle screens on distraction and the risk of crashes – there is a growing body of evidence that indeed distractions by screens while driving can be risky. Associations between mobile phone distracted driving and crash risk suffer from underreporting (exposure to phones not reported by the police in case of a crash) (Oviedo-Trespalacios et al., 2016). Nevertheless, in the United States, a study of police crash reports estimated that mobile phone distraction resulted in 18% of fatal crashes and 5% of injury crashes (Overton et al., 2015). In Europe, in approximately 5 to 25% of all traffic crashes distraction plays a role (Vias institute, 2022). In Belgium about 150 traffic deaths per year can be attributed to distraction (Vias institute, 2022).

Beyond distraction, speed camera warning systems can reduce drivers' perceived risk of apprehension, thereby **eroding the deterrent effect of enforcement** (Oviedo-Trespalacios & Watson, 2021; Truelove et al., 2023). And finally, well-established companies that provide a feature to escape police enforcement may undermine the legitimacy of road rules (Oviedo-Trespalacios & Watson, 2021).

Speed camera or other police alerts are often **integrated into navigation systems**. These devices or smartphone apps also warn for other dangers on the road, like road works, rail crossings, dangerous curves, or nearby schools. Several of these alerts are expected to be beneficial for road safety (when distraction does not lead to the opposite effect) – yet, quantitative evidence from the field is largely missing. On the downside, several countries receive regular complaints about cut-through traffic on local roads induced by navigation systems. In none of the countries, however, there have been legal actions, for example by imposing restrictions on the routing algorithm of navigation system providers (e.g. avoiding the use of residential roads when far away from the destination). If the use of these systems gets more widespread, governmental action in this field will be recommended, either legally or through partnerships and cooperation (see chapter 2).

Advantages and disadvantages of proposed legislations

The table below summarizes the advantages and disadvantages for the government/society of possible legislations related to in-vehicle speed camera warning systems.

Proposed legislation	**Advantages**	**Disadvantages**
Current legislation in Belgium: the exact location of a speed camera can be indicated	▸ No change in legislation ▸ Local reduction in speed near speed cameras ▸ May promote exposure to enforcement (but not found in our sample) ▸ No enforcement is necessary (unless for radar detectors and radar jammers)	▸ Signal that it is acceptable to undermine police enforcement (impact on safety unknown) ▸ Allowing drivers to avoid punishment ▸ Distraction of drivers
Legislation with 'danger zones' indicating the possible presence of a speed camera (French system)	▸ Local reduction in speed near speed cameras and somewhat further away (2-4 km) (comparable to the impact of a section control) ▸ May promote exposure to enforcement (but not found in our sample) ▸ This system is preferred by Belgian drivers	▸ Signal that it is acceptable to undermine police enforcement (impact on safety unknown) ▸ Allowing drivers to avoid punishment ▸ Distraction of drivers ▸ Enforcement is necessary, but difficult
Total ban on all in-vehicle systems that warn drivers for speed cameras (German system)	▸ Clear signal that it is unacceptable to undermine all types of enforcement (impact on safety unknown)	▸ No local reductions in speed near hidden, temporary speed cameras (but similar kangaroo jumps near fixed speed cameras in France, Germany and Belgium)

	▸ Higher chance that drivers who usually drive too fast, are caught speeding.	▸ Enforcement is necessary, but difficult (only 659 fines in 2021 in Germany; legal discussion in Germany – the total ban (not only inside the vehicle) in Switzerland is clearer)

Prohibiting the broadcasting of **other police enforcement**, like roadside checks for alcohol or drugs, car or truck documents, or in the framework of a criminal investigation is a related legislative measure that could improve (road) safety. In France, this was implemented in November 2021. 46% of the Belgian drivers questioned in the current study would agree with such an approach. Yet, the impact on (road) safety was not quantitatively assessed in this study.

Legal advice on proposed legislations

Anticipating a possible tightening of the legislation on speed camera warning systems, the legal feasibility of a more stringent legislation is evaluated. The main conclusions and points of attention are summarized below (advice by Renaud Vanbergen & Sébastien Kaisergruber (lawyers at Gillard & Sterckx)).

- A total ban on speed camera warning systems does not seem unconstitutional. Moreover, a ban is necessary to ensure the effectiveness and efficiency of the traffic police, whose aim is to protect the safety of road users. Neither the European Court of Human Rights nor the Constitutional Court has established the right to receive or transmit information that would facilitate the commission of crimes. Speed cameras are used to enforce speed limits; speed camera warning systems thus indirectly interfere with the objectives of ensuring the safety of road users.
- The law must be well reasoned, motivated and explained.
- The law should be precisely defined for both citizens and businesses.
- The law should not prohibit communications designed to warn of road dangers.
- There should be no discrimination: why are radar detectors and radar jammers banned, and are other speed camera warning systems that in essence do the same thing (i.e. reporting speed cameras) currently allowed?
- The law should apply to the entire road network, and not to certain roads only.
- The ban could very well apply to all communications designed to warn of police enforcement (alcohol, on-board documents, vehicle searches, etc.) – this too would be in the public interest.
- There is no precedent in Belgium; the analysis is based on general legal principles and reasoning.

Recommendations

Changes in speed due to speed camera warning systems are local, and only temporary in the case of mobile speed cameras. Advanced driver assistance systems (ADAS), such as intervening **Intelligent Speed Adaptation (ISA)**, would be more likely to result in lower speeds, fewer speed infractions and significant gains in overall road safety in all locations. Many apps or cars nowadays already show the speed limit combined with the driven speed – it would be an opportunity to use these systems more to inform or warn drivers about speed infractions on the full road network and not just at locations with a speed camera. This will likely not impact those who intentionally speed (except for intervening or mandatory ISA), but those that use the apps for good reasons can be assisted by the system to maintain a safe speed below the speed limit. This approach recognizes that this technology is here to stay; and that it can be a tool in a Safe System approach of traffic safety. Of course, speed enforcement should stay a top priority and exposure to police enforcement should not be reduced.

For in-vehicle police alerts, **a harmonized European approach** would be beneficial for all. It would increase clarity for drivers, especially international travellers, that are currently confronted with a diversity in legislations on speed camera warning systems. Together in a European approach, national governments could take a much stronger position against well-established companies, ensuring that their laws are effectively respected.

Finally, operators get clarity and would be able to develop one system for the full European zone under fair competition, rather than adjusting their systems for each country separately.

Pending a European approach, Vias is in favour of **adapting the current Belgian legislation and ban systems that allow drivers to escape speed cameras or other police checks as a clear signal that risky behaviour on the road cannot be accepted** despite the difficulty in quantifying the impact of these systems on traffic safety.

Belgium aims to reduce the number of traffic deaths to zero by 2050, but after a continuous decline in the last decades, we are now faced with a trend towards a status quo in traffic deaths. The government should take all measures possible to prevent drivers from engaging in risky behaviour, such as inappropriate or excessive speed or distraction from phones. The ability of systems that warn for speed cameras or other police roadside enforcement to undermine the effectiveness and efficiency of the traffic police, whose aim is to protect the safety of road users, is in contradiction with the aim for zero road deaths (with speed being one the main killers in traffic). In addition, all triggers that encourage drivers to get their eyes off the road are inherently dangerous; nudging people to their screen and even interact with it, is not acceptable from a road safety point of view (18% of all fatal crashes is suspected to be related to mobile phone use).

However, the impact of a total ban on traffic safety could not be fully quantified and is thus uncertain. Our study shows that when an alert is active, drivers do slow down (which is beneficial for road safety), albeit only by a little and only locally. Furthermore, users of speed camera warning systems are drivers that generally drive faster on all roads and get more speeding fines per 10,000 kilometres. It is unlikely that drivers who intentionally speed will adapt their driving behaviour following a legislation that bans speed camera warning systems – or will they eventually change behaviour after numerous speeding fines? Finally, a ban of speed camera warning systems is difficult to enforce and it will be a challenge to remove all speed cameras from existing systems. In the case of Germany, the number of fines for using speed camera warning systems is very little, however, also the use of a system such as Waze is low, likely because of their current legislation.

Given the uncertainty about the total impact of a ban of speed camera warning systems on traffic safety, a somewhat more conservative approach could be considered instead. The French system with 'danger zones' indicating the possible presence of a speed camera could be a compromise that is also supported by the majority of Belgian drivers. Or an approach where only reporting and/or broadcasting of alerts for mobile and temporary speed cameras is prohibited, and alerting for fixed speed cameras is still allowed. Then older systems would not need to be updated to remove alerts for fixed speed cameras. This would in fact prohibit all real-time communication about speed cameras. Both approaches can either only mention speed cameras, or preferably also include other police roadside checks if requested by the police – from a safety point of view, both seem to be in the public interest.

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Appendix 1: Expert survey

Part 1: In-vehicle warning systems for speed cameras

We distinguish between four systems:

1. **Radar detectors**: small, specialised radio receivers tuned to the frequency range used by police radar guns. This is a separate device.
2. **Radar jammers/scramblers**: Radar detector that can additionally distort the radar signal making their vehicles invisible to police radar.
3. **Speed camera alerts *without* user community**: Navigation system, purpose-built device, smartphone app, or similar, indicating the location of a speed camera. The location of the speed camera is provided with the digital maps. Generally, these are the well-known visible speed cameras present for a long time, possibly even indicated on the road with a traffic sign. These systems cannot alert for temporary and hidden speed checks by the police.
4. **Speed camera alerts *with* user community**: Same as number 3, but in addition, it is possible for a user to indicate the location of a new speed camera and share it with a user community, or to be notified of a speed camera that was entered by another user in real-time.

Which systems are allowed in your country?

If there exists a legislation banning the use of some of these systems, are there specific conditionalities? For example, is it allowed in some regions but not in others, is it prohibited for commercial vehicles only, or is it allowed in a limited way (e.g. providing an approximate location of a speed camera but not the exact one)?

If some of the systems are banned, how is this enforced? Which fines can be imposed?

Is the legislation (or lack thereof) controversial? Do you often get questions on this topic?

Part 2: Restrictions posed upon navigation system providers with respect to routing

The use of in-vehicle navigation systems for **routing** purposes can lead to undesired cut-through traffic on local streets or near schools. This may cause liveability and safety concerns. Is this a matter of concern in your country? Are there policy guidelines or legislation in place that providers need to adhere to?

Appendix 2: Questionnaire (Dutch)

Herinnert u zich nog de papieren wegenkaarten waarmee we ons een weg baanden naar onze bestemming? Technologie heeft onze mobiliteit veranderd. Met deze vragenlijst willen we inzicht krijgen in het bezit en gebruik van navigatiesystemen in de wagen in België.

Ook als u nooit een navigatiesysteem gebruikt, zijn uw antwoorden voor ons nuttig.

Alle informatie die verzameld wordt in deze studie volgt strikt de regels zoals gespecifieerd in de Algemene Verordening Gegevensbescherming (GDPR). De gegevens die u in deze vragenlijst verstrekt zijn anoniem en kunnen niet teruggeleid worden tot één persoon. Het invullen van de vragenlijst zal ongeveer 15 minuten in beslag nemen.

Als u vragen heeft met betrekking tot de vragenlijst kan u via e-mail contact opnemen met de hoofdonderzoeker van deze studie, Evi Dons.

Q1	Wat is uw geboortejaar?	☐☐☐☐ (dropdown 1910-2020) [if 2003 or later: end of survey]
Q2	Bent u in het bezit van een autorijbewijs (rijbewijs B)? Infotext: Inclusief voorlopig rijbewijs	O Ja O Neen [end of survey]

Door de COVID-19 pandemie is voor velen van ons het verplaatsingsgedrag gewijzigd. Indien uw huidige verplaatsingsgedrag niet overeenkomt met wat u in normale omstandigheden zou doen, mag u bij het beantwoorden van de vragen terugdenken aan de periode voor het uitbreken van de coronacrisis.

Q3 Hoe vaak gebruikt u elk van volgende vervoermiddelen om ergens heen te gaan?
Infotext: Vergeet de wandel- en fietsritten niet die deel uitmaken van uw verplaatsing met het openbaar vervoer.

	Dagelijks of bijna dagelijks	1-3 dagen per week	1-3 dagen per maand	Minder dan 1 keer per maand	Nooit	Weet ik niet
Te voet	☐	☐	☐	☐	☐	☐
Fiets	☐	☐	☐	☐	☐	☐
Elektrische fiets	☐	☐	☐	☐	☐	☐
Motorfiets/bromfiets	☐	☐	☐	☐	☐	☐
Openbaar vervoer	☐	☐	☐	☐	☐	☐
Auto/bestelwagen als bestuurder	☐	☐	☐	☐	☐	☐
Auto/bestelwagen als passagier	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]
[End of survey if not: 'Auto/bestelwagen als bestuurder': 'Dagelijks of bijna dagelijks' OR '1-3 dagen per week' OR '1-3 dagen per maand']

We stellen eerst een aantal vragen over uw verplaatsingsgedrag.

Q4	Bent u een beroepschauffeur (bestuurder van metro, vrachtwagen, bus, trein, bestelwagen, taxi...)?	O Neen O Ja, hoofdzakelijk passagierstransport op de weg (vb. bus, taxi) O Ja, hoofdzakelijk passagierstransport op rails (vb. trein, tram, metro) O Ja, hoofdzakelijk goederentransport op de weg (vb. vrachtwagenbestuurder, pakjesbezorger, postbode) O Ja, hoofdzakelijk goederentransport op rails (vb. goederentrein) O Ja, hoofdzakelijk andere vorm bezoldigd bestuurder namelijk: [string]
[show this message when 'Ja, passagierstransport OF goederentransport op rails' OF 'andere vorm' in Q4] U bent beroepschauffeur. Mogen wij u vragen om het vervolg van de vragenlijst in te vullen voor uw privé-verplaatsingen met de auto.		

[show this message when 'Ja, passagierstransport OF goederentransport op de weg' in Q4] U bent beroepschauffeur. Mogen wij u vragen om het vervolg van de vragenlijst in te vullen alsof u onderweg bent voor uw beroep, met de bus, taxi, bestelwagen of vrachtwagen. [show this message when 'Neen' in Q4] Misschien gebruikt u een navigatiesysteem op de fiets of in een ander vervoermiddel, maar gelieve het vervolg van de vragenlijst in te vullen alsof u onderweg bent met de auto. Dit kan ook een deelauto zijn.		
Q5	Hoeveel kilometer legt u in een gemiddeld jaar met uw voertuig af als bestuurder? Infotext: Gemiddeld in een normaal jaar zonder beperking of lockdown	O Minder dan 5000 km O Tussen 5001 en 10 000 km O Tussen 10 001 en 20 000 km O Tussen 20 001 en 30 000 km O Meer dan 30 000 km O Ik weet het niet
Q6	Is het voertuig waar u meestal mee rijdt een bedrijfswagen?	O Ja O Neen O Ik weet het niet
Q7	Hoe vaak gebruikt u elk van onderstaande wegen met uw voertuig? Infotext: Gemiddeld in een normaal jaar zonder beperking of lockdown	

	Dagelijks of bijna dagelijks	1-3 dagen per week	1-3 dagen per maand	Minder dan 1 keer per maand	Nooit	Weet ik niet
Snelwegen / autostrades	☐	☐	☐	☐	☐	☐
Gewestwegen	☐	☐	☐	☐	☐	☐
Lokale wegen	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q8 Hoe vaak staat u in de file met uw voertuig?
Een file is een verkeerssituatie waarbij je gemiddeld niet sneller kunt rijden dan 25 km/u en af en toe stil staat. Die situatie moet minimaal 5 minuten duren.
Infotext: Gemiddeld in een normaal jaar zonder beperking of lockdown

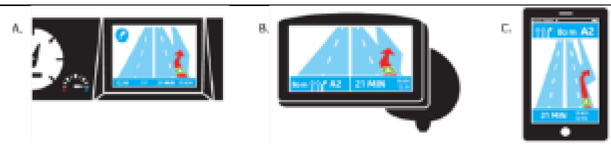
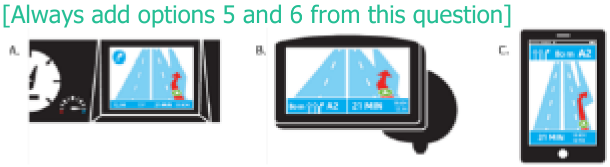
	Dagelijks of bijna dagelijks	1-3 dagen per week	1-3 dagen per maand	Minder dan 1 keer per maand	Nooit	Weet ik niet
Hoe vaak staat u in de file?	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q9	Stel, u bent onderweg en komt in een file terecht. Welke gevoelens roept dit bij u op? Meerdere antwoorden zijn mogelijk.	☐ Stress ☐ Ontspanning ☐ Bezorgdheid ☐ Boosheid ☐ Frustratie ☐ Irritatie ☐ Berusting ☐ Acceptatie [multiple answers possible]

Q10	Bent u in de voorbije drie jaar betrokken geweest bij een verkeersongeval met doden of gewonden? Infotext: Ongeval met minstens één voertuig (incl. fiets) met gewonden of doden. Bijvoorbeeld, botsing tussen voertuigen, aanrijding van een voetganger of een dier, botsing tegen een obstakel, val van een (motor)fietser.	x [numeric, max value 10] ongevallen met de dood van één of meer personen tot gevolg x [numeric, max value 10] ongevallen met lichamelijk letsel
Q11	Is er iemand die u dierbaar is in de voorbije drie jaar betrokken geweest bij een ongeval met doden of gewonden?	O Ja O Neen O Ik weet het niet
Q12	Hoeveel PV's heeft u het voorbije jaar ontvangen wegens te hoge snelheid? Infotext: Deze vraag betreft de overtredingen die u zelf heeft begaan, niet die andere mensen met uw voertuig zouden hebben begaan	O 0 O 1 O 2 O 3 tot 5 O 6 tot 10 O Meer dan 10 O Ik weet het niet

Q13	Hoe vaak bent u <u>het voorbije jaar</u> voor de rechtbank gedagvaard wegens een snelheidsovertreding?	O 0 O 1 O 2 O Meer dan 2
Q14	Hoeveel PV's heeft u <u>het voorbije jaar</u> ontvangen voor een andere verkeersovertreding dan een te hoge snelheid? Infotext: Deze vraag betreft de overtredingen die u zelf heeft begaan, niet die andere mensen met uw voertuig zouden hebben begaan	O 0 O 1 O 2 O 3 tot 5 O 6 tot 10 O Meer dan 10 O Ik weet het niet

Q15	Bezit u een smartphone?	O Ja, en ik heb mijn smartphone meestal bij als ik onderweg ben. O Ja, maar ik heb mijn smartphone meestal <u>niet</u> bij als ik onderweg ben. O Neen
Q16	Welk type navigatiesysteem <u>bezit</u> u? Meerdere antwoorden zijn mogelijk. Infotext: Navigatiesystemen voor gebruik in uw voertuig tijdens een rit.	 □ Ingebouwd in het dashboard (figuur A) □ Los niet-geïntegreerd navigatiesysteem (figuur B) □ Smartphone of tablet met navigatie-app (figuur C) □ Navigatie-app voor de smartphone die op het dashboard getoond wordt (vb. Apple CarPlay, Android Auto) □ Ik bezit geen navigatiesysteem □ Ik weet het niet [multiple answers possible]
Q17	Welk type navigatiesysteem <u>gebruikt</u> u het vaakst? Slechts één antwoord mogelijk. Infotext: Navigatiesystemen voor gebruik in uw voertuig tijdens een rit.	[only show options that were checked in the previous question – answers 1 to 4] [Always add options 5 and 6 from this question]  O Ingebouwd in het dashboard (figuur A) O Los niet-geïntegreerd navigatiesysteem (figuur B) O Smartphone of tablet met navigatie-app (figuur C) O Navigatie-app voor de smartphone die op het dashboard getoond wordt (vb. Apple CarPlay, Android Auto) O Ik gebruik geen navigatiesysteem O Ik weet het niet
Q18	Gebruikt u gewoonlijk een van de onderstaande apparaten tijdens het rijden of voor vertrek?	

	Ja	Neen	Weet ik niet
Een toestel of een betalende applicatie waarmee u gewaarschuwd wordt voor de aanwezigheid van vaste en mobiele flitsers (vb. Coyote, Wikango).	□	□	□
Een gratis smartphone-applicatie waarmee u gewaarschuwd wordt voor de aanwezigheid van vaste en mobiele flitsers (vb. Waze).	□	□	□
Een pagina op Facebook of op andere sociale netwerken en forums met informatie over flitsers.	□	□	□
Een radardetector (apparaat voor het detecteren van golven uitgezonden door politieradars).	□	□	□
Een radarverstoorder.	□	□	□

[1 mandatory answer per row]
[statements NOT in randomized order]

[Only show this question IF YOU DON'T OWN OR USE A NAVIGATION SYSTEM OR DON'T KNOW → see Q16 and Q17]

Q19	Welke kanalen gebruikt u om informatie over uw route te vergaren?	□ Radio □ Klassieke wegwijzers

		□ Dynamische Route Informatie Panelen boven of naast de weg □ Internet □ Papieren wegenkaart □ Aanwijzingen van familie, vrienden, collega's □ Ik ga nooit naar plaatsen die ik niet ken □ Geen andere bronnen [multiple answers possible]

[Only show the following questions IF YOU USE A NAVIGATION SYSTEM → option 1 to 4 in Q17]

Q20	Waarom gebruikt u uw navigatiesysteem? Meerdere antwoorden zijn mogelijk.	□ Route-aanwijzingen □ Informatie over de weg (vb. maximumsnelheid, aantal rijstroken om af te slaan) □ Informatie over tijdstip van aankomst □ Ontwijken van files □ Waarschuwingen voor snelheidscontroles □ Veiligheidswaarschuwingen (vb. spookrijder, vertraagd verkeer, gevaarlijke bocht, voorrang van rechts) □ Andere:... [string] [multiple answers possible]
Q21	Gaat u akkoord met volgende stellingen over navigatiesystemen...	

	Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord	Ik weet het niet
De informatie die een navigatiesysteem geeft, is betrouwbaar.	□	□	□	□	□	□
Ik begrijp altijd precies wat mijn navigatiesysteem bedoelt en wat ik moet doen.	□	□	□	□	□	□
Een navigatiesysteem in mijn voertuig leidt mij af.	□	□	□	□	□	□
Ik voer mijn bestemming altijd in voordat ik vertrek.	□	□	□	□	□	□
Eens ik onderweg ben, pas ik mijn route niet meer aan, zelfs niet als mijn navigatiesysteem aangeeft dat er een snellere route bestaat.	□	□	□	□	□	□
Ik volg altijd exact, stap voor stap, de aanwijzingen van mijn navigatiesysteem.	□	□	□	□	□	□
Als u dit leest, antwoord "Helemaal akkoord".	□	□	□	□	□	□
Sinds ik een navigatiesysteem gebruik, rij ik vaker op lokale wegen.	□	□	□	□	□	□
Het verkeer in mijn straat is drukker geworden door chauffeurs met een navigatiesysteem.	□	□	□	□	□	□
Ik gebruik soms meerdere navigatiesystemen of navigatie-apps tijdens eenzelfde rit.	□	□	□	□	□	□
Ik maak mij zorgen over mijn privacy wanneer ik een navigatiesysteem gebruik.	□	□	□	□	□	□

[1 mandatory answer per row]

Q22	Hoe vaak gebruikt u momenteel elk van volgende smartphone-apps of systemen <u>in uw voertuig</u> tijdens een verplaatsing?

VIAS institute

	Dagelijks of bijna dagelijks	1-3 dagen per week	1-3 dagen per maand	Minder dan 1 keer per maand	Nooit	Ken ik niet
Ingebouwd navigatiesysteem	☐	☐	☐	☐	☐	☐
Coyote	☐	☐	☐	☐	☐	☐
Google Maps	☐	☐	☐	☐	☐	☐
Apple Maps	☐	☐	☐	☐	☐	☐
Waze	☐	☐	☐	☐	☐	☐
CamSam	☐	☐	☐	☐	☐	☐
Wikango	☐	☐	☐	☐	☐	☐
Flitsmeister	☐	☐	☐	☐	☐	☐
Garmin	☐	☐	☐	☐	☐	☐
TomTom	☐	☐	☐	☐	☐	☐
Mio	☐	☐	☐	☐	☐	☐
Andere: …. [string]	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q23 [don't show statements 1, 2 and 3 for professional drivers → when 'Ja, passagierstransport OF goederentransport op de weg' in Q4]

Hoe vaak staat uw navigatiesysteem aan als u met uw voertuig onderweg bent…

	Altijd	Vaak	Af en toe	Zelden	Nooit	Niet van toepassing
om naar het werk te gaan?	☐	☐	☐	☐	☐	☐
om dagelijkse boodschappen te doen?	☐	☐	☐	☐	☐	☐
voor een dagje weg (vb. naar een pretpark, naar de kust)?	☐	☐	☐	☐	☐	☐
voor een verplaatsing langer dan 150 kilometer?	☐	☐	☐	☐	☐	☐
en het erg belangrijk is dat u op tijd komt.	☐	☐	☐	☐	☐	☐
en het niet zo belangrijk is dat u op tijd komt.	☐	☐	☐	☐	☐	☐
naar een bestemming die u erg goed kent.	☐	☐	☐	☐	☐	☐
naar een bestemming die u niet goed kent.	☐	☐	☐	☐	☐	☐
en last hebt van files op uw route.	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q24	Hebt u een navigatiesysteem dat over actuele file-informatie beschikt? Infotext: Deze systemen zijn verbonden met het internet. Onderweg geeft dit systeem in real-time informatie over ongevallen die net gebeurd zijn, plaatsen waar op dat moment files staan, enzovoort.	O Ja O Neen O Ik weet het niet.
Q25	Wanneer u een route die voorgesteld wordt door uw navigatiesysteem <u>niet</u> volgt, wat is hiervoor de reden?	☐ Ik volg steeds de voorgestelde route. ☐ Tijdswinst is onvoldoende. ☐ Ik wil niet door woonwijken of langs kleinere wegen rijden. ☐ Ik verkies mijn gebruikelijke route. ☐ De voorgestelde route is te complex. ☐ Ik ken de situatie en weet dat de voorgestelde route niet sneller is. ☐ Andere. ☐ Ik weet het niet. [multiple answers possible]
Q26	Hoeveel minuten tijdswinst zijn naar uw mening nodig om af te wijken van uw gebruikelijke route?	O 0 minuten (u volgt steeds de snelste route) O 1-2 minuten O 3-5 minuten O 6-10 minuten O meer dan 10 minuten O Ik wijk nooit af van mijn route O Ik weet het niet.
Q27	Meldt u soms zelf incidenten, files of flitslocaties via uw navigatiesysteem, smartphone-app, of op sociale media?	O Ja O Neen O Ik weet het niet

	Infotext: Hiermee bedoelen we dat u zelf actief een bericht post of een melding aanmaakt.	
Q28	Wanneer heeft u voor het laatst uw navigatiesysteem geüpdatet?	O Wordt automatisch geactualiseerd O Minder dan 1 jaar geleden O Tussen 1 en 3 jaar geleden O Meer dan 3 jaar geleden O Nog nooit O Ik weet het niet.

[for all respondents]

Q29 Gaat u akkoord met volgende stellingen over snelheid…

	Helemaal niet akkoord	Niet akkoord	Neutraal	Akkoord	Helemaal akkoord	Ik weet het niet
Er zouden meer 30 km/u zones moeten zijn in dorps- en stadscentra.	☐	☐	☐	☐	☐	☐
Als een weg verlaten is, is het veilig om de maximumsnelheid te overschrijden.	☐	☐	☐	☐	☐	☐
Over het algemeen zijn snelheidscontroles (vaste camera's, trajectcontroles en mobiele controles) nuttig voor de verkeersveiligheid.	☐	☐	☐	☐	☐	☐
Snelheidscontroles dienen enkel om de staatskas te spijzen.	☐	☐	☐	☐	☐	☐
Snelheidscontroles zorgen voor plots remmen en snel optrekken.	☐	☐	☐	☐	☐	☐
Het is een goed idee om een <u>zone</u> met een snelheidscontrole aan te kondigen (vb. op een stuk weg van 2 kilometer).	☐	☐	☐	☐	☐	☐
Systemen die de exacte locatie van snelheidscontroles aanduiden (type Coyote, Waze) hebben een negatieve invloed op de verkeersveiligheid.	☐	☐	☐	☐	☐	☐
Er moet een verbod komen op systemen die de exacte locatie van snelheidscontroles aanduiden (type Coyote, Waze).	☐	☐	☐	☐	☐	☐
Er moet een verbod komen op systemen (type Coyote, Waze) die waarschuwen voor andere politiecontroles op de weg, vb. alcoholcontrole.	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]
[statements NOT in randomized order]

Q30 Heeft u de neiging om langzamer of sneller te rijden of uw gebruikelijke gedrag niet te veranderen onder de volgende omstandigheden?

	Ik rij langzamer dan gewoonlijk	Ik verander mijn gedrag niet	Ik rij sneller dan gewoonlijk	Ik weet het niet / Niet van toepassing
Als u te laat bent voor een afspraak	☐	☐	☐	☐
Als u zeker weet dat er geen snelheidscontrole is	☐	☐	☐	☐
Als u een flitspaal of flitscamera ziet	☐	☐	☐	☐
Als u een aankondiging voor een snelheidscontrole opmerkt (verkeersbord of melding op een navigatiesysteem)	☐	☐	☐	☐

	Als u een onbekende route neemt	☐	☐	☐	☐
	Als u een route op uw navigatiesysteem volgt	☐	☐	☐	☐
	[1 mandatory answer per row]				

De volgende vraag lijkt misschien wat vreemd, maar voor de analyse die wij in gedachten hebben, is het voor ons belangrijk dat u ze beantwoordt.

Q31	Hieronder vindt u een lijst met uitspraken. Lees elke uitspraak zorgvuldig door en beslis of die uitspraak u beschrijft of niet. Als de uitspraak u beschrijft, kruis dan het woord "Waar" aan; zo niet, kruis dan "Niet waar" aan.		
		Waar	Niet waar
	Ik gooi wel eens rommel op de grond.	☐	☐
	Ik geef mijn fouten altijd openlijk toe en accepteer de mogelijke negatieve gevolgen.	☐	☐
	In het verkeer ben ik altijd hoffelijk en houd ik rekening met anderen.	☐	☐
	Ik accepteer altijd de mening van anderen, zelfs als die niet overeenkomt met die van mij.	☐	☐
	Wanneer ik slecht gezind ben, reageer ik dit soms af op anderen.	☐	☐
	Ik heb wel eens misbruik gemaakt van de goedheid van iemand anders.	☐	☐
	In gesprekken luister ik altijd aandachtig en laat anderen hun zinnen afmaken.	☐	☐
	Ik aarzel nooit om iemand te helpen in geval van nood.	☐	☐
	Als ik een belofte heb gedaan, kom ik die na.	☐	☐
	Ik spreek soms slecht over anderen achter hun rug.	☐	☐
	Ik zou nooit op de rug van andere mensen leven.	☐	☐
	Ik blijf altijd vriendelijk en beleefd tegen andere mensen, zelfs als ik gestrest ben.	☐	☐
	Tijdens ruzies blijf ik altijd objectief en zakelijk.	☐	☐
	Er is ten minste één keer geweest dat ik een geleend voorwerp niet heb teruggebracht.	☐	☐
	Ik eet altijd gezond.	☐	☐
	Soms help ik alleen omdat ik er iets voor terug verwacht.	☐	☐
	[1 mandatory answer per row]		

U bent er bijna. We hebben nog enkele laatste vragen over u en uw huishouden.

Q32	Wat is uw geslacht?	O Man O Vrouw O Anders
Q33	Hoe kan u uw familiale situatie het best omschrijven?	O Alleenstaand, zonder kinderen onder hetzelfde dak O Alleenstaand, met kinderen onder hetzelfde dak O Als koppel, zonder kinderen onder hetzelfde dak O Als koppel, met kinderen onder hetzelfde dak O Anders
Q34	Wat is de postcode van uw hoofdverblijfplaats?	Postcode ☐☐☐☐ (four numbers: 0-9) OF Gemeente of stad [text]
Q35	In welke stad of gemeente bevindt uw hoofdactiviteit zich? Infotext: Waar u het vaakst naartoe gaat voor uw activiteiten	Postcode ☐☐☐☐ (four numbers: 0-9) OF Gemeente of stad [text]
Q36	Welke van de volgende termen beschrijft het beste uw huidige beroepssituatie?	O Werknemer (bediende / ambtenaar) O Arbeider O Management O Vrij beroep O Zelfstandige O Ondernemer O Op dit moment niet beroepsmatig actief
Q37	Wat is op dit ogenblik het hoogste diploma of getuigschrift dat u heeft behaald?	O Maximum hoger middelbaar onderwijs O Hoger onderwijs
Q38	Wat is bij benadering het jaarlijkse netto-inkomen van uw huishouden?	O Minder dan €10 000 O Tussen €10 000 en €25 000 O Tussen €25 000 en €50 000

	Infotext: Het bedrag dat uw huishouden elk jaar verdient of verwerft, na aftrek van belastingen en overdrachten. Dit is het totale te besteden inkomen, beschikbaar voor aankoop van goederen en diensten.	O Tussen €50 000 en €75 000 O Tussen €75 000 en €100 000 O Meer dan €100 000 O Geen antwoord

Dit is het einde van de vragenlijst. Bedankt voor uw deelname.

Appendix 3: Questionnaire (French)

Vous souvenez-vous des cartes routières en papier que nous utilisions pour nous frayer un chemin jusqu'à notre destination ? La technologie a changé notre mobilité. Avec ce questionnaire, nous voulons avoir un aperçu de la possession et de l'utilisation des systèmes de navigation dans les voitures en Belgique.

Même si vous n'utilisez jamais un système de navigation, vos réponses nous sont utiles.

Toutes les informations recueillies dans le cadre de cette étude suivent strictement les règles spécifiées dans le règlement général sur la protection des données (RGPD). Les données que vous fournissez dans ce questionnaire sont anonymes et ne peuvent être rattachées à une seule personne. Le questionnaire durera environ 15 minutes.

Si vous avez des questions concernant le questionnaire, vous pouvez contacter l'investigatrice principale de cette étude, par e-mail, Evi Dons.

Q1	Quelle est votre année de naissance ?	□□□□ (dropdown 1910-2020) [if 2003 or later: end of survey]
Q2	Êtes-vous en possession d'un permis de conduire automobile (permis B) ? Infotext: permis de conduire provisoire inclus	O Oui O Non [end of survey]

La pandémie de COVID-19 a modifié les habitudes de voyage de bon nombre d'entre nous. Si votre comportement actuel en matière de voyage ne reflète pas ce que vous feriez dans des circonstances normales, vous pouvez penser à la période précédant le commencement de la crise corona lorsque vous répondez aux questions.

Q3 À quelle fréquence utilisez-vous chacun des moyens de transport suivants pour vous rendre quelque part ?
Infotext: N'oubliez pas les déplacements à pied et à vélo qui font partie de vos déplacements avec les transports publics.

	Tous les jours ou presque	1-3 jours par semaine	1-3 jours par mois	Moins d'une fois par mois	Jamais	Je ne sais pas
A pied	☐	☐	☐	☐	☐	☐
Vélo	☐	☐	☐	☐	☐	☐
Vélo électrique	☐	☐	☐	☐	☐	☐
Moto/Motocyclette	☐	☐	☐	☐	☐	☐
Transports publics	☐	☐	☐	☐	☐	☐
Voiture/Camionnette en tant que conducteur	☐	☐	☐	☐	☐	☐
Voiture/Camionnette en tant que passager	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]
[End of survey if not: 'Voiture/Camionnette en tant que conducteur': 'Tous les jours ou presque' OR '1-3 jours par semaine' OR '1-3 jours par mois]

Nous allons d'abord vous poser une série de questions sur vos habitudes de trajet.

Q4	Êtes-vous un conducteur professionnel (métro, camion, bus, train, camionnette, taxi, etc.) ?	O Non O Oui, principalement le transport routier de passagers (par exemple, bus, taxi) O Oui, principalement le transport de passagers sur rails (par exemple, train, tramway, métro) O Oui, principalement le transport routier de marchandises (par exemple, chauffeur de camion, livreur de colis, facteur) O Oui, principalement le transport de marchandise sur rails (par exemple, le train de marchandises) O Oui, principalement une autre forme de conducteur salarié, à savoir: [string]

[show this message when 'Oui, transport de passagers OU transport de marchandises sur rails' OU 'une autre forme' in Q4] Vous êtes un conducteur professionnel. Nous vous demandons de bien vouloir remplir le reste du questionnaire pour vos voyages privés en voiture. [show this message when 'Oui, transport routier de passagers OU transport routier de marchandises' in Q4] Vous êtes un conducteur professionnel. Nous vous demandons de remplir le reste du questionnaire comme si vous étiez sur la route pour votre profession, en bus, taxi, camionnette ou camion. [show this message when 'Non' in Q4] Vous utilisez peut-être un système de navigation sur votre vélo ou dans un autre mode de transport, veuillez cependant remplir le reste du questionnaire comme si vous voyagiez <u>en voiture</u>. Il peut également s'agir d'une voiture partagée.		
Q5	Dans une année moyenne, combien de kilomètres parcourez-vous avec votre véhicule en tant que conducteur ? Infotext: Moyenne dans une année normale sans restriction ni confinement.	O Moins de 5000 km O Entre 5001 et 10 000 km O Entre 10 001 et 20 000 km O Entre 20 001 et 30 000 km O Plus de 30 000 km O Je ne sais pas
Q6	Le véhicule que vous conduisez habituellement est-il un véhicule de société ?	O Oui O Non O Je ne sais pas
Q7	À quelle fréquence utilisez-vous chacune des routes suivantes avec votre véhicule ? Infotext: Moyenne dans une année normale sans restriction ni confinement.	

	Tous les jours ou presque	1-3 jours par semaine	1-3 jour par mois	Moins d'une fois par mois	Jamais	Je ne sais pas
Autoroutes / voies rapides	☐	☐	☐	☐	☐	☐
Routes régionales	☐	☐	☐	☐	☐	☐
Routes locales	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q8 Combien de fois vous retrouvez-vous dans un embouteillage avec votre véhicule ?
Un embouteillage est une situation de circulation dans laquelle vous ne pouvez pas rouler à plus de 25 km/h en moyenne et où vous êtes occasionnellement bloqué. Cette situation doit durer au moins 5 minutes.
Infotext: Moyenne dans une année normale sans restriction ni confinement.

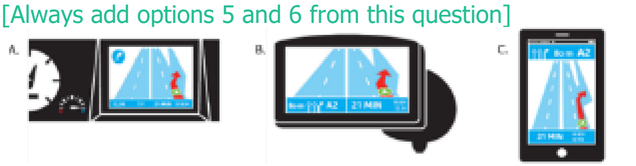
	Tous les jours ou presque	1-3 jours par semaine	1-3 jour par mois	Moins d'une fois par mois	Jamais	Je ne sais pas
Combien de fois vous retrouvez-vous dans un embouteillage ?	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q9	Imaginez que vous êtes sur la route et que vous vous retrouvez dans un embouteillage. Quels sentiments cela évoque-t-il pour vous ? Plusieurs réponses sont possibles.	☐ Stress ☐ Détente ☐ Préoccupation ☐ Colère ☐ Frustration ☐ Irritation ☐ Résignation ☐ Acceptation [multiple answers possible]

Q10	Avez-vous été impliqué dans un accident de la circulation avec décès ou blessures au cours des <u>trois</u> dernières années ? Infotext: Accident impliquant au moins un véhicule (y compris une bicyclette) et entraînant des blessures ou la mort. Par exemple, collision entre véhicules, collision avec un piéton ou un animal, collision avec un obstacle, chute d'un (moto)cycliste.	x [numeric, max value 10] accidents ayant entrainé la mort d'une ou plusieurs personnes x [numeric, max value 10] accidents ayant impliqué des dommages corporels
Q11	Un de vos proches a-t-il été impliqué dans un accident avec décès ou blessure au cours des <u>trois</u> dernières années ?	O Oui O Non O Je ne sais pas

Q12	Combien de PV avez-vous reçu l'année dernière pour excès de vitesse ? Infotext: Cette question concerne les infractions commises par vous-même, et non les infractions prétendument commises par d'autres personnes utilisant votre véhicule.	O 0 O 1 O 2 O 3 à 5 O 6 à 10 O Plus de 10 O je ne sais pas
Q13	Combien de fois au cours de l'année écoulée avez-vous été convoqué au tribunal pour une contravention pour excès de vitesse ?	O 0 O 1 O 2 O Plus de 2
Q14	Combien de PV avez-vous reçus au cours de l'année écoulée pour une infraction au code de la route autre qu'un excès de vitesse ? Infotext: Cette question concerne les infractions commises par vous-même, et non les infractions prétendument commises par d'autres personnes utilisant votre véhicule.	O 0 O 1 O 2 O 3 à 5 O 6 à 10 O Plus de 10 O Je ne sais pas

Q15	Possédez-vous un smartphone ?	O Oui, et j'ai généralement mon smartphone avec moi lorsque je suis sur la route. O Oui, mais je n'ai généralement pas mon smartphone avec moi lorsque je suis sur la route. O Non
Q16	Quel type de système de navigation possédez-vous ? Plusieurs réponses sont possibles. Infotext: Systèmes de navigation à utiliser dans votre véhicule pendant la conduite.	 ☐ Intégrée au tableau de bord (Figure A) ☐ Système de navigation autonome non intégré (figure B) ☐ Smartphone ou tablette avec application de navigation (Figure C) ☐ Application de navigation pour le smartphone affichée sur le tableau de bord (par exemple, Apple CarPlay, Android Auto) ☐ Je ne possède pas de système de navigation ☐ Je ne sais pas [multiple answers possible]
Q17	Quel type de système de navigation utilisez-vous le plus souvent ? Une seule réponse est possible. Infotext: Systèmes de navigation à utiliser dans votre véhicule pendant la conduite.	[only show options that were checked in the previous question – answers 1 to 4] [Always add options 5 and 6 from this question]  O Intégrée au tableau de bord (Figure A) O Système de navigation autonome non intégré (figure B) O Smartphone ou tablette avec application de navigation (Figure C) O Application de navigation pour le smartphone affichée sur le tableau de bord (par exemple, Apple CarPlay, Android Auto) O Je n'utilise pas de système de navigation O Je ne sais pas
Q18	Utilisez-vous habituellement l'un des dispositifs suivants en conduisant ou avant le départ ?	

	Oui	Non	Je ne sais pas
Un dispositif ou une application payante qui vous avertit de la présence de radars fixes et mobiles (par exemple, Coyote, Wikango).	☐	☐	☐
Une application gratuite pour smartphone qui vous avertit de la présence de radars fixes et mobiles (par exemple, Waze).	☐	☐	☐
Une page sur Facebook ou d'autres réseaux sociaux et forums avec des informations sur les radars.	☐	☐	☐
Un détecteur de radar (appareil permettant de détecter les ondes émises par les radars de police).	☐	☐	☐
Un brouilleur de radar.	☐	☐	☐

	[1 mandatory answer per row] [statements NOT in randomized order]

[Only show this question IF YOU DON'T OWN OR USE A NAVIGATION SYSTEM OR DON'T KNOW → see Q16 and Q17]

Q19	Quels canaux utilisez-vous pour recueillir des informations sur votre itinéraire ?	☐ Radio ☐ Panneaux indicateurs classiques ☐ Panneaux d'information dynamiques sur l'itinéraire au-dessus ou à côté de la route ☐ Internet ☐ Carte routière en papier ☐ Instructions de la famille, des amis, des collègues ☐ Je ne vais jamais dans des endroits que je ne connais pas. ☐ Aucune autre source [multiple answers possible]

[Only show the following questions IF YOU USE A NAVIGATION SYSTEM → option 1 to 4 in Q17]

Q20	Pourquoi utilisez-vous votre système de navigation ? Plusieurs réponses sont possibles.	☐ Suggestions d'itinéraires ☐ Informations sur la route (par exemple, la limitation de vitesse, le nombre de voies dans lesquelles il faut tourner) ☐ Informations sur l'heure d'arrivée ☐ Éviter les embouteillages ☐ Avertissements pour les contrôles de vitesse ☐ Avertissements de sécurité (par exemple, conducteur fantôme, trafic retardé, virage dangereux, priorité de passage). ☐ Autre:... [string] [multiple answers possible]

Q21 Êtes-vous d'accord avec les déclarations suivantes concernant les systèmes de navigation...

	Pas du tout d'accord	Pas d'accord	neutre	D'accord	Tout à fait d'accord	Je ne sais pas
Les informations fournies par un système de navigation sont fiables.	☐	☐	☐	☐	☐	☐
Je comprends toujours exactement ce que signifie mon système de navigation et ce que je dois faire.	☐	☐	☐	☐	☐	☐
Un système de navigation dans mon véhicule me distrait.	☐	☐	☐	☐	☐	☐
Je saisis toujours ma destination avant de partir.	☐	☐	☐	☐	☐	☐
Une fois sur la route, je ne change pas d'itinéraire, même si mon système de navigation indique qu'il existe un chemin plus rapide.	☐	☐	☐	☐	☐	☐
Je suis toujours exactement, étape par étape, les indications de mon système de navigation.	☐	☐	☐	☐	☐	☐
Si vous lisez ceci, répondez "Tout à fait d'accord".	☐	☐	☐	☐	☐	☐
Depuis que j'utilise un système de navigation, je conduis plus souvent sur des routes locales.	☐	☐	☐	☐	☐	☐
Le trafic dans ma rue est devenu plus dense à cause des conducteurs équipés de systèmes de navigation.	☐	☐	☐	☐	☐	☐

J'utilise parfois plusieurs systèmes ou applications de navigation au cours d'un même voyage.	☐	☐	☐	☐	☐	☐
Je suis préoccupé par le respect de ma vie privée lorsque j'utilise un système de navigation.	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q22 À quelle fréquence utilisez-vous actuellement chacune des applications ou systèmes pour smartphone suivants dans votre véhicule pendant un voyage ?

	Tous les jours ou presque	1-3 jours par semaine	1-3 jours par mois	Moins d'une fois par mois	Jamais	Je ne sais pas
Système de navigation intégré	☐	☐	☐	☐	☐	☐
Coyote	☐	☐	☐	☐	☐	☐
Google Maps	☐	☐	☐	☐	☐	☐
Apple Maps	☐	☐	☐	☐	☐	☐
Waze	☐	☐	☐	☐	☐	☐
CamSam	☐	☐	☐	☐	☐	☐
Wikango	☐	☐	☐	☐	☐	☐
Flitsmeister	☐	☐	☐	☐	☐	☐
Garmin	☐	☐	☐	☐	☐	☐
TomTom	☐	☐	☐	☐	☐	☐
Mio	☐	☐	☐	☐	☐	☐
Autre: .... [string]	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q23 [don't show statements 1, 2 and 3 for professional drivers → when 'Oui, transport routier de passagers OU transport routier de marchandises' in Q4]

À quelle fréquence votre système de navigation est-il allumé lorsque vous êtes sur la route dans votre véhicule …

	Toujours	Souvent	Parfois	Rarement	Jamais	Non applicable
pour aller travailler ?	☐	☐	☐	☐	☐	☐
pour faire vos courses quotidiennes ?	☐	☐	☐	☐	☐	☐
pour une journée de sortie (par exemple, dans un parc d'attractions, à la côte) ?	☐	☐	☐	☐	☐	☐
pour un voyage de plus de 150 kilomètres ?	☐	☐	☐	☐	☐	☐
et il est très important que vous arriviez à l'heure.	☐	☐	☐	☐	☐	☐
et il n'est pas si important que vous arriviez à l'heure.	☐	☐	☐	☐	☐	☐
vers une destination que vous connaissez très bien.	☐	☐	☐	☐	☐	☐
vers une destination que vous ne connaissez pas très bien.	☐	☐	☐	☐	☐	☐
et subissez des embouteillages sur votre route.	☐	☐	☐	☐	☐	☐

[1 mandatory answer per row]

Q24	Disposez-vous d'un système de navigation avec des informations actualisées sur les embouteillages ? Infotext: Ces systèmes sont connectés à l'internet. Sur la route, ce système fournit des informations en temps réel sur les accidents qui viennent de se produire, les endroits où il y a actuellement des embouteillages, etc.	O Oui O Non O Je ne sais pas.
Q25	Si vous ne suivez pas un itinéraire proposé par votre système de navigation, quelle en est la raison ?	☐ Je suis toujours l'itinéraire proposé. ☐ Le temps gagné ne suffit pas. ☐ Je ne veux pas conduire dans les zones résidentielles ou sur les petites routes. ☐ Je préfère ma route habituelle. ☐ Le trajet proposé est trop complexe.

		☐ Je connais la situation et je sais que la route proposée n'est pas plus rapide. ☐ Autre. ☐ Je ne sais pas. [multiple answers possible]
Q26	À votre avis, combien de minutes de temps vous faudrait-il gagner pour vous faire dévier de votre itinéraire habituel ?	O 0 minute (vous prenez toujours le chemin le plus rapide) O 1-2 minutes O 3-5 minutes O 6-10 minutes O Plus de 10 minutes O Je ne dévie jamais de ma route O Je ne sais pas.
Q27	Vous arrive-t-il de signaler vous-même des incidents, des embouteillages ou des emplacements de radars via votre système de navigation, l'application de votre smartphone ou sur les médias sociaux ? Infotext: Nous entendons par là que vous publiez activement un message ou créez une notification.	O Oui O Non O Je ne sais pas.
Q28	Quand avez-vous mis à jour votre système de navigation pour la dernière fois ?	O Mise à jour automatique O Il y a moins d'un an O Entre 1 et 3 ans O Il y a plus de 3 ans O Jamais auparavant O Je ne sais pas.

[for all respondents]

Q29 Êtes-vous d'accord avec les affirmations suivantes concernant la vitesse…

	Pas du tout d'accord	Pas d'accord	Neutre	D'accord	Tout à fait d'accord	Je ne sais pas
Il devrait y avoir davantage de zones 30 km/h dans les centres des villages et des villes.	☐	☐	☐	☐	☐	☐
Si une route est déserte, il n'y a aucun risque de dépasser la limite de vitesse.	☐	☐	☐	☐	☐	☐
En général, les contrôles de vitesse (caméras fixes, contrôles de tronçons et contrôles mobiles) sont utiles pour la sécurité du trafic.	☐	☐	☐	☐	☐	☐
Les contrôles de vitesse ne servent qu'à alimenter le trésor public.	☐	☐	☐	☐	☐	☐
Les contrôles de vitesse provoquent des freinages brusques et des accélérations rapides.	☐	☐	☐	☐	☐	☐
C'est une bonne idée d'annoncer une zone avec un contrôle de vitesse (par exemple sur un tronçon de route de 2 km).	☐	☐	☐	☐	☐	☐
Les systèmes qui indiquent l'emplacement exact des contrôles de vitesse (type Coyote, Waze) ont un impact négatif sur la sécurité routière.	☐	☐	☐	☐	☐	☐
Les systèmes indiquant l'emplacement exact des contrôles de vitesse (type Coyote, Waze) devraient être interdits.	☐	☐	☐	☐	☐	☐
Il faudrait interdire les systèmes (type Coyote, Waze) qui préviennent d'autres contrôles de police sur la	☐	☐	☐	☐	☐	☐

	route, par exemple les contrôles d'alcoolémie. [1 mandatory answer per row] [statements NOT in randomized order]

Q30	Avez-vous tendance à conduire plus lentement ou plus rapidement ou à ne pas changer votre comportement habituel dans les circonstances suivantes ?			
	Je conduis plus lentement que d'habitude	Je ne change pas mon comportement	Je conduis plus vite que d'habitude	Je ne sais pas / Ne s'applique pas
Quand vous êtes en retard à un rendez-vous	☐	☐	☐	☐
Quand vous êtes sûr qu'il n'y a pas de contrôle de vitesse	☐	☐	☐	☐
Quand vous voyez un radar ou une caméra de surveillance de la vitesse	☐	☐	☐	☐
Quand vous remarquez un avertissement de contrôle de vitesse (panneau de signalisation ou message sur un système de navigation).	☐	☐	☐	☐
Quand vous prenez une route inconnue	☐	☐	☐	☐
Quand vous suivez un itinéraire sur votre système de navigation	☐	☐	☐	☐
[1 mandatory answer per row]				

La question suivante peut sembler un peu étrange, mais pour l'analyse que nous avons en tête, il est important pour nous que vous y répondiez.

Q31	Vous trouverez ci-dessous une liste de déclarations. Lisez attentivement chaque affirmation et décidez si elle vous décrit ou non. Si l'affirmation vous décrit, cochez la case "Vrai" ; sinon, cochez la case "Faux".	
	Vrai	Faux
Je jette parfois des déchets par terre.	☐	☐
J'admets toujours ouvertement mes erreurs et je fais face aux conséquences négatives potentielles.	☐	☐
Dans la circulation, je suis toujours poli et respectueux des autres.	☐	☐
J'accepte toujours l'opinion des autres, même si elle ne correspond pas à la mienne..	☐	☐
Je passe ma mauvaise humeur sur les autres de temps en temps.	☐	☐
Il m'est arrivé de profiter de quelqu'un d'autre..	☐	☐
Dans les conversations, j'écoute toujours attentivement et je laisse les autres finir leurs phrases..	☐	☐
Je n'hésite jamais à aider quelqu'un en cas d'urgence.	☐	☐
Quand j'ai fait une promesse, je la tiens.	☐	☐
Il m'arrive de dire du mal des autres dans leur dos.	☐	☐
Je ne vivrais jamais aux crochets des autres..	☐	☐
Je reste toujours aimable et courtois avec les autres, même lorsque je suis stressé.	☐	☐
Pendant les disputes, je reste toujours objectif et concret..	☐	☐
Il m'est arrivé au moins une fois de ne pas rendre un objet que j'avais emprunté.	☐	☐
Je mange toujours sainement.	☐	☐
Parfois, j'aide seulement parce que j'attends quelque chose en retour.	☐	☐
[1 mandatory answer per row]		

Vous y êtes presque. Nous avons quelques dernières questions à propos de vous et de votre foyer.

Q32	Quel est votre sexe ?	O Homme O Femme O Autre

Q33	Comment pouvez-vous décrire au mieux votre situation familiale ?	O Célibataire, sans enfant sous le même toit O Célibataire, avec enfants sous le même toit O Couple, sans enfant sous le même toit O En couple, avec enfants sous le même toit O Autre.
Q34	Quel est le code postal de votre résidence principale ?	Postcode □□□□ (four numbers: 0-9) OU Commune ou ville [text]
Q35	Dans quelle ville ou commune se situe votre activité principale ? Infotext: Où vous allez le plus souvent pour vos activités	Postcode □□□□ (four numbers: 0-9) OU Commune ou ville [text]
Q36	Lequel des termes suivants décrit le mieux votre situation professionnelle actuelle ?	O Travailleur (employé/fonctionnaire) O Ouvrier O Management O Profession libérale O Indépendant O Entrepreneur O Pas d'activité professionnelle pour le moment
Q37	Quel est actuellement le plus haut diplôme ou certificat que vous avez obtenu ?	O Maximum enseignement secondaire supérieur O Enseignement supérieur
Q38	Quel est le revenu net annuel approximatif de votre ménage ? Infotext: Le montant que votre ménage gagne ou acquiert chaque année, après impôts et transferts. Il s'agit du revenu disponible total, disponible pour l'achat de biens et de services.	O Moins de €10 000 O Entre €10 000 et €25 000 O Entre €25 000 et €50 000 O Entre €50 000 et €75 000 O Entre €75 000 et €100 000 O Plus de €100 000 O Pas de réponse

C'est la fin du questionnaire. Merci de votre participation.

Appendix 4: Impact of a speed camera alert on speed – results by session

Session: deploy_20220302_133631

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	276	221	55	53	105.1739	109.6154	19.20290
1	2124	1752	372	378	107.2641	111.2540	17.79661

Session: deploy_20220307_152913

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	243	204	39	46	109.1646	112.9559	18.93004
1	2685	2363	322	443	109.0834	111.9302	16.49907

Session: deploy_20220320_160236

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	292	287	5	87	116.8870	117.2787	29.79452
1	1861	1834	27	597	116.5223	116.8190	32.07953

Session: deploy_20220323_070759_071236

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
1	8192	7345	847	1144	107.626	110.1201	13.96484

Session: deploy_20220323_081716

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	51	46	5	6	105.2353	106.8261	11.764706
1	3202	2467	735	282	102.3810	106.7418	8.806996

Session: deploy_20220402_071500

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	137	134	3	25	112.0219	112.4701	18.24818
1	5021	4814	207	1135	112.9257	113.9518	22.60506

Session: deploy_20220412_072058

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	77	63	14	15	107.5974	112.6667	19.48052
1	4911	4469	442	948	109.7039	111.9996	19.30360

Session: deploy_20220413_073136

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	98	74	24	18	108.2245	115.2297	18.36735
1	2630	2065	565	325	105.8779	110.9506	12.35741

Session: deploy_20220418_100353

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	290	284	6	83	115.4483	115.7676	28.62069
1	2710	2610	100	650	113.9531	114.7061	23.98524

Session: deploy_20220418_163033

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	354	347	7	107	116.1102	116.6513	30.22599
1	4371	4287	84	1499	116.7129	117.1763	34.29421

Session: deploy_20220420_161629

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
1	2389	2189	200	497	111.0435	113.0799	20.80368

Session: deploy_20220503_080246

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	161	152	9	28	109.4472	110.7303	17.39130
1	4400	4068	332	779	109.6973	111.5543	17.70455

Session: deploy_20220506_070023

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	298	266	32	48	108.3423	110.8534	16.10738
1	5931	5413	518	1116	109.1293	111.3440	18.81639

Session: deploy_20220511_090411

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	332	287	45	61	105.5964	108.8014	18.37349
1	3801	3351	450	595	106.8082	109.6455	15.65378

Session: deploy_20220514_081858

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	173	164	9	44	113.1329	114.2744	25.43353
1	2136	2073	63	561	114.2350	114.9889	26.26404

Session: deploy_20220514_082154

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	384	375	9	104	113.9609	114.4987	27.08333
1	6284	6039	245	1342	113.2447	114.1772	21.35582

Session: deploy_20220514_110415

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	209	200	9	46	113.3876	114.5550	22.00957
1	858	815	43	180	111.9639	113.1313	20.97902

Session: deploy_20220517_151506

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	199	183	16	36	110.1759	111.9563	18.09045
1	3004	2619	385	492	108.8322	111.8018	16.37816

Session: deploy_20220529_070808

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	284	280	4	53	113.4155	113.6536	18.66197
1	3787	3666	121	742	113.9649	114.6822	19.59335

Session: deploy_20220531_173231

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	90	82	8	11	109.6111	111.2561	12.22222
1	617	562	55	117	110.6386	112.8861	18.96272

Session: deploy_20220611_065102

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	2407	2316	91	689	113.5941	114.5402	28.62484
1	6294	6051	243	1603	113.2747	114.2586	25.46870

Session: deploy_20220826_081557

Waze_alert	Number of vehicles	Number of cars	Number of trucks	Number of speed violations	Avg speed of vehicles	Avg speed of cars	Share of speed violations
0	1148	1031	117	198	108.3345	110.8244	17.24739
1	5323	4846	477	932	108.7511	110.9216	17.50892

Appendix 5: Big data study: Speed camera locations

Belgium

Nr	Latitude, Longitude	Speed limit	Description
B1	[49.688159, 5.355085]()	70	W → E; rural road with some houses; 1 x 1 lane; speed camera on the right side of the road Warning sign on approx. 160m ("70" sign directly after the camera) Level rail crossing 260m after the camera; Built-up area 600m after the camera (speed limit 50 km/h) 
B2	[49.922013, 5.589093]()	70	S → N; long straight rural road with some houses; 1 x 1 lane; speed camera on the right side of the road Warning sign on approx. 200m 
B3	[51.201514, 4.938595]()	70	E → W; long straight rural road; 1 x 1 lane with trees; speed camera on the right side of the road; no warning sign, but camera is visible Low traffic intensity? 
B4	[50.791186, 4.902842]()	120	N → S; E40 highway; 3 x 3 lanes with a shoulder; speed camera on the central reservation Warning sign on approx. 200m; exit approx. 1km after the camera

			 
B5	[50.473923, 4.555999]	120	E → W; E42 highway; 3 x 3 lanes with a shoulder; speed camera on the central reservation Warning sign on approx. 700m; exit approx. 700m after the camera  
B6	[50.985392, 3.688348]	120	Both directions; E17 highway; 3 x 3 lanes with a shoulder; speed camera on the central reservation E → W: Warning sign on approx. 560m; exit approx. 1km after the camera W → E: Warning sign on approx. 500m; entrance approx. 1km before the camera  
B7	[50.942592, 4.762716]	120	! Camera may have been removed in Spring 2021. E → W; E314 highway; 2 x 2 lanes with a shoulder; speed camera on the central reservation Warning sign on approx. 190m; exit approx. 1.25km after the camera; entrance approx. 1.8km before the camera

France

Nr	Latitude, Longitude	Speed limit	Description
F1	49.036303, 3.252414	70	W → E; rural road with a minor curve right after the speed camera; 1 x 1 lane; speed camera on the right side of the road Warning sign on approx. 700m  
F2	48.376718, 5.156815	70	S → N; rural road; 1 x 1 lane; speed camera on the right side of the road; an intersection approx. 50m before the speed camera; end of “70 km/h” 100m after the camera Warning sign on approx. 1800m  
F3	44.983245, -0.409635	70	W → E; long straight rural road with some houses; 1 x 1 lane; speed camera on the right side of the road Warning sign on approx. 470m (“70 km/h” sign on 140m)

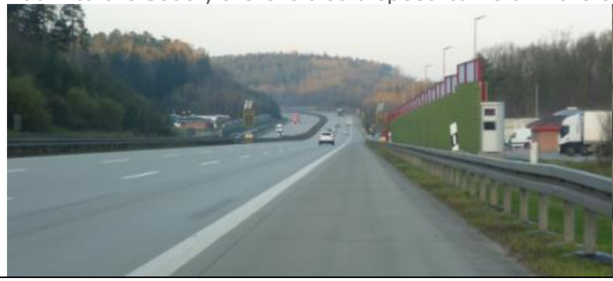
			 
F4	48.957939, -0.226234	110	S → N; regional road/highway; 2 x 2 lanes with a narrow shoulder; speed camera on the right side of the road; bad pavement Warning sign on approx. 550m ("110 km/h" sign on 140m)  
F5	46.428534, 1.475099	130	N → S; highway; 2 x 2 lanes with a narrow shoulder; speed camera on the right side of the road Warning sign on approx. 400m ("130 km/h" sign also on 400m)  
F6	44.574099, -0.316720	130	W → E; highway; 2 x 2 lanes with a shoulder; speed camera on the central reservation Warning sign on approx. 510m ("130 km/h" sign also on 510m)

			 
F7	[47.406693, 6.474526]()	130	W → E; highway; 2 x 2 lanes with a shoulder; some high-speed curves; slightly downhill (maximum speed of 90 km/h for cars with a caravan); speed camera on the right side of the road Warning sign on approx. 900m (“130 km/h” sign also on 900m)  

Germany

Nr	Latitude, Longitude	Speed limit	Description
G1	[51.878032, 9.784342]()	70	! Camera may have been removed. Direction is unclear (probably also for the drivers. E → W (?); rural road with some houses; 1 x 1 lane; speed camera on the right side of the road  
G2	[52.478772, 10.465560]()	70	W → E; rural road with some houses; 1 x 1 lane; speed camera on the right side of the road

			 
G3	[53.106755, 11.026713]()	70	W → E; rural road with trees; 1 x 1 lane; speed camera on the right side of the road; low traffic intensity?  
G4	[54.259481, 12.512320]()	70	Both directions; rural road; 1 x 1 lane; speed camera on the right side of the road, on both sides  
G5	[52.785963, 13.583857]()	120	S → N; highway (straight!) with trees; 2 x 2 lanes with a narrow shoulder; speed camera on the right side of the road; lots of traffic  

G6	[50.960850, 11.851544]	120	N → S; highway; 3 x 3 lanes with a shoulder; speed camera on the right side of the road; the camera is in between the highway and a highway parking; entrance of the parking is approx. 100m before the speed camera; highway entrance approx. 1km before the speed camera 400m to the South, there is also a speed camera in the other direction (S → N) 
G7	[51.373599, 13.746643]	120	S → N; highway; 2 x 2 lanes with a shoulder; speed camera on the right side of the road Exit approx. 1250m after the speed camera 

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