TRUCK PLATOONING

DRIVING THE FUTURE OF TRANSPORTATION

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innovation for life

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EXECUTIVE SUMMARY

Truck Platooning is the future of transportation in which trucks drive cooperatively at less than 1 second apart made possible by automated driving technology. Transportation companies benefit from lower fuel consumption and improvements in (driver) productivity, while society benefits from fewer accidents, safer traffic and less congested roads, and lower carbon emissions.

In this TNO whitepaper, we explain what platooning is, what kind of benefits it brings for which parties in the supply chain, and the roadmap towards deployment of platooning on Dutch and European roads. Developments in the underlying Cooperative Adaptive Cruise Control (CACC) technology have been ongoing for years, yet wide-scale deployment of truck platooning is a system-wide innovation challenge that requires a concerted approach of all stakeholders in society. For instance, policy-makers have to contribute supporting legislation, regulators such as the RDW need to develop safety-focussed type approval methodologies, truck manufacturers and OEM should strive for plug-and-plug compatibility of platooning systems, insurance firms are required to develop new liability coverage schemes, and shippers can urge their carriers and logistics service providers to form as many platoons as possible and change their supply chains, while other road users need to learn to accommodate the two-truck road trains. Right now the political and econom ic climate is positive for a broad deployment of platooning as initial legislation amendments are proposed to allow testing and experimentation on Dutch roads. For this system-wide innovation, we suggest to establish an Shared Innovation Programme, based on open innovation principles. In the programme, we can jointly work towards commercial deployment of platooning to implement a safe, reliable and efficient two-truck platooning concept by 2020.

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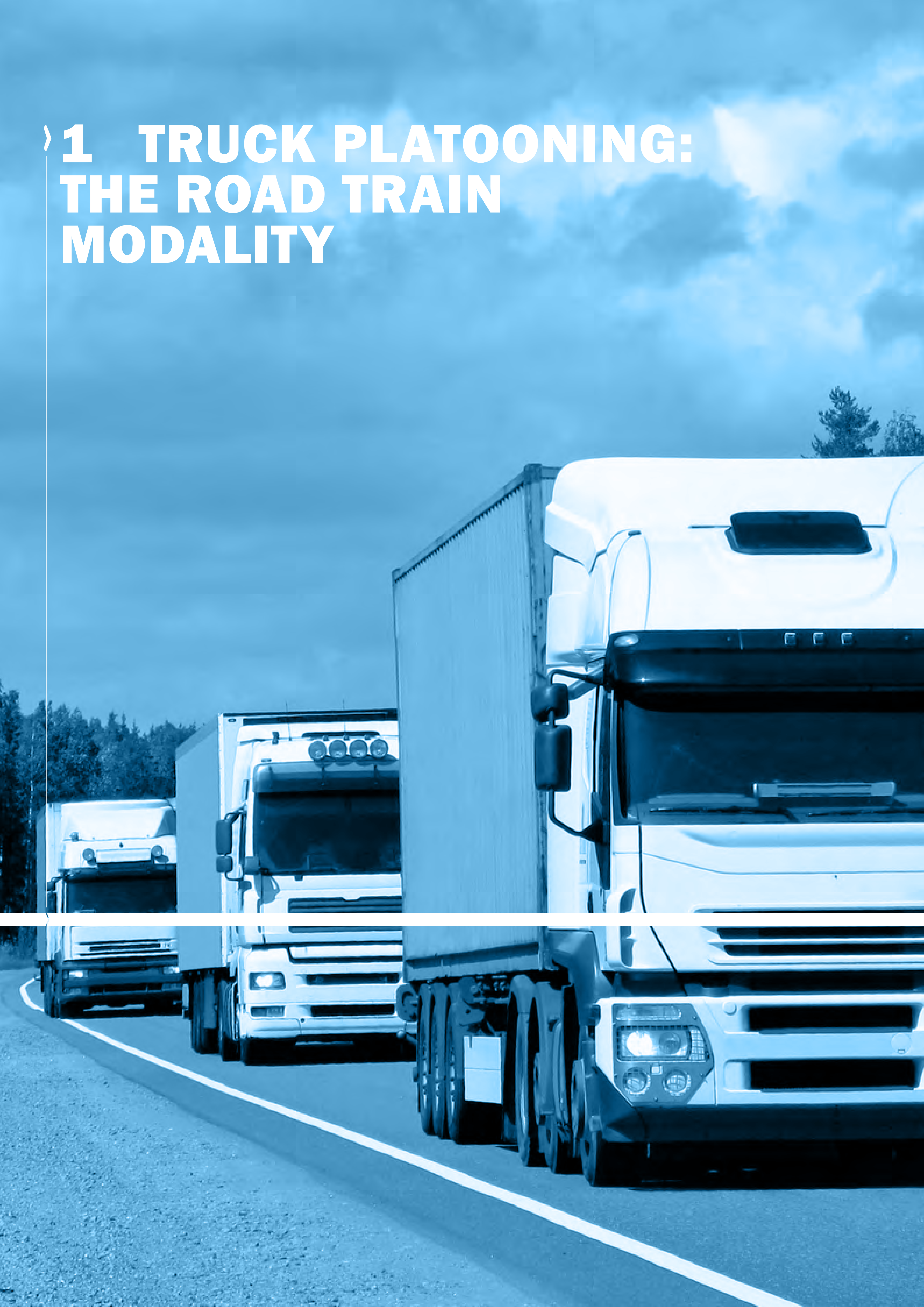


Imagine a self-driving truck as part of a road train. One that can drive solely by communicating with the truck driving in front of it, forming a **truck platoon**. The driver of the leading truck takes the first shift, driving from Rotterdam to Paris. The driver of the following truck is asleep, as their truck automatically follows the platoon leader. Near Paris, the drivers switch their roles and reverse the order of the trucks. The driver of the now following truck can take a nap or perform administrative work. There is no need to stop for a rest; resting can be done while driving. The drivers trade place a few more times. Upon arrival in Madrid, the trucks separate and individually drive to their final destinations.

This advanced scenario may be at least decades away, but within a few years taking the hands of the steering wheel in slow rush hour traffic will be the reality. Self-driving passenger cars have already proved their feasibility on the public road, as TNO has shown on the Dutch A10 highway [1]. Other OEMs such as Daimler-Mercedes, BMW, Audi and Tesla have demonstrated their automated driving solutions. As for truck platooning – the subject of this whitepaper – the investments in research and development are high and promising, not only at TNO but across Europe [2], for instance at Scania, Volvo, and DAF. At TNO, we are in the process of making this possible for truck platoons in the Netherlands by developing technological solutions and implementing these solutions in innovative logistics concepts.

1.1 TRUCK PLATOONS: TWO VIRTUALLY CONNECTED TRUCKS DRIVING AT LESS THAN 1 SECOND HEADWAY

In essence, a platoon of two trucks is like a short train driving on the road, with the trucks driving very closely behind each other (see Fig. 2). The distance between the two trucks can really be extremely small – creating a desirable form of tailgating. The distance can be as low as 0.3 seconds, which at 80 km/h is about 6.7 metres distance between the vehicles. Driving so close together is made possible by advanced Automated Driving technology (AD, see Box 1), in conjunction with wireless vehicle-to-vehicle (V2V) communication that makes it possible that the vehicles communicate with each other (Fig. 2).

Once platooning is activated, a Following Vehicle in the platoon trails the Leading Vehicle. The Following Vehicle now follows the Leading Vehicle automatically, without interference of its driver. Because the vehicles are able to communicate with each another, they can adjust their speed and position without the typically delayed response time of a human driver. The vehicles communicate both ways, so also the Leading Vehicle can adjust its speed or position based on the response of the Following Vehicle. And since the vehicles are wirelessly coupled, it is possible to easily hop-on and hop-off from the platoon on-the-fly. There is no need to stop driving; connecting to a platoon or disconnecting can happen while driving by a push of a button.

Truck platooning: two trucks driving less than 1 second apart, made possible by wireless vehicle-to-vehicle communication

Fig. 1 The Dutch minister Schultz in a self-driving car. (Source: NOS.nl [1])

BOX 1

AUTOMATED DRIVING TECHNOLOGY

Automated Driving (AD) technology offers the possibility of fundamentally changing transportation. The goal of AD technology is to make vehicles drive autonomously, in a safe and comfortably way. Equipping cars and large goods vehicles with this technology will likely reduce accidents, fuel consumption, pollution, and congestion [3].

Many systems that are part of AD technology are already commercially available, such as Adaptive Cruise Control (ACC), Lane Keeping Assist (LKA), Autonomous Emergency Braking (AEB) and Automated Parking or parking assist [4]. Platooning builds upon these technologies, by developing the Cooperative Adaptive Cruise Control (CACC).

The SAE International Levels of Automation for On-road Vehicles lists 5 levels from no automation to full automation, where truck platoon can be placed from levels 2 to 4 included [5].

Summary of Levels of Driving Automation for On-Road Vehicles

This table summarises SAE International's levels of *driving* automation for on-road vehicles. Information Report J3016 provides full definitions for these levels and for the italicised terms used therein. The levels are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. 'System' refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate.

The table also shows how SAE's levels definitively correspond to those developed by the Germany Federal Highway Research Institute (BASt) and approximately correspond to those described by the US National Highway Traffic Safety Administration (NHTSA) in its 'Preliminary Statement of Policy Concerning Automated Vehicles' of May 30, 2013.

Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt Level	NHTSA Level
***Human driver* monitors the driving environment**								
0	No automation	The full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	N/a	Driver only	0
1	Driver assistance	The *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	Partial automation	The *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automised	2
***Automated driving system* ('system') monitors the driving environment**								
3	Conditional automation	The *driving mode*-specific performance by an automated *driving system* of all aspects of the *dynamic driving task*, with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automised	3
4	High automation	The *driving mode*-specic perfomance by an automated *driving system* of all aspects of the *dynamic driving task*, even if a human driver does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automised	3/4
5	Full automation	The full-time performance by an automated *driving system* of all aspects of the *dynamic driving task*. under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**	-	

Fig. 3. SAE International levels of development in Automated Vehicle automation [5].

In general, AD technology are robotic systems that 'sense' the environment using a combination of sensors, such as lidar (light detection and ranging), radar, and cameras. The sensors can also make up for each other's weaknesses and provide redundancy. For instance, if it is extremely foggy on the road, cameras are practically useless. However radar and lidar still work and compensate for the lack of information provided by the camera.

For localisation, an automated vehicle can use global positioning systems (GPS) and inertial navigation systems (INS). Again, if GPS fails temporarily, INS can take over using accelerometers (motion sensors) and gyroscopes (rotation sensors), helping the vehicle to orientate until GPS comes back online. This is a very likely scenario when driving in tunnels where GPS does not work, but the car is still able to orientate itself using INS.

For wireless communication, a specific Wi-Fi standard has been approved: IEEE 802.11p. It is an extension of the Wi-Fi technology (802.11) that we all know from our homes and work environment, but adds support for Intelligent Transport Systems (ITS) applications such as Truck platooning. The 802.11p standard allows data exchange between vehicles (V2V), and for vehicle-to-infrastructure (V2I) communication, and operates at the 5.9 GHz frequency band.

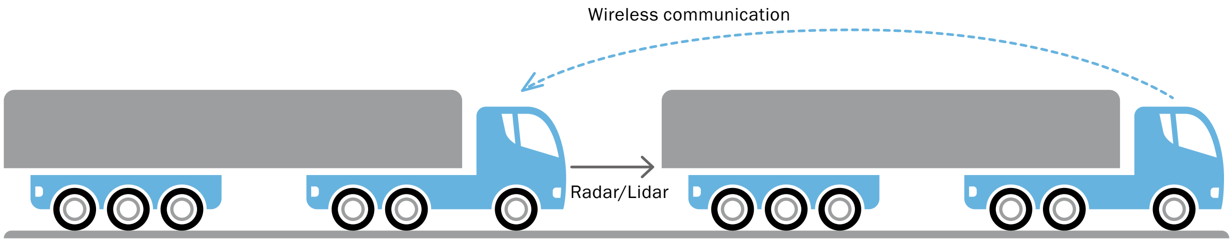


Fig. 2. A two-truck platoon with wireless communication and radar technology

1.2 WHY PLATOONING? LOWER COSTS, BETTER SAFETY, LESS EMISSIONS

Truck platooning has great potential for reducing transport costs, by lowering fuel consumption due to improved aerodynamics from reduced air resistance, eliminating the need for an attentive driver in the second vehicle, and better usage of truck assets, by optimisation of driving times and minimisation of idle time. On the societal level, driving safety increases as typically 90% of all accidents are human-induced, and platooning technology prevents human errors, leading to less accidents and damages. Greenhouse gas and air-quality related emissions decrease, and congestion and traffic jams are reduced. More details on the benefits of platooning are described in Chapter 4.

1.3 COOPERATIVE AUTOMATED DRIVING VERSUS AUTONOMOUS DRIVING

In the media, quite a buzz surrounds Google's driverless car [7]. Google's vehicles, operating fully autonomously, have driven more than 500,000 miles in the United States with no single crash attributable to the automation. The way Google, and some other car manufacturers, consider automated driving should be distinguished from the idea of truck platooning that is the subject of this paper.

The Google driverless car is conceptualised as an autonomously driving car. It does not communicate and share information with other road users. Because the car operates autonomously and the goal is comfort and safety for the driver, it requires more distance between other cars than human drivers would typically allot. This also means it takes up more space on the road and thus actually increases congestion. These driverless cars typically need about 2 to 3 seconds headway, which is more than the 1 second that a human driver normally allocates in busy rush hour traffic in Europe [8].

Truck platooning exists on the principle of communication vehicles: the basis lies in Cooperative Adaptive Cruise Control (CACC)

Truck platooning, on the other hand, exist on the principle of communicating vehicles. That is, the vehicles can 'talk' with each other. The basis lies in Cooperative Adaptive Cruise Control (CACC) technology [8], and the emphasis is on driving as close together as possible, typically at 0.3 seconds or less. Also, it is important to note that the vehicles are 'virtually linked' by means of wireless communication technology. Yet, platooning can be seen as an intermediate step to fully automated driving, so it is not necessary to draw a massive line between the Google car and cooperative-oriented platooning.

1.4 SCOPE: TRUCK PLATOONS CONSISTING OF 2 TRUCKS

In theory, a platoon can consist of many different vehicles, including combinations of trucks and passenger cars. In this whitepaper, we restrict ourselves to **two-vehicle truck** platoons, because we believe this is the right first step for widespread deployment of platooning.

Two-vehicle platoons

Why do we restrict ourselves to only two platooning vehicles? The answer to this is simple: we do not want to intimidate fellow road-users. European drivers, and Dutch drivers in particular, are used to long trucks on the road such as tractor-trailer combinations of 18.75 metres or LZVs (Langere en Zwaardere Vrachtautocombinatie, also known as Ecocombi or Gigaliner) of 25.25 metres. If two LZVs would form a platoon the length of this platoon will be about 57 metres [1]. For a more common platoon configuration, consisting of two regular tractor-trailers, the road use would be over 44 metres [2]. Already at these lengths, truck platoons are expansive 'blocks' that can intimidate fellow road-users and make it troublesome to leave or enter the highway for a car driver. A platoon of than two trucks would really cause trouble for car drivers when having to merge into highway traffic from the on and off ramps. We believe that broad public and political approval of piloting and further upscaling is aided if truck platooning initially is limited to two-truck platoons.

1 The combined train length will be over 50 metres. The distance between the trucks would be about 7 metres, assuming the platoon drives at 80 km/h, at an average headway of 0.3 seconds.
2 18.75 m × 2 + 6.67 m (distance between vehicles).

Trucks instead of passenger cars

Why do we restrict ourselves to trucks, instead of including passenger cars? Transportation is the core business of carriers, freight forwarders and logistics service providers. The advantages platooning can generate, will lead to viable business cases for carriers (see Chapter 4), and give them a strong incentive to install the technology in their trucks. Car-driving civilians use their car less than carriers use their trucks, hence the investment needed to install the technology in their car, will have a much longer return on investment. Also, civilians will only profit from the technology if enough other cars have installed the technology, whereas carriers can profit immediately once they have two trucks equipped with the technology. Therefore, the adoption of platooning technology in passenger cars will have a much longer time-horizon than in trucks.

1.5 TOWARDS WIDESPREAD DEPLOYMENT OF TRUCK PLATOONING

As you can imagine, the introduction of platooning will cause a paradigm shift in road transportation and supply chain design. Carriers can obtain higher profits by collaborating with other carriers in order to platoon as much as possible. To enable this collaboration between carriers and to enable on-the-fly platooning, a service provider will arise to connect the trucks of different carriers. Hence, the introduction of platooning cannot be separated from an analysis of the supply chain. Platooning will only become successful if the crucial stakeholders in the supply chain have a positive business case with regards to platooning. To that end, we draw a broad view of the development paths of platooning (Chapter 2), a supply chain analysis (Chapter 3), and the carriers' business case (Chapter 4). We also discuss the barriers and risks that need to be overcome in order to make platooning for trucks an everyday reality (Chapter 5). Finally, a step-by-step approach is described to introduce platooning (Chapter 6). Starting small, but eventually changing the world of logistics.

Fig. 4. Platooning technology will eventually allow pelotons beyond two vehicles (Source: Road Safety GB [9])

2 A BRIEF GLANCE INTO THE FUTURE: PLATOONING 2020

This section describes how we see the development of truck platooning. We first identify three development stages, and subsequently show various development paths – future scenarios of truck platooning. And more importantly, we show how three logistics firms, ECT, De Winter Logistics, and Peter Appel Transport, see the potential of platooning in their day-to-day operations.

2.1 TIMELINE OF PLATOONING DEVELOPMENT STAGES

A phased implementation is crucial for widespread acceptance of platooning technology in the society at large, and especially of other road users. We expect that large-scale deployment in the commercial transportation industry is possible within approximately a five year period [10] (see Fig. 5), so that in 2020, a form of truck platooning (e.g., SAE levels 2 or 3) is legally permitted and commercially available. More extensive applications of platooning (e.g., SAE level 4 or 5) are not expected before 2030. Of course, there is a fair amount of guesswork in this timeline, as timing is very much dependent on political support, innovation funding, technological advancement, and public acceptance. This timeline is elaborated in Section 6.2, in which we propose to commission a five-year Dutch open innovation programme towards the goal of commercial platooning in 2020.

In terms of development process, we might compare truck platooning with the growth trajectory of the LZV developments in the Netherlands. Initial small-scale experimentation started in 2000, the first wide-scale tests initiated in 2006. Final developments were wrapped up in 2012 when the LZV was officially allowed on Dutch main roads, so about 6 years later [11]. Leveraging the encouraging experience of the LZV, we expect that developments will be along the lines of the LZV, such that platooning trucks are officially allowed on Dutch main roads in about five years' time [10]. Required changes to European legislation and alignment in Dutch legislation with regard to driving/resting times (EC 561/2006) and the digital tachograph (EEC 3821/85) legislation will be among the greatest threats to this timeline, as well as the technological difficulty associated with ensuring robust control over the platoon under all circumstances.

We expect that truck platooning is legally permitted and commercially available in five years' time.

2.2 DEVELOPMENT PATHS OF 2-TRUCK PLATOONING

Where will platooning technology take the transportation industry? From driving on closed infrastructures such as terminal yards to platooning on public roads, perhaps even crossing country borders. The platoon can be formed by logistics planners in the office, or better yet, formation can happen on-the-fly, connecting to a nearby driving truck. And finally, what about a truck without cabin? That is possible when the driver in the Following Vehicle can be replaced by the platooning technology, and the Following Vehicle autonomously trails the Leading Vehicle.

In this section, we show three main development paths of truck platooning (see Fig. 6) that signal the breadth of potential platooning applications: a growth in (1) infrastructure usage, (2) platoon formation, and (3) level of automation. These development paths indicate how platooning can be deployed in our society. Trajectories that can start small and easy, and scale up later. The small-scale paths can be used as a proof of concept and will convince the parties involved of the safety and value of platooning. To make it more concrete, we have included some practical applications from Dutch logistics firms in the boxes, that illustrate the development paths.

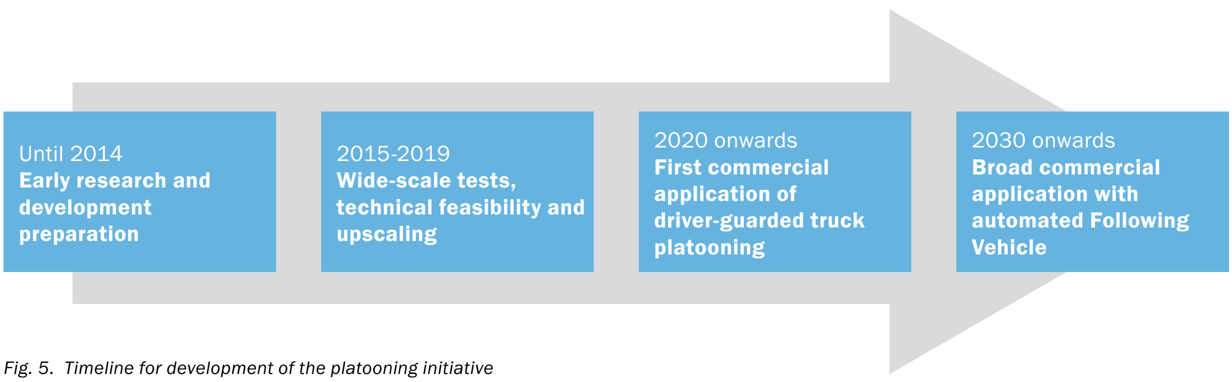


Fig. 5. Timeline for development of the platooning initiative

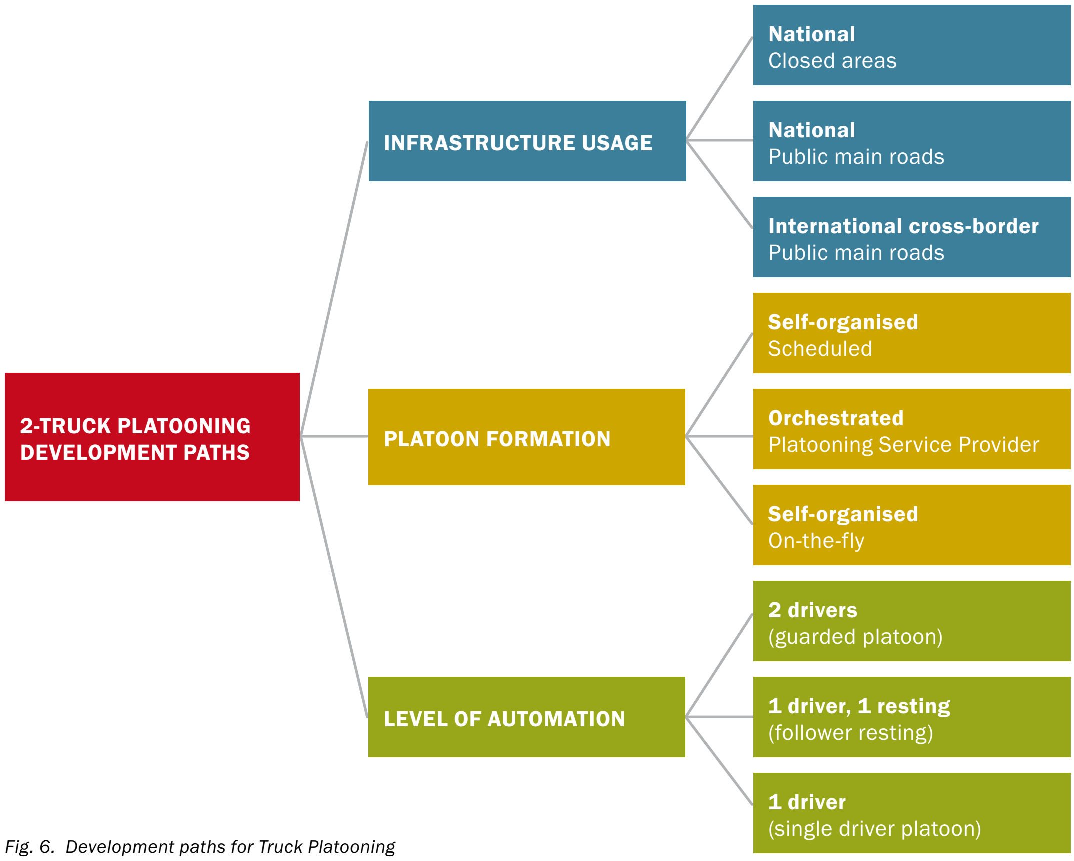


Fig. 6. Development paths for Truck Platooning

2.3 INFRASTRUCTURE USAGE REQUIREMENTS: FROM CLOSED AREAS TO PUBLIC MAIN ROADS

Truck platooning technology will have to prove to be safe and reliable first and foremost, and the best place to test this is on non-public road networks, before platooning can be scaled up to public road networks. So far, large-scale tests on public road networks are not yet legally permitted, but The Dutch Ministry of Infrastructure and the Environment has already reported on a public consultation on how legislation should be amended for large-scale tests on public road networks [12, 13].

The Dutch Ministry of Infrastructure and the Environment has already reported on a public consultation on how legislation should be amended for large-scale tests platooning tests on open road networks

Platooning on closed infrastructure

On closed infrastructure, for instance on a terminal yard or at secured airport areas, experiments can be set up to check the safety of the technology. For instance, human behaviour of drivers in a platoon is a key issue that needs to be investigated, examining how a driver responds to driving in such close proximity of a Leading Vehicle, and what kind of tools and support mechanisms can aid the driver in such situations. Also, it allows logistics companies to try-out various vehicle configurations of truck platoons, such as operating a twin LZV, platoons consisting of dual multi-trailer systems (MTS), and combinations of heavy duty and light duty vehicles. Most importantly, it will help to build the confidence that a single driver can drive the two vehicles in a platoon safely and efficiently.

Platooning on public main roads

Once initial testing on closed infrastructure is underway and the legal barriers preventing platooning on open roads are mitigated, broad large-scale tests on open infrastructure can be conducted. Again, platooning technology needs to demonstrate its safety and reliability. Not just with respect to the drivers and platoon vehicles, but also on how other road users interact with the new platoons on the road, and the effects of platoons on the road infrastructure. Other road users need to get acquainted with truck platoons entering and exiting the highways and learning to accommodate the relatively long road trains. Platoons also need to be able to safely navigate bridges, roundabouts,

BOX 2

INFRASTRUCTURE USAGE

Platooning on (semi-)closed infrastructure at Europe Container Terminals

Europe Container Terminals (ECT) exploits three container terminals in the Maasvlakte port area: the Euromax terminal and the Delta terminal. In the port area, their subsidiary Maasvlakte Transport is active, specialising in transporting containers on and between the terminals at the Maasvlakte over very short distances, such as taking containers from the stacks to the customs' x-ray container scan at the Bosporusstraat.

ECT Euromax Terminal

Aerodynamic advantages from platooning, and resulting fuel savings, do not apply at slow speeds, such as the speeds typically driven on terminal yards

Platooning on closed infrastructure: from Delta terminal stacks to the customs x-ray scan

In order to experiment with platooning on a closed infrastructure, ECT envisages to use platooning technology on the intra-terminal transport at the Delta terminal. For instance, for customs declaration and safety inspection, some containers need to be unloaded from the stacks and brought to the customs x-ray scanner. These extremely short-haul trips from the stacks to the customs scanner are usually performed by Maasvlakte Transport. Since the containers are transported at low speeds (e.g. 30-50 km/h) and aerodynamic advantages do not apply at low speeds the fuel usage benefits are very limited, if non-existent. Still, a positive business case could emerge if they only need a single driver to transport a two-truck platoon to the customs scanner and back (see Section 4.4).

Platooning on public roads: container transports from Euromax to customs x-ray scan

Another application for ECT would lie in moving containers between the Euromax and customs x-ray scan. The 16km-trip from the Euromax terminal to the x-ray scanner over the Maasvlakteweg at the far end of Maasvlakte II, which is actually part of the open road network (Fig. 7). However, since it so remote, it is used almost exclusively for professional transport. Due to the lack of other road users, safety and reliability are easier to maintain, which makes it an ideal opportunity to experiment with truck platooning. Maasvlakte Transport, as one of the companies able to efficiently execute these transports, would be able benefit from fuel usage improvements and emission reductions, as regular trucking speeds can be achieved on the Maasvlakteweg. At the same time, they can experiment with having a single driver managing a two-truck platoon, reducing labour costs.

Fig. 7. Platooning on public roads: from the Euromax terminals to custom's x-ray scan over the Maasvlakteweg (16 km)

Terminal container move

and tunnels. While we do not expect that, for instance, bridge strength would be a limiting factor for application of platooning, it still warrants further examination. Similarly, the European SARTRE project found that platooning would require some adaptations to the infrastructure. For instance, road-side barriers are only built on 'catching' one vehicle at a time, as opposed to a whole platoon [14].

Eventually, we foresee platooning across country borders, such that platooning is permitted in the whole of Europe. But even before that is the case, platooning can already bring about significant benefits with applications across the Netherlands as we demonstrate in this white paper.

2.4 PLATOON FORMATION: FROM SCHEDULED TO ON-THE-FLY PLATOONING

Who takes care of forming the platoon? In the first developmental phases a limited number of vehicles will have been outfitted with the platooning technology and devices, and widespread market penetration is still limited. In later stages, platoons might be formed dynamically on-the-fly. Or even by means of a specialised Platooning Service Provider (PSP).

Scheduled platooning

This means the platoon might need to be planned by the regular transport planners of the own transport company. We call this 'scheduled platooning'. Basically, it is similar to how a transport company planner already plans regular transports, in this case making sure two trucks depart at the same time.

On-the-fly platooning

As soon as market penetration of platooning has taken off, it becomes possible to dynamically connect to any other truck. Similar to being able to connect to any WiFi network with your cell phone, it would be possible to link with any truck, which we call 'on-the-fly platooning'. Especially with on-the-fly platooning formation, you can imagine that economic and societal benefits can be quite significant, as the number of kilometres platooned can increase dramatically.

For instance, there are plenty of daily transports from the Maasvlakte port area towards the German border over the A15 highway. The key idea here is that all those trucks could form platoons on-the-fly and enjoy improved mileage and perhaps even have the second driver take a short nap until they reach the German border, where they would need to disconnect as long as legislation does not permit continuation of the platoon across borders. Since it does not matter what kind of cargo is carried by trucks, the 2-truck platoons can be formed with container carriers, bulk trucks and distribution vehicles, et cetera. For instance, near the Botlek tunnel, traffic data shows there are 12 trucks passing by per minute, which underlines there is great potential for on-the-fly platooning on such key transport corridors as the A15 highway.

12 trucks per minute pass the Botlek tunnel on the A15 – meaning a huge potential for dynamic on-the-fly platooning

BOX 3

PLATOON FORMATION

Scheduled platooning for inter-DC retail transports at Peter Appel Transport
Peter Appel Transport transports about 100 shipments per day from the Albert Heijn distribution centre in Geldermalsen (LDC) to supply the 4 regional distribution centres (RDCs) in Zwolle, Tilburg, Zaandam, and Pijnacker. These DC-to-DC flows are ideal candidates for scheduled platooning.

PETER APPEL Transport

Peter Appel Transport platooning mock-up

From Geldermalsen to Zwolle: 70% of the distance can be platooned
The trip from LDC Geldermalsen to RDC Zwolle is about 123 kms one-way. Peter Appel Transport estimates that 70% of that distance, approximately 86kms, is driven on major roads with cruise control engaged. This would be ideal circumstances for truck platooning. Peter Appel Transport noted that platooning would initially only occur with trusted partners, that is, other logistics service providers of Albert Heijn, and essentially competitors of Peter Appel Transport. Scheduling these platoons would be possible, as Albert Heijn is already building a Retail Control Tower together with its logistics service providers, and software partners, in which all relevant order data and transport assignments are aggregated [15].

Still, an important trade-off has to be considered between the benefits of platooning and the impact on DC operations. For example, it is quite customary to balance shipments over a day. That way, distribution centres and warehouses do not get flooded with a lot of shipments at the same time, clogging their operations. Yet, in order to form a platoon, a transport planner needs to synchronise two shipments together. This can get in the way of warehouse operations and efficiency and thus needs to be off-set with the potential benefits of driving in a platoon, in order to avoid local sub-optimisation.

Peter Appel Transport platooning mock-up

The Platooning Service Provider (PSP)

For on-the-fly platooning it is not necessary to know exactly where your platoon partner is going. However, for reasons of safety and trusting your platooning partner – especially if you are the driver of the Following Vehicle – you might want to know where your platoon partner is going, whether the leading driver took the required rests, and whether the Leading Vehicle is in good mechanical shape and maintenance is alright. This is where we see a role for Platooning Service Providers (PSPs). A PSP can be considered a control tower or orchestrator that acts as an intermediary between various transport companies in order to establish platoons. The PSP takes care of forming the platoon by having detailed routing schedules and transport plans available from all kinds of transport companies. Also, PSPs can establish quality schemes such that truck drivers can have the confidence that on-the-fly platoons are only formed with 'trusted partners'. The PSPs also deal with administrative duties from the platooning activities, arrange insurances, and make sure that benefits of platooning are distributed fairly among the platooning partners.

2.5 LEVEL OF AUTOMATION: FROM TWO DRIVERS TO ONE DRIVER

The ultimate ambition of automated driving is to let technology take full control of all vehicles without any driver involvement [3]. But that is still some decades away; the first step is to have a platoon consisting of two vehicles with two active drivers.

Guarded platoon

Initially, if Dutch and European legislation have not caught up with automated driving developments yet, and public acceptance needs to be build, the driver of the Following Vehicle still has to keep its attention on driving, and 'guards' the platoon [16]. It might be perceived that two drivers are a relatively safe and dependable option, not too far-removed from the current non-platooning world. Added benefits are that platoons with two drivers can easily be disconnected if needed to traverse more complex traffic situations such as roundabouts, cloverleaf interchanges, and on- and off ramps.

Follower resting

As legislation is revised, the second driver can be allowed to take his resting time, or to be just inattentive, whilst being in a moving vehicle [16]. He may sleep, read a newspaper, do administrative work or play a game on a tablet device. It can still be beneficial to have the second driver actually in the vehicle, in order to disengage the platoon near the final destination and have both drivers individually drive the last mile.

As legislation is amended, a driver can be allowed to take his resting time in a moving vehicle.

Single driver platoon

The aim for truck platooning resides in the second big development: being able to let the second vehicle drive autonomously following the first truck without an actual driver in the cabin, that is: two trucks, one driver. This option can have significant man-hour cost reductions, for instance if applied on relatively long-haul transport that takes place multiple times per day. As soon as the platoon reaches the built-up area or a terminal site, the last mile can still be executed by an additional driver that is picked up at the start of the last mile. Of course, this scenario requires, amongst others, close examination of interference with European digital tachograph regulations [17, 18], and there are quite some other barriers, which we discuss in Chapter 5.

BOX 4

LEVEL OF AUTOMATION

Every day, many transports of flowers and plants happen between the auction sites of FloraHolland. De Winter Logistics is one of the logistics service providers executing such transports, for instance between the auction sites in Naaldwijk and Herongen (just across the German border near Venlo). Almost 200 kms is driven over Dutch provincial roads and highways with just the last 3 kms driven in Germany. This provides a desirable setting to use platooning. Especially since De Winter Logistics does quite a number of these transports per day, it is possible to form many platoons.

Docking at De Winter Logistics

Beyond platooning: innovations like Stop-and-Go, Automated Docking and C-AEB use the same technological principles

De Winter Logistics executes inter-auction transports

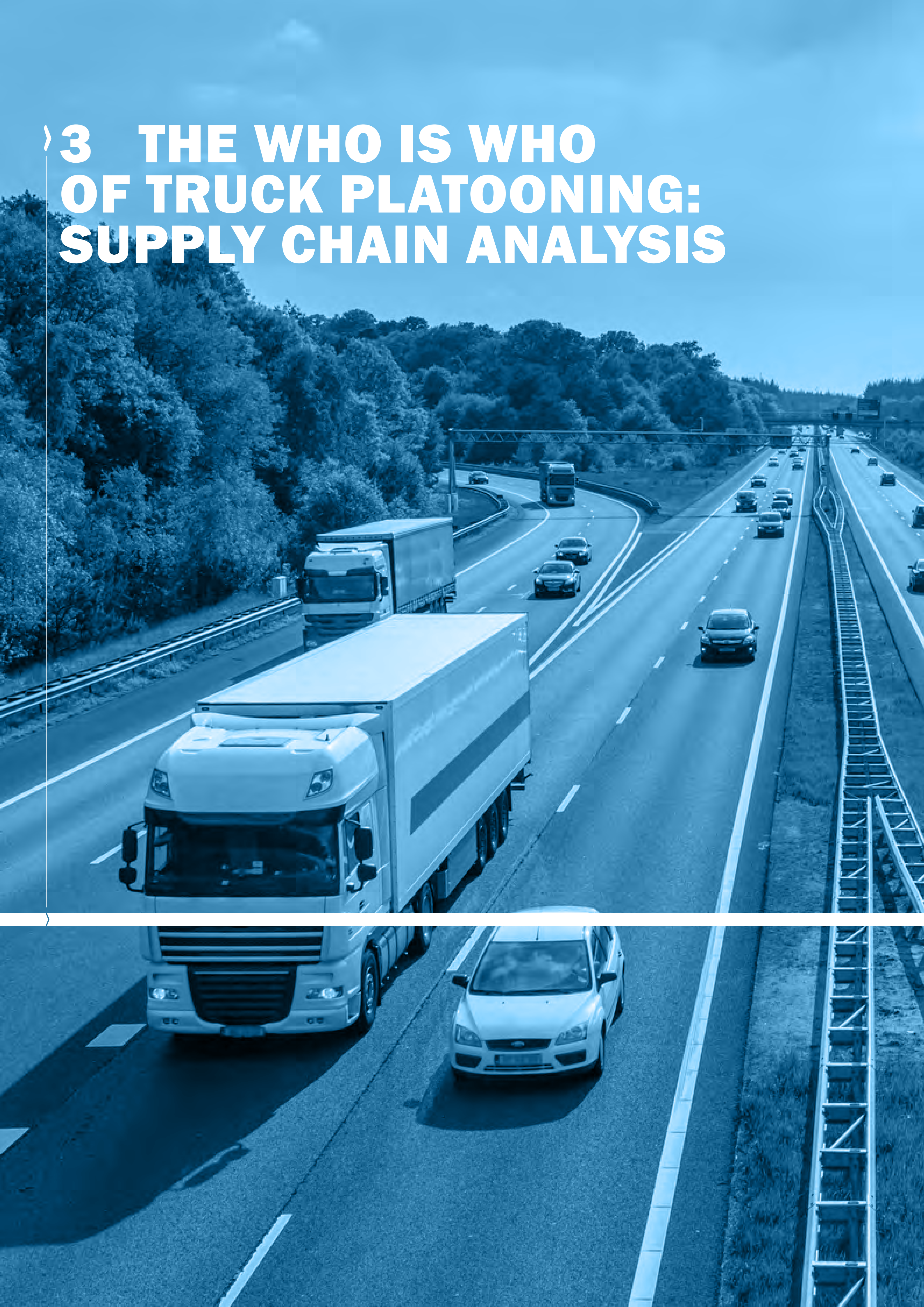
Currently, De Winter Logistics executes these so-called inter-auction transports with tractor-trailer combinations and some LZV combinations, as the major share of the haul is over LZV-approved roads [19]. Truck platooning can be applied on the main highway haul, just having to disconnect the platoon at the German border if required by German law. This leads to fuel usage improvements already in the guarded platoon and follower resting scenarios. If it would be allowed for the driver of the Following Vehicle to rest in their moving vehicle, De Winter Logistics would be able to improve turnaround times and effective driving time. Benefits can be even larger in the 'single driver platoon' scenario, in which there is no driver in the Following Vehicle and in which both fuel and labour cost reductions are present. Section 4.4 shows the real-life business case behind these scenarios.

Automated docking at auction sites

Typically, the platoon needs to be disbanded near the final destination, driving the last mile individually. Also, docking usually needs to be done by a real driver. That means that a second driver needs to be picked-up at the start of the last mile, just to drive the last mile and take care of docking, loading and unloading. That limits the potential of platooning. Note, however, automated vehicle technology makes it possible to do docking automatically as well, using Automated Docking and Parking systems so that there is no need for a driver just for the last mile. Also other valuable innovations are developed in conjunction with platooning, such as Stop-and-Go support, Lane Keeping Assist, Blind Spot mitigation, and Cooperative Autonomous Emergency Braking (C-AEB), jointly enhancing safety, efficiency, and comfort.

De Winter Logistics LZV for use in inter-auction transports

3 THE WHO IS WHO OF TRUCK PLATOONING: SUPPLY CHAIN ANALYSIS



Platooning will cause a shift in the logistics and supply chain network. More specifically: platooning entails a system-wide innovation, that impacts every party involved with shipping and transportation. In order to deploy platooning in society a concerted effort of all stakeholders is needed. Shippers will encourage carriers to collaborate, even among competitors, to form platoons and exploit the synergy potential. To enable platooning on the fly, a Platooning Service Provider will arise to mediate platoon formation. Carriers and logistics service providers source the technology from truck manufacturers and OEMs, but only if platooning is compliant with legislation. Policy-makers and regulators can facilitate this change. This chapter shows who is involved in the introduction of platooning and describes their (changing) role, in order to achieve commercial deployment of platooning in 2020.

Platooning is a system-wide innovation: a concerted approach of all parties is needed for large-scale deployment in society

3.1 STAKEHOLDERS: DEVELOPERS, USERS, POLICY-MAKERS AND REGULATORS

For platooning, there are four key categories (Fig. 8) of stakeholders, being (1) developers and (2) users, both on the commercial side of the innovation. Then there is the enabling side of the innovation, consisting of (3) policy-makers and (4) regulators. Of course stakeholders can be united or represented in groups, such as branch organisations. We consider these unions as part of the stakeholders. For instance, a branch organisation for carriers, will be part of the group 'carriers'. We discuss the stakeholders' interest and roles in truck platooning in the next section.

3.2 DEVELOPERS: TRUCK OEMS AND TIER SUPPLIERS

Developers are involved in the technical development and facilitation of the equipment and complementary technologies. There are two distinct stakeholders here:

- **Truck manufacturers, Original Equipment Manufacturers (OEMs)**. Truck manufacturers such as DAF, Volvo, and Scania produce trucks, and they themselves can integrate technological innovations – in a role as OEM – that enables platooning, primarily through the Cooperative Adaptive Cruise Control (CACC). For the truck manufacturer, first mover advantages apply, as being the first manufacturer delivering trucks that are able to form and join platoons will give the opportunity to gather a bigger market share. Other advantages are insights in the test requirements and type approval, and a positive effect on image and marketing. Although first movers gain advantage, it is in the interest of all manufacturers that there is standardisation and compatibility of platooning technology among different makes and brands. The technology roadmap for platooning introduces opportunities for additional functions or services such as Automated Docking and Parking, and cooperative functions such as low-speed Stop-and-Go, and Cooperative Autonomous Emergency Braking (C-AEB).
- **Tier suppliers**. Tier suppliers provide components or products that are used to assemble a truck. Tier suppliers will add the required communication hardware to their catalogue if there is a demand from the truck manufacturers. They provide the hardware for new trucks, but also provide retrofitting the current truck fleet.

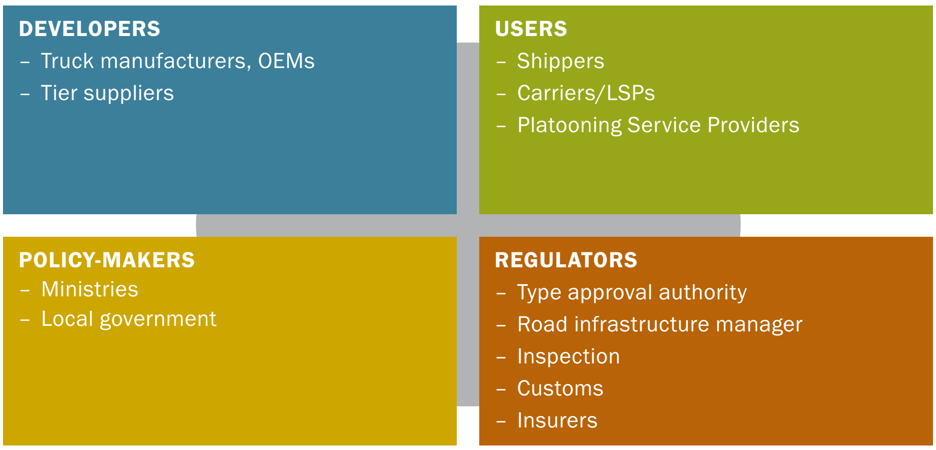


Fig. 8. Stakeholders influenced by the platooning innovation

3.3 USERS: SHIPPERS, CARRIERS, AND PLATOONING SERVICE PROVIDERS

Users of platooning technology are the parties involved in logistics (Fig. 9):

- **Shippers**. Shippers want their products to be transported from one location to another. Although their role in the process will not change, their influence in the implementation of platooning could be significant. When carriers that use platooning can deliver goods for a lower price, these carriers will be preferred over their non-platooning competitors. This implies that part of the platooning benefit is appropriated by the shipper, rather than just the carrier. Platooning will not be suitable for all types of shippers, but as mentioned earlier, there are cases which would benefit from platooning. Shippers that hold sustainability and emission reduction as a key performance indicator, also benefit from platooning, as the technology allows significant fuel savings and resulting emission reductions.
- **Carriers and LSPs**. Carriers and LSPs transport products that are commissioned by shippers. We elaborate on the business cases for platooning for carriers in Chapter 4. Carriers articulate their wishes for equipment to the truck manufacturers as they are the main beneficiary of platooning. Due to their central position in the sector their role changes during the implementation phases. For platooning within their own company, they must adapt their planning processes to enable platooning. However, benefits will be larger when they platoon with other carriers, perhaps even competitors. Carriers that are innovative and early adoptors of new technologies will be the first to benefit from costs reductions due to platooning.
- **Platooning Service Providers**. Platooning requires a different way of planning logistics. Matching the combination of trucks becomes a new additional service. Platooning Service Providers do not yet exist, but it is plausible that at some point in time, they will arise to provide services around platooning, with the significance of their role developing through time. During the initial development phase of platooning, a minor adjustment to the transport management software of a carrier is sufficient. However, when trucks of different carriers cooperate and platoon on-the-fly, an independent service provider is necessary to link the trucks. Using a Platooning Service Provider, as neutral third party, may also foster trust between the platooning carriers. To that end, the PSP will ensure that insurances are in order, maintenance reports exchanged, an agreement is settled on the division of benefits among the participants in the platoon and on-time payments are safeguarded. For the PSP, in the end it is a numbers game: the larger the pool of participating carriers and shippers, the more trucks will be matched into platoons, and the larger their resulting management fee.

Platoons can be established by a Platooning Service Provider, which fosters trust among platooning partners and takes care of administrative back-office duties

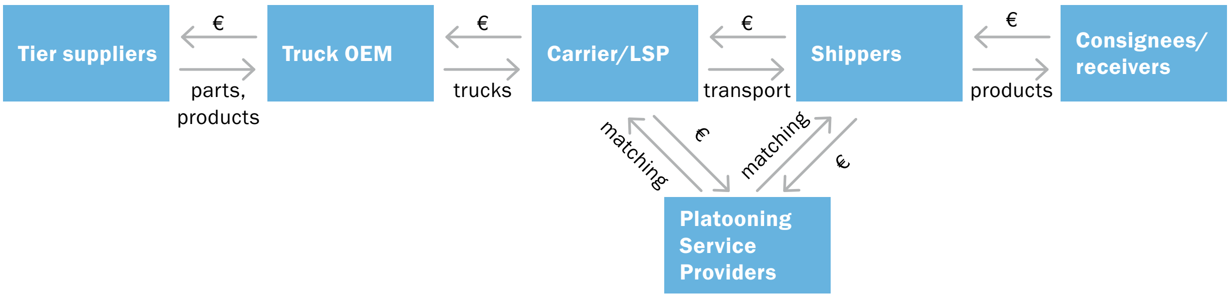


Fig. 9. Value network showing operational platooning and services exchanged

3.4 POLICY MAKERS: MINISTRIES AND LOCAL AUTHORITIES

There are actions, mostly related to legal aspects that need to be taken before platooning can become reality. How long and heavy can a platoon be? During which times are platoons allowed to drive on public roads? Can the law around driving and resting times be adapted for the driver of the Following Vehicle? Can the second driver eventually be omitted? These are just a few examples of questions that policy makers must answer. The most important policy makers, and their interest and role in platooning are:

- **Ministry of Infrastructure and the Environment**. The interest of the ministry is to have enabling innovations in The Netherlands. These innovations can target better usage of existing infrastructure, increased accessibility and reduced environmental impact of the transportation system. The ministry has different subsidising programmes that could integrate platooning.
- **Ministry of Economic Affairs.** Their interest is competitiveness of The Netherlands, using high end technological innovations to maintain a strong position in Europe. The ministry has different subsidising programmes that could integrate platooning.
- **Local authorities**. The interest of the local authorities is to increase the innovation in their region. Local authorities can permit platooning on the local road. A local authority focused on innovation could permit the testing of platooning on a local road.

3.5 REGULATORS: TYPE APPROVAL AUTHORITY, ROAD INFRASTRUCTURE MANAGER, LAW ENFORCEMENT, INSURANCE

Regulators enforce the law or make the law implementable. The most important regulators for platooning are:

- **RDW**. The RDW is responsible for the type approval and licensing, so has multiple interests for platooning. Trucks equipped with technology that enables platooning must have type approval before they are allowed to use the technology on public roads. A strong safety case and enough test kilometres are needed to get the type approval. The other role of the RDW is the licensing of truck drivers. Truck drivers of a platoon have additional responsibilities, so additional training is required. Both the type approval and the licensing are innovative in Europe, so being the first to have type approval and a licensing procedure for platooning may attract other countries to use this knowledge. The RDW has test facilities available that could be used for the first field tests of platooning.
- **Rijkswaterstaat and local/regional road authorities**. Rijkswaterstaat is responsible for the maintenance and expansion of the road infrastructure network, and will investigate the impact of platooning on road capacity, the environment, the road safety, the incidents and road works. Rijkswaterstaat tries to enable innovation in traffic and transport systems that increase the effectiveness of the road network.
- **Inspection Living Environment and Transport (ILT)**. The ILT has regulations for enforcement of driving and resting times for truck drivers (e.g., EC 561/2006). Different aspects of platooning have influence on the driving task of the truck driver. The truck driver in the second truck of the platoon has a reduced required alertness, which could be seen as resting time. This is linked to European digital tachograph law (EEC 3821/85), which requires amendments or provisions to enable platooning.
- **Customs**. The Customs Authority has procedures on (documents of) cargo that require a truck driver to be present in the truck, as the driver needs to be able to show the documents when needed. Cross-border platooning may also require new customs legislation to be developed.
- **Insurers**. Since liability is addressed in law, although a commercial party, insurance firms also need to adapt to platooning. Normally, a driver would be responsible for an accident, but what if the driver is no longer present in the vehicle – who is liable in that case? Perhaps the truck manufacturer who developed the platooning software, or maybe the driver in the Leading Vehicle? Insures could see platooning as a strong threat to their existence, as accidents caused by human error will be reduced by platooning, meaning insurance becomes less attractive. Also, in case of accidents, system faults in the combination of two trucks of different companies are difficult to trace. An auditable trace, in turn, introduces privacy issues. There are a lot of open questions to be addressed by the insurance community to be able to insure platoons, such as how many kilometres have to be driven in order to insure an OEM platooning solution?

4 PLATOONING BRINGS GREAT VALUE: BUSINESS CASE ANALYSIS

Art Konovalov – shutterstock.com

Carriers and logistics service providers are motivated to use platooning when the business case is positive i.e., the monetised benefits exceed the costs. When societal benefits are large, the government is encouraged to adjust regulation and make platooning possible. This chapter delivers a cost-benefit analysis of platooning.

First, all the benefits and all the costs are described. Next, we zoom in on the three logistics firms ECT, De Winter Logistics and Peter Appel Transport. We discuss three real-life business cases, in which we analyse the annual financial benefits and costs for the logistics service provider once platooning is implemented.

4.1 BUSINESS VALUE AND SOCIETAL VALUE OF PLATOONING

Platooning has the potential to deliver many business and societal benefits. Fig. 10 shows the key benefits that we explain in more detail next.

Less fuel consumption from aerodynamic drag reduction

Both trucks driving in a platoon, have a decreased fuel consumption compared to the benchmark situation, which we state as regular cruise control driving. The fuel reduction of the Following Vehicle varies between 8-13%, according to the SARTRE project [20]. Also the Leading Vehicle has a significant fuel reduction; 2-8% [20]. This amounts to approximately 2.0 L to 3.3 L per 100 km for the Following Vehicle, if we use an average mileage of 0.25 litre per kilometre.

Since we look at two-truck platooning, we can use the average of the Leading and Following Vehicle in our calculations. We work with an average fuel saving of 10% per truck driving in a platoon. With a diesel price of € 1.20 per litre and a usage of 0.25 litre per kilometre [14], two trucks driving 100,000 kilometres annually, platooning can save € 6,000 on fuel compared to driving with cruise control.

Platooning yields average fuel consumption reductions of 10%, with both the Leading Vehicle and Following Vehicle enjoying savings

Emission reduction

A reduction in fuel usage is not only beneficial for the financial situation of the carriers, but also for society. After all, reduction in usage of diesel, means a reduction of congestion, CO_2 footprint and fine dust. Thus, platooning is better for the environment than driving without platooning. With an average CO_2 emission of 2.6 kg per litre of diesel, a 10% fuel reduction can lead to substantial environmental benefits. Since CO_2 is not transferable in logistics, we do not take this into account in the business case for the carriers.

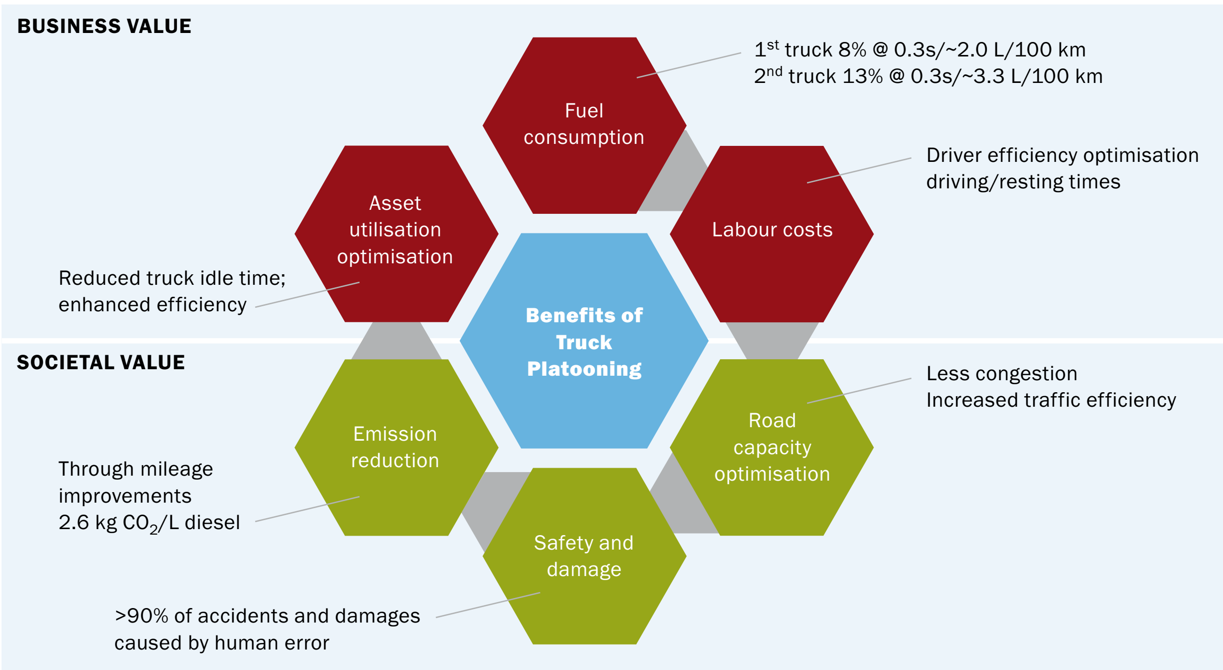


Fig. 10. Benefits of Platooning

Labour costs

Platooning will eventually result in better utilisation of driver capacity. In a later stage of the deployment of platooning, when legislation is altered, the driver of the Following Vehicle might be omitted completely. In an earlier stage, the driver of the Following Vehicle might be allowed to rest while his truck is still driving, thereby optimising the resting times and minimising truck idle time. Hence, the savings that can be obtained, depend on the stage of implementation. We refer to these two situations as Scenario A – 2 trucks - 2 drivers, and Scenario B – 2 trucks - 1 driver, respectively.

Below we detail the expected benefits for a carrier regarded improved utilisation of labour . The resulting reduction in man-hours is not only a benefit for the carrier, but also for society. Drivers are getting scarce in the Netherlands, as a shortage is expected within a few years [21]. Platooning will cause a shift in the labour market, in which demand for lower skilled drivers and jobs is substituted for a higher demand in skilled labour, for instance people working at Platooning Service Providers. This fits the Dutch labour market supply better.

Scenario A. 2 trucks - 2 drivers

When there are two drivers per platoon, we assume for the business case that the driver of the Following Vehicle can rest while at the same time being productive as his truck is still driving (the plausibility of this assumption depends on the law and implementation phase). When the trucks and their drivers switch places every now and then – the Following Vehicle becomes the Leading Vehicle and vice versa-, the resting times can be reduced compared to the benchmark situation. In the business case we assume, based on interviews with the carriers, the optimisation of resting times can save 45 min. per driver per workday.

Scenario B. 2 trucks–1 driver

When there are two trucks and one driver, this means a reduction of one driver. However, platooning is never applicable all the time and loading and unloading still needs to be done. It depends on how much of the time drivers drive on the high-way, how many man-hours can be saved. From the interviews, it appeared that about 15% to 25% of the labour time can be saved by platooning in this scenario.

Asset utilisation optimisation

Can platooning reduce the idle time of the trucks? The answer to this, depends again on the stage of implementation. With one driver per platoon, there is no difference. However, with two drivers per platoon, the assumption is that the idle time can be reduced.

Scenario A. 2 trucks - 2 drivers

When we again assume that the driver of the Following Vehicle can rest while his truck is still driving, trucks can be used more efficiently and drive more kilometres per year. We assume that the number of extra hours a truck can drive, is the same as the reduction labour time of the driver. After all, since a driver rests while driving, the route is accomplished faster, the truck is earlier at its destination from which it can start a new route. Thus, a truck is additionally employable for 45 min. a day.

Road capacity optimisation

Platooning will allow a more optimal use of the available road capacity. Considering a normal situation with 2 trucks driving 80 km/h with a 2 seconds gap. With a truck length of 18.75 metres this results in a claim of 82 metre road, excluding the gaps in front of the first truck and behind the following truck. Using platooning, a 0.3 second gap would decrease the length of those two trucks with 46% to 44 metres. With platooning the existing roads will suffice longer without the need for additional lanes or roads, especially on road segments with a high percentage of trucks, so road investment projects could be delayed.

Safety

Platooning technology will only be introduced and accepted by society if it is (close to) fail-safe. Since more than 90% of the accidents are caused by human error [22], this implies a drastic decrease in accidents. This in turn implies fewer fatalities and wounded, less traffic jams and a higher work productivity – there is less absence of work due to accidents and traffic jams. At the moment of writing, the exact impact of platooning on safety is not yet known. Therefore no estimation can be made yet of the benefits that this will bring.

Over 90% of all traffic accidents are caused by human error. Platooning holds the promise to overcome these human-induced accidents

4.2 COSTS OF IMPLEMENTATION

There are various costs involved with the implementation of platooning. These costs can be divided in two categories. The first category are societal/governmental costs, such as the time investment to adjust legislation, the possible adaptation of infrastructure and the possible additional maintenance costs of infrastructure. Also, there are costs involved with the development and refinement of the technology. At the moment, these costs are not tangible enough to be discussed in detail.

Next to this, the second category consist of more tangible costs that the carriers need to pay once they acquire and use the technology. We discuss these costs in more detail, since they are relevant for the business case for the carriers. We discuss the costs for a carrier implementing platooning, additional to the current situation without platooning. Some costs, such as installing the technology, are part of the initial investment. We convert these into annual costs, in order for the business case to give a clear overview. Box 5 gives an overview of these costs. Note that we do not take interest rates into account, since the assumptions are so rough that this would create only an appearance of precision.

Technology

Trucks need to be equipped for vehicle to vehicle communication, communication with the driver and with the necessary additional safety measures. Currently, those costs are about € 10,000 per truck, according to TNO experts who have experience with the implementation of the technology in cars. However, in the future the add-on costs are assumed to be lower, about € 2,000 [14]. With a depreciation term of 7 years per truck, this amounts to € 286 per year.

BOX 5

BUSINESS CASE FOR CARRIERS: THE ASSUMPTIONS

We calculate the factors in comparison to the Cruise Control situation. In both scenario's the same route is driven by two trucks, the key difference being cruise control vs platooning.

Factors taken into account	Explanation	Assumptions
Benefits		
Fuel consumption	The savings of fuel usage over the platooning route, stemming from air drag reduction	– 10% reduction of fuel for both trucks, an average of the Leading and Following Vehicle [14] – Average fuel consumption of 4 km/L [23] – Price of diesel € 1.20 per litre [24]
Labour cost	Two scenario's: *A. 2 trucks-2 drivers*. Resting times can be reduced. B. 2 trucks -1 driver. Part of the time, a driver can be omitted.	– Labour costs of € 20 to € 25 per hour per driver, dependent on the carrier – The labour costs of the reduction in man-hours, are the savings Scenario A. 8% savings in resting times per day Scenario B. Reduction in man-hours of 15% to 25%, depending on case
Asset utilisation optimisation	Only applicable in *Scenario A. 2 trucks-2 drivers*. The truck is is additionally employable for the reduction in resting times per driver.	*Scenario A. 2 trucks-2 drivers* – A truck is worth € 4 per hour, based on depreciation of a € 160,000 truck combination, over 7 years. We assume the truck is used 51 weeks a year, 110 hours a week.
Costs		
Technology	Annual depreciation of the technology	– Technology costs € 2,000 per truck – Average depreciation period for a truck is 7 years
Service Provider	Annual membership costs for service provider	– € 150 per year per truck
Additional periodic testing	Annual costs for additional testing & maintenance	– € 150 per year per truck
Training drivers	Annual depreciation for the training	– € 75 per year per driver

Costs for Service provider
The estimated costs for the Platooning Service Provider are € 150 per truck per year [14], based on a subscription service fee.

Additional periodic testing
The estimated costs for periodic testing and maintenance of the system are also assumed to be € 150 per truck per year [14]. For instance, it is currently expected that brakes will need two check-ups per year, instead of one annual currently.

Training drivers
The lead driver will need to follow an additional training to obtain a license. The estimated costs for that are € 1,500 per driver, based on experiences with LZV and SARTRE [14], including periodic re-examination. Assuming a driver will on average have 20 years profit from this training, the annual costs are € 75 per driver.

Higher wage driver
In the Netherlands we have experienced the introduction of the LZV, which also required an additional license for the driver. However, this did not lead to a wage increase of that driver. Therefore, we assume there will be no wage increase for drivers of a platoon.

4.3 BUSINESS CASE PARAMETERS AND ASSUMPTIONS

We discuss the business cases for three real-life carriers. First, we discuss the generic component of these business cases. The benefits and costs are described in the previous sections. To eventually monetise the benefits, we use some indicators, such as labour costs per driver, fuel consumption per truck etc. Box 5 summarises the factors taken into account in the business case and the assumptions on the indicators used.

The business case compares the situation in which platooning is in use, with the benchmark situation of trucks using cruise control. Note that the business case depends on many assumptions, thereby giving an idea of the benefits of platooning for the carriers, but with a considerable bandwidth. Also, we take a conservative approach in estimating savings in order to obtain acceptable and carefully constructed results.

4.4 THREE POSITIVE REAL-LIFE BUSINESS CASES FOR CARRIERS

In this chapter, we discuss three real-life business cases; Peter Appel Transport (PAT), De Winter Logistics (DWL) and Europe Container Terminals (ECT). The business cases are based on the use cases detailed in the previous chapters.

Fig. 11 shows the basic parameters used in the cases, in terms of numbers of trucks, distance platooned, and man-hours associated with these routes. For confidentiality reasons, we do not mention all other specific parameters and indicators for the particular carriers. The calculations for the business case are based on the carriers' own estimations of the application of platooning. Also, we have validated all our additional assumptions with the three carriers.

In the figures below the results of the business cases are shown for all three carriers. A distinction is made between the scenarios A (2 trucks - 2 drivers) and B (2 trucks - 2 drivers). We have made annual business cases, meaning

Parameters	Peter Appel Transport	De Winter Logistics	Europe Container Terminals
Number of trucks used for platooning	35	44	10
Number of km per year per truck platooning	77,500	44,000	40,000
Number of man-hours	169,500	246,800	7,500

Fig. 11. The parameters used in the three business cases for carriers

Business Case – per year [3]					
Case	**Scenario**	**Total benefits**	**Total Costs**	**Profits**	**Profits per truck**
Peter Appel Transport (PAT)	A. 2dr B. 1dr	492,000 1,157,200	28,400 28,400	463,500 1,128,800	13,200 32,300
De Winter Logistics (DWL)	A. 2dr B. 1dr	572,000 870,800	32,400 32,400	539,600 838,400	12,300 19,100
Europe Container Terminals (ECT)	A. 2dr B. 1dr	19,800 30,500	6,600 6,600	13,200 23,900	1,300 2,400

Fig. 12. The results of the business cases for the three carriers. (Scenario A: 2 trucks - 2 drivers denoted as 2dr, and scenario B: 2 trucks - 1 driver denoted as 1dr)

3 Note, these numbers are rounded to hundreds (00).

that all costs and benefits are calculated on an annual basis. It also ties is with current trends that investments are only considered that at least break-even within one year.

We see the total benefits far outweigh the total costs in all considered cases. For Peter Appel Transport, platooning can be applied in its inter-DC transports between Albert Heijn warehouses, yielding over 1 million euros per year in Scenario B. Per platooning truck, this means a profit of € 32,300 per truck per year. At De Winter Logistics, with platooning mostly applied on traffic between flower auction sites, benefits significantly outweigh costs, with average savings per truck in the range of € 12,300 and € 19,100. For ECT, even with total volumes and distances being smaller, and limited fuel savings, the business cases are still encouraging.

Fig. 13 shows the subdivision of the costs and benefits per truck. We can see the largest benefit by far is the reduction in man-hours – whether or not there is one driver per platoon. Furthermore, fuel reduction is a substantial benefit, which for the PAT and DWL case alone is enough to compensate for all the annual costs that are incurred (Fig. 14). In the ECT case, since driving is mostly low-speed over short distances, fuel savings are very limited and the savings in man-hours are needed to gain a positive business case.

Fuel savings alone already offset annual costs – labour cost savings are pure profits

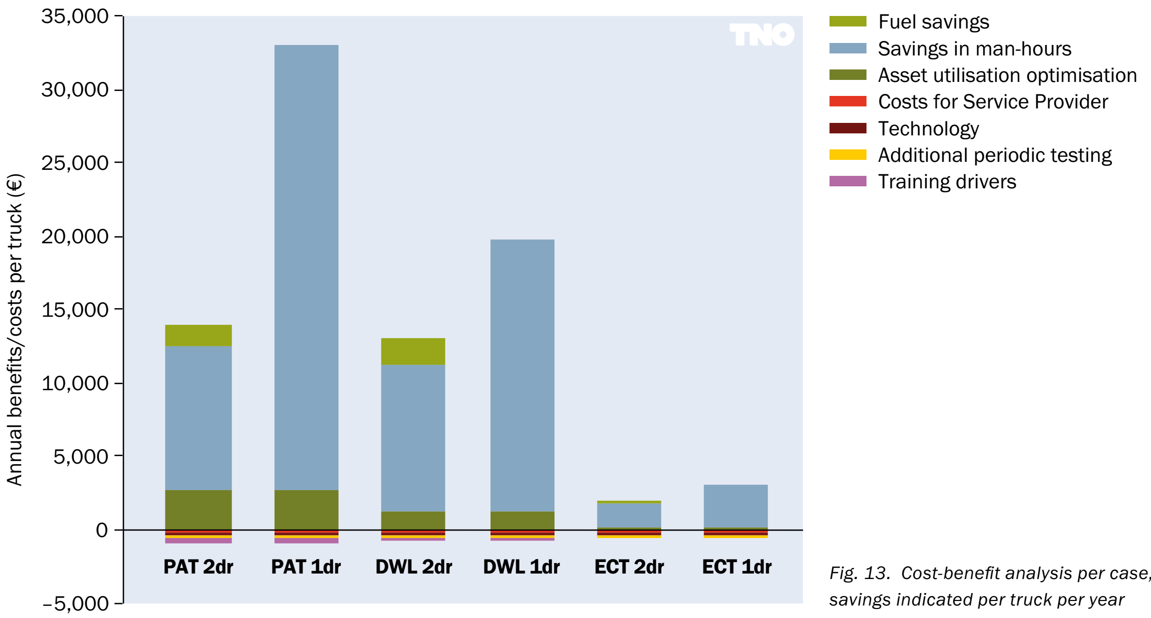


Fig. 13. Cost-benefit analysis per case, savings indicated per truck per year

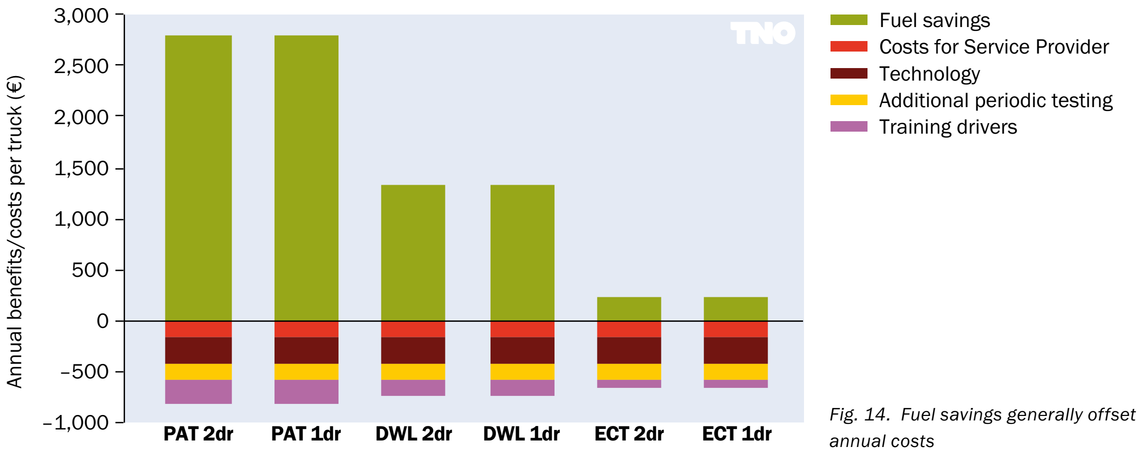
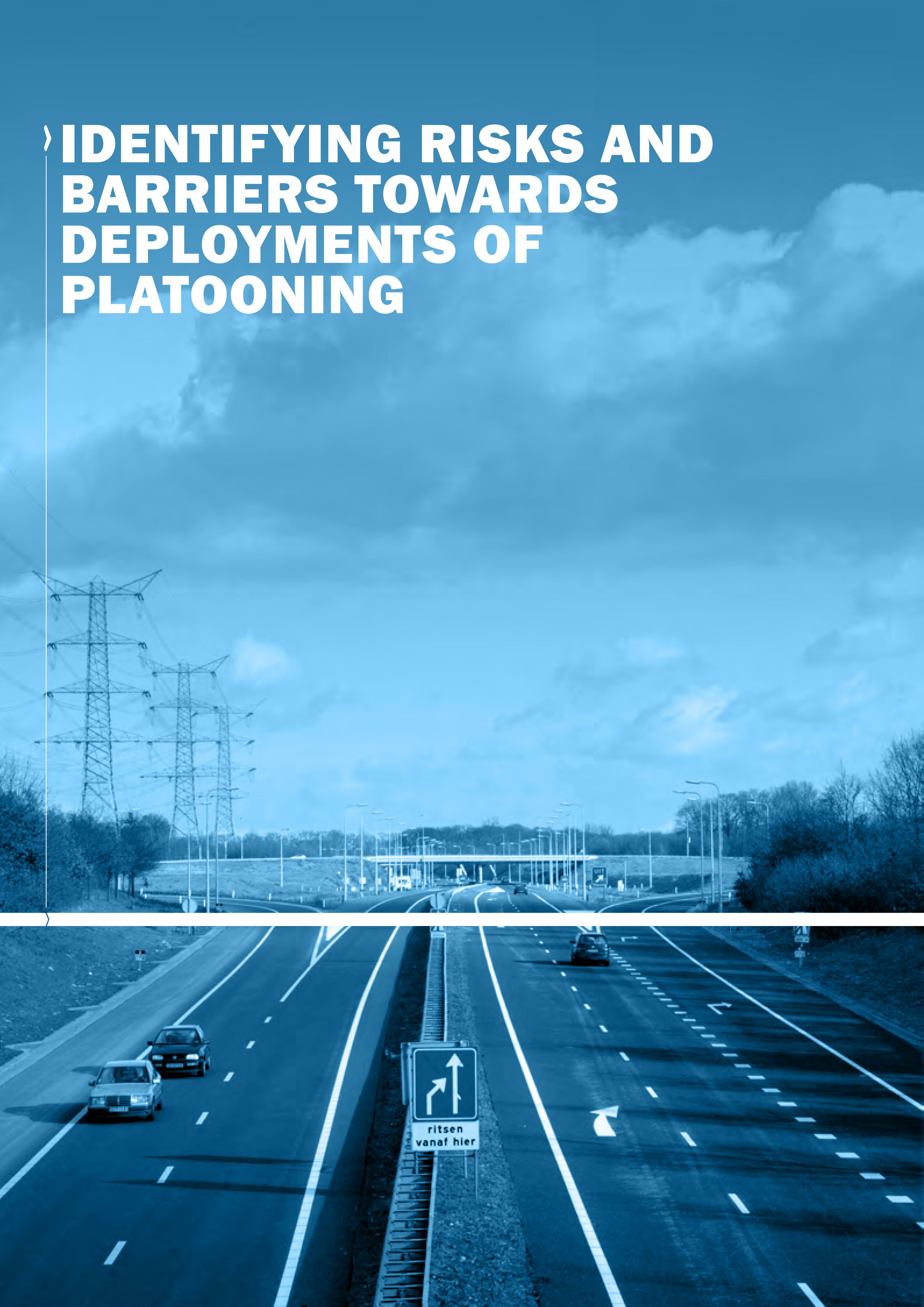


Fig. 14. Fuel savings generally offset annual costs

IDENTIFYING RISKS AND BARRIERS TOWARDS DEPLOYMENTS OF PLATOONING



In this section we identify some risks and barriers towards deployment of platooning. Risks and barriers are inevitable when there are multiple stakeholders with conflicting interests and expected added value of platooning. For example, platooning may have a positive business case for logistics service providers, but the public opinion about a potential 'wall of trucks' may backlash against platooning. The government may favour the users of platooning by allowing it in its regulations and legislation, or give in to the public opinion and prohibit platooning on the public roads.

5.1 SIX CATEGORIES OF RISKS AND BARRIERS TOWARDS PLATOONING

Our analysis identified a non-exhaustive list of 32 risks and barriers for all the stakeholders (Fig. 15). The risks and barriers are divided in six categories: Business, Deployment/Timing, Legal/Conditional, Safety/Security, Technology and User Acceptance.

We evaluated the risks and barriers on levels of probability and impact, indicating risks and barriers with high impact and high probability with H for High. Likewise, M for Medium risks and barriers and L for risks and barriers scoring Low on impact and probability.

The two categories with the highest number of risks and barriers are Business and Legal/Conditional. We explain some important risks/barriers in further detail next, also highlighting a risk/barrier from every category that has not been treated in this whitepaper before.

Limited first mover advantages for platooning adaptation are relevant for all stakeholders. Benefits of platooning are greatest when many firms participate, however it takes a while before broad market penetration is achieved. This typical chicken or egg causality dilemma is a barrier for broad deployment of platooning. Some companies must invest in this technology and be the first mover. Normally first mover advantages justify the additional investment costs, but when the advantages are limited it could be difficult to get a group of first users and could hamper the deployment.

Digital tachograph and driving/resting times legislations are currently the main barriers towards wide-spread testing and adoption of platooning. Additional changes in regulations and legislation are required before platooning can be used on the public roads, for example the type approval, truck driver's license and driving and resting times regulations. When the *adaptation of regulations exceeds the 5 year R&D programme*, this will delay the deployment.

BUSINESS

- **M** Appropriation of main platooning benefits by downstream chain members
- **M** Not enough market take-up/commitment (in €) of platooning (all stakeholders)
- **L** Marginal platooning opportunities due to non-overlapping routes (intra company)
- **L** Limited first mover advantages for platooning adaptation
- **L** Fragmentation of platooning service providers
- **L** Willingness of competing logistics service provider to cooperate to increase the market share for the service provider?
- **L** Absence of platooning partners for on-the-fly platooning (intercompany)

DEPLOYMENT/TIMING

- **H** Adaptation of regulation exceeds 5 year R&D program
- **M** Outdated/obsolete platooning on-board vehicle technology
- **M** Broad market penetration of substitutive cooperative driving technology
- **L** Policy competition from other countries

LEGAL/CONDITIONAL

- **H** EU digital tachograph legislation (EEC 3821/85)
- **H** EU driving/resting times (EC 561/2006) legislation
- **H** International boundary crossing platooning prohibited
- **H** Prior earmarked budget constraints (government)
- **M** Inability to insure platooning driver/vehicles
- **M** Government disagreements/dispute on multiple governmental levels
- **M** Complex regulatory pressure of Platooning exemptions
- **M** Driving exemptions discontinued after R&D stage
- **L** Liability dispute disagreements

SAFETY/SECURITY

- **M** Road infrastructure constraints (roundabouts, bridges, on/off ramps)
- **M** Accidents resulting in image loss
- **L** Hijacking of trailing vehicle
- **L** Loss of vehicle by disconnected platoon

TECHNOLOGY

- **H** Full platoon control under all possible circumstance (insurance threshold)
- **L** Unreliability of V2V data interchange
- **L** Intrusion /hacking of the wireless V2V communication
- **L** Cross-vendor platooning solution incompatibility
- **L** Trailing vehicle overheating

USER ACCEPTANCE

- **H** Boycott by driver-representation lobbies
- **M** Public opinion backlash against platooning (e.g. 'wall of trucks')
- **M** Digital tachograph system abused/sabotaged by platoon drivers
- **L** Political opinion backlash for governmental support of road transportation (instead of multimodal)

Fig. 15. Risks and barriers towards deployment of two-truck platooning

Prior earmarked budget constraints may be a barrier too. There are several subsidising programmes available under the involved ministries that could be linked to platooning, and public funding is required for the development costs of the platooning technology. However, whether or not these budgets can be allocated to platooning depends if these budgets are not already earmarked for other purposes. This could be a risk for the availability of the public funding of the programme.

Road infrastructure constraints impact how platooning can be implemented. Originally, our physical infrastructure was not designed to accommodate platoons. Roundabouts, bridges and on/off ramps could be infrastructural constraints for platooning. The national road authority, Rijkswaterstaat, is responsible for the infrastructure and may be forced to make changes to the road design before platoons are allowed on certain roads.

Platooning uses vehicle-to-vehicle communication. *Unreliability of V2V communication* and *intrusion and hacking of wireless V2V communication* are typical risks on the technological side. This could lead to unsafe situations and could be a risk for the users of the platooning technology.
Finally, deployment of platooning may be hampered by *boycotts from driver-representation lobbies* for fear of loss of employment. This fear is fuelled by the platooning potential of driving without a driver in the Following Vehicle, however this risk does not materialise in the near future. Similarly, *public opinion backlash against platooning* driven by concerns about the 'wall-of-trucks' should be vigilantly monitored and mitigated.

5.2 THE ROLE OF THE GOVERNMENT: COMMUNICATE, STIMULATE, REGULATE

Although the innovation of platooning is primarily driven commercially, the government has a direct role in the introduction of automated driving on public roads, for instance by changing regulations and legislation. We list six key governmental roles, which can hinder of drive the deployment of platooning:

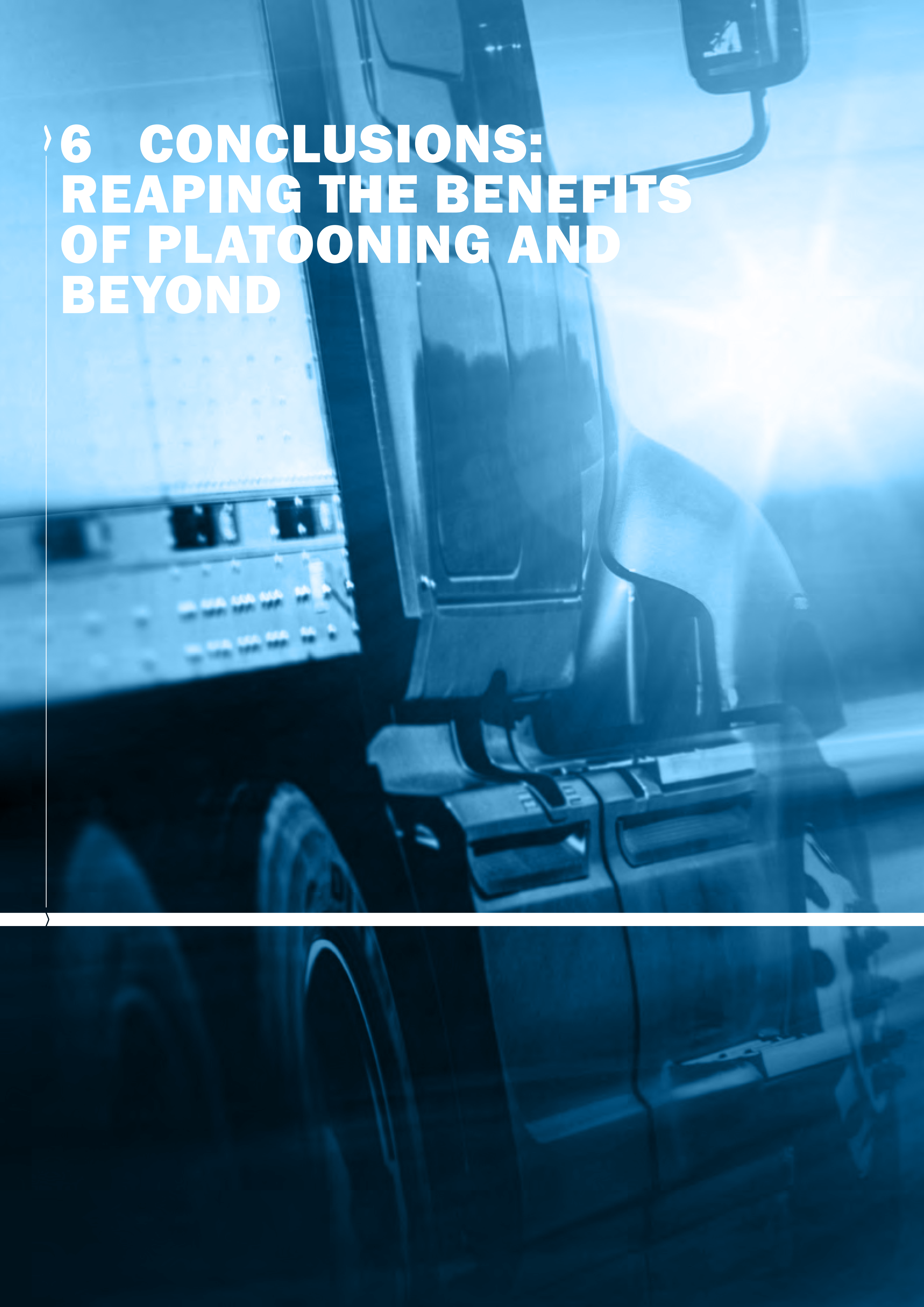
1. **Vehicle type approval**. As a vehicle type approval authority and the issuer of driving licenses the government needs to develop the criteria and requirements for admittance and application. There is currently a lack of knowledge and understanding on how the new technology will impact the current regulation and associated criteria on vehicle safety, safe driving and enforcement of driving and resting times.
2. **Digital tachograph, driving and resting time legislation**. The enforcement of driving and resting times will be influenced by allowing platooning. Monitoring driving times is currently recorded via the tachograph. To advocate fair competition (national and EU level) the inspection procedures and requirements of the tachograph need to be adapted for platooning conditions. The way this is applied and can be enforced will be a main factor influencing the potential of the technology investment for business with professional drivers.
3. **Develop financial incentives for platooning**. The government influences mobility patterns by means of measures such as financial incentives on clean driving (bijtellingsregeling), optimising usage policy (Beter Benutten) and via so-called Green Deals. Platooning for trucks will support these government goals and drive developments on implementation of cooperative

infrastructure and services (ITS-corridor, C-ITS platforms and services); both warrant the development of financial incentives for platooning.

4. **Road infrastructure management**. Platooning influences traffic safety, traffic efficiency and road capacity. How and to what extend depends on configuration and the conditions set by Dutch and European platooning legislation. Platooning will also influence the mix of (policy) measures on mobility management, traffic efficiency and CO_2 emissions. How to incorporate platooning in the traffic system and what societal benefits this will generate requires thorough impact analysis and ex-ante evaluation.
5. **Use public-private collaboration for platooning development**. Since both private and societal benefits can be reaped by platooning, a public-private collaboration is the preferred setting for alleviating regulatory constraints and developing solutions. The government may foster the development of a dedicated PPP programme for truck platooning.
6. **Local, national and international policy coordination**. The Dutch government pro-actively supports the testing of solutions for automation on Dutch roads including platooning. Coordination of all government interests is thereof important in order to accelerate the introduction of platooning on public roads. This has to be seen in the context of the European deployment of platooning. For the public authorities to be able to advocate the view of the Dutch government and to give directions there is a need for knowledge and understanding of platooning.

The balance between ambitions and the provision of answers to the range of questions that still exist in this public-private domain could be realised by an active contribution of the government to a nationwide programme directed to reaping the benefits of platooning for trucks.

6 CONCLUSIONS: REAPING THE BENEFITS OF PLATOONING AND BEYOND



6.1 PLATOONING IS THE FUTURE OF TRANSPORTATION

Driving 0.3 seconds apart: Truck Platooning is the future of transportation. Whereas road transportation companies are continuously challenged to remain profitable and improve sustainability, platooning really is the innovation that brings the much-wanted double-digits improvement. Along with the promise of better road safety, less damages, lower emissions, and more comfort for all road users. Developments in the underlying technology, the Cooperative Adaptive Cruise Control (CACC), have been ongoing for years, and right now the political and economic climate is positive for a broad societal deployment of platooning as initial legislation amendments are proposed to allow testing and experimentation on Dutch roads. And as we are getting used to automated driving technologies, platooning benefits from the concurrent rollout of complementary innovations such as automated docking and parking, stop-and-go systems and cooperative automated emergency braking (C-AEB).

Still, wide-scale deployment of platooning in Dutch and European does not come easy. Platooning, as a system-wide innovation, requires a concerted approach of all parties in the society. Other road users need to learn to accommodate the two-truck road trains, policy-makers have to contribute supporting legislation, regulators such as the RDW need to develop safety-focussed type approval methodologies, truck manufacturers and OEM should strive for plug-and-plug compatibility of platooning systems, insurance firms are required to develop new liability coverage schemes, and shippers can urge their carriers and logistics service providers to form as many platoons as possible, even among competitors, perhaps facilitated by Platooning Service Providers.

Platooning, as a system-wide innovation, requires a concerted approach of all parties in the society

In the end the carriers and logistics service providers are the parties that stand to gain the most, as we have shown in the business cases for the three carriers, Peter Appel Transport, De Winter Logistics and ECT. The business case of platooning is driven mainly by the fairly low total costs of implementing platooning technology and very significant fuel and labour cost savings. With fuel savings weighing in at 10%, costs for using platooning technology are covered year-on-year.

Even so, for such positive business cases to materialise, broad testing and experimentation is needed. Platooning will develop along three lines, in which we move from closed to open infrastructures, from scheduled to on-the-fly platooning, and from two drivers to one driver running the platoon. For this system-wide innovation, at TNO, we suggest to establish an Shared Research Programme, based on open innovation principles. In the programme, we can jointly work towards commercial deployment of platooning and mitigate the risks and barriers identified, to finally implement a safe, reliable and efficient two-truck platooning concept by 2020.

6.2 TNO CAN HELP: JOIN THE SHARED INNOVATION PROGRAMME TOWARDS TRUCK PLATOONING

TNO advocates the constitution of a nation-wide Shared Innovation Programme aiming *'to enable the deployment of truck platooning in the Netherlands within 5 years'*. Fig. 16 shows the five phases, covering 5 years of deployment. TNO welcomes all parties with a stake in truck platooning to participate. The programme is not limited to just Dutch parties, as truck platooning is an international challenge.

Goals

The goal of this programme is defined to enable the deployment of truck platooning in the Netherlands within 5 years:

1. Implement a safe, reliable and efficient 2-truck platooning concept within 5 years, approved by the Dutch governmental bodies.
2. Stakeholder interest: organising all stakeholders around the deployment process, and coordinating their interests on national and European level. Involving carriers and logistics service providers, shippers, OEMs, suppliers, technology providers, type approval authority, policy making bodies, branches.
3. Technology development: (vehicle) safety and fail-safe design using cooperative driving components, within a newly developed and accepted regulatory framework.
4. Business value: platooning integrated in operations of logistics service providers and shippers.
5. Upscaling: in terms of penetration, level of automation, and from closed infrastructure to open roads.
6. Pilots and testing: phased, fail-safe controlled approach, real traffic conditions.
7. Awareness and outreach: ensuring wide-scale implementation moving towards cross-border platooning.

Open innovation principles

The shared innovation programme is based on the rules of engagement for open innovation projects, meaning funding for this programme consists of partner contributions in kind and in cash, and innovation programmes (national/EU programmes, such as TKI Logistiek, Horizon 2020). Financing a programme with such challenging ambitions and goals requires a significant amount of resources and determination. Please contact TNO if you are interested in participating in this programme and want to drive transportation into the future.

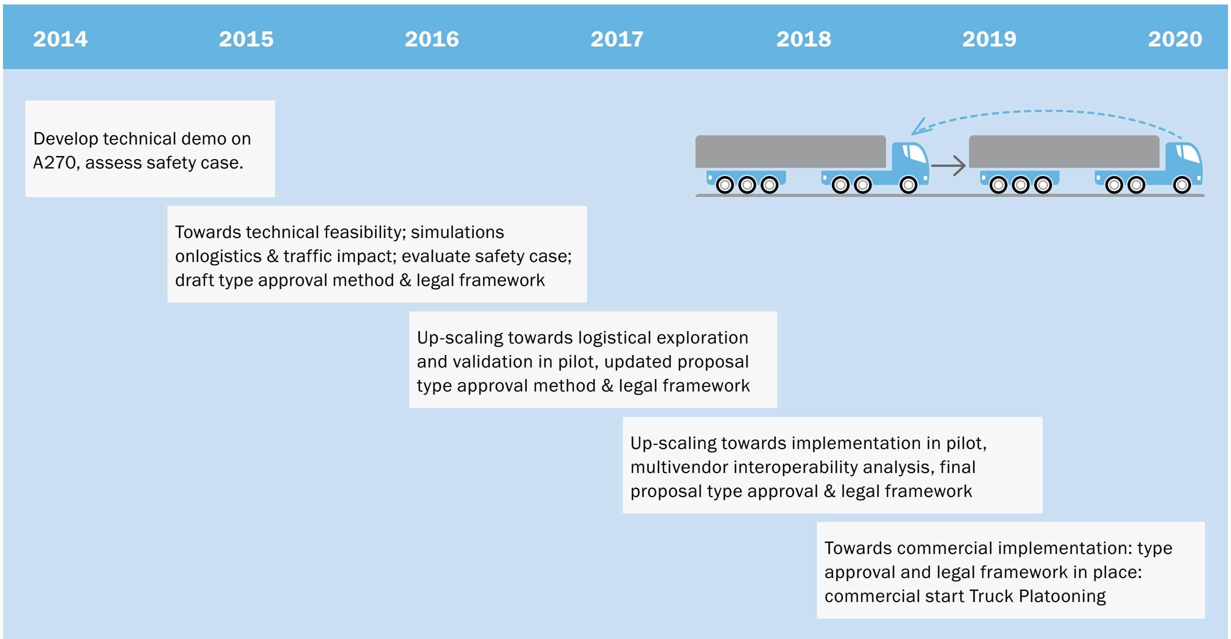


Fig. 16: Five phases, five years: the Shared Research Programme towards commercial Truck Platooning

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