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INSIGHT

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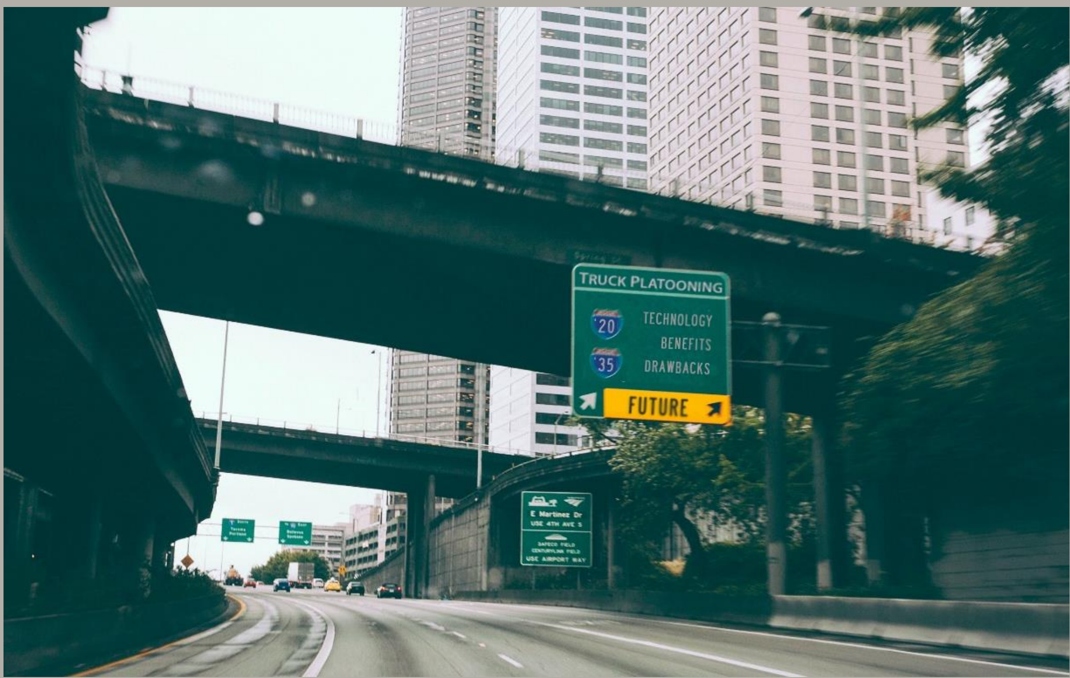
PLATOONING TOWARDS SUSTAINABLE ROAD FREIGHT TRANSPORT

THE BENEFITS, DRAWBACKS AND FUTURE OUTLOOK



Truck Platooning essentially is two or more trucks driving very close behind the platoon leader, with the next truck automatically following the leader through vehicle-to-vehicle (V2V) communication. In addition to V2V communication, trucks rely on an abundance of technologies and sensors, such as radar and GPS, to allow them to 'sense' their environment and to be part of a platoon safely. Using truck platooning will result in a reduction of road freight operational costs due to fuel savings and possible higher productivity of both truck and driver. Furthermore, widespread use of truck platooning will significantly reduce the volume of greenhouse gas that originate from road freight transport. Other important benefits that could stem from truck platooning are increased road safety, more efficient use of infrastructure, and less road congestion. All of its benefits make platooning a good way to help meet several challenges that are currently faced by the road freight transport sector and society as a whole. Platooning is thought of as an incremental step towards fully autonomous freight transport over public roads and is expected to become commercially available by 2019-2020 under the form of Driver Assistive Truck Platooning (DATP). The market penetration of truck platooning is predicted to achieve 5.5% by 2025, growing to 22% in 2030 and about 30% in 2035. The benefits of truck platooning increase with the market penetration, which ideally should achieve a value of over 60%.

Exploration of platooning and a general outlook

SUCCESSFUL TESTS

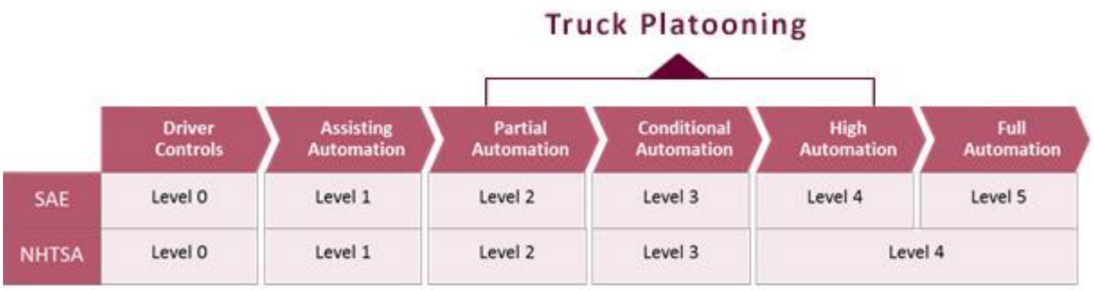
Truck platooning and the use of autonomous trucks have many opportunities and advantages, but is still a developing technology. **A first phase of truck platooning, Driver Assistive Truck Platooning, has been tested with success and might be coming to the roads as early as 2019.**

On the 6th of April 2016 six 2- or 3-truck platoons arrived in Rotterdam in the Netherlands to conclude the European Truck Platooning Challenge (ETPC). During this extensive test six platoons drove several 1,000 kilometres from several locations in Europe on the Trans European Road Network, crossing multiple national borders. The test showed that it is already technically possible to platoon – with two or three trucks from the same brand – on public roads throughout Europe. Besides this, the ETPC raised stakeholders' awareness about truck platooning and its possibilities. Maybe the most important result the ETPC delivered is a kick-start to the future development and deployment of platooning in Europe and a lot of positive energy with several parties involved in the process.

How does it work?

With platooning, two or more trucks drive closely one after the other at possibly high velocity. A small gap between the trucks is necessary to obtain significant fuel savings through increased aerodynamics, and correspondingly reduced aerodynamic drag. For the gap to be small at high velocities while ensuring the safety, platooning requires a certain level of automation of the trucks. This automation is divided in different levels by the National Highway Traffic Safety Administration (NHTSA) and SAE (Society of Automotive Engineers). The starting point is the control of the vehicle by a driver. The end state would be to have a fully autonomous vehicle driven by artificial intelligence. As of now we are at the early market stage of partial automation (lane assist and adaptive cruise control) and on the verge of developing a transition to more conditional automated vehicles.

There already exist several – rather mature – technologies that, in combination with the right software, allow the truck to 'sense' its environment. Radar, lidar (light detection and ranging), infrared sensors, laser sensors and cameras are used to detect the distance and relative speed to other vehicles on the road and to register road markings



SAE and NHTSA vehicle automation levels

and signs. These different sensors provide redundancy of the data they record which allows them to make up for each other's weaknesses. Lidar and radar for example can compensate for the lack of data provided by camera technology when there is very limited sight due to weather conditions. Global position systems (GPS) and inertial navigation systems (INS), which includes motion and rotation sensors, are used for localisation of the vehicle. Also here, GPS and INS are able to back each other up if one of the technologies fails. INS can provide the necessary data in tunnels where GPS does not work for example. Vehicle-to-vehicle (V2V) technology is necessary as it enables direct communication between the different vehicles forming a platoon. For this purpose, a specific WIFI standard has been approved which can also be used for vehicle-to-infrastructure (V2I) communication.

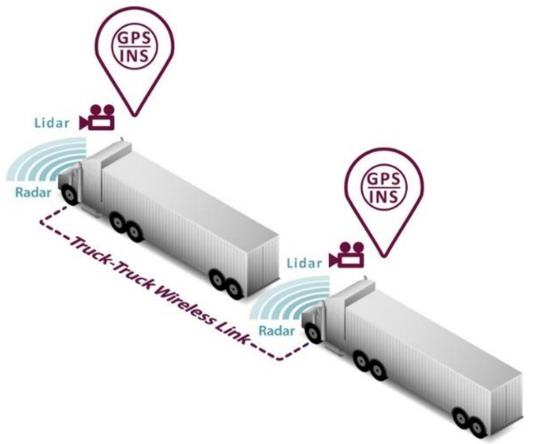


Illustration of the basic technologies necessary for truck platooning. (Based on Illustration of Peleton Tech)

By using these technologies effectively in combination with excellent software and communication, two trucks will be able to form a platoon. They will be able to drive with a smaller gap in between them relatively higher and more continuous speeds which directly results in less fuel consumption and a reduction of gas exhaustion as compared to when the two trucks would drive independently of each other. The gap between two manually controlled vehicles varies on average between 1.2 and 1.5 seconds[1]. With higher levels of vehicle automation, i.e. truck platooning, this gap could be reduced to 0.5 or even 0.3 seconds[2]. Decreasing the gap between trucks implies increasing the road capacity. If for example two trucks of 19 metre length drive independently at a speed of 80 km/h with a distance of 1.5 seconds in between them, which corresponds to 33 metre at this speed, they use 71 metres of road infrastructure. By forming a platoon, they could reduce their gap to 0.5 seconds, which corresponds to an 11-metre gap and a usage of 49 metres of road infrastructure. Thus, in this case, forming a platoon increases road infrastructure capacity by over 30%.

General outlook to the future of truck platooning

For several years already, truck manufacturers are offering adaptive cruise control (ACC) and lane keeping assist (LKA). Currently several manufacturers, such as DAF and Volvo, put these technologies on all of their trucks as part of the standard equipment. ACC works similar to cruise control, but it adds functionality to monitor the relative distance to and velocity of the vehicle ahead using radar and lidar. This way a truck equipped with ACC can be programmed to keep the same speed as the vehicle ahead and to brake or accelerate accordingly, with the aim of keeping a fixed headway. LKA detects when the truck is deviating from its lane, and if no action is undertaken by the driver the LKA will make sure the truck does not leave its lane. When coupling two trucks that are equipped with ACC through V2V communication, changes of velocity by the first truck can be communicated directly to the following vehicle instead of through the radar technology of the following vehicle. This way the reaction time of the following vehicle to alterations in velocity of the vehicle ahead can be reduced to almost zero, allowing the gap between two coupled trucks to be decreased. This extension of ACC is referred to as cooperative-adaptive cruise control or driver assisted truck platooning (DATP).

DATP will be the first commercially available form of platooning on public roads and is expected to become available in 2019. DATP will facilitate the formation of two- or three-truck platoons and will require as much active, concentrated drivers as there are trucks in the platoon. The driver of the following truck is still in control of the steering, and he has the ability to override the system's brake or throttle commands.

[1] Varies depending on the source. Here: Heavy Truck Cooperative Adaptive Cruise Control: Evaluation, Testing, and Stakeholder Engagement for Near Term Deployment: Phase One Final Report by the Auburn University

[2] TNO paper : Truck Platooning Vision 2025

In this first phase of the deployment and evolution of platooning the platoon formation will be scheduled in advance with long-haul heavy-duty vehicles (HDV) that belong to the same company and that have similar routing and dispatching environments. Big transport companies with large fleets who perform long-haul transport are expected to become the early adopters, followed by other companies with differing core businesses who perform their own transport and own rather large fleets of long-haul HDV’s.

As technology matures, legislation adapts, and the automation level of the vehicles increases, the driver of the following vehicle(s) does not have to control his truck anymore and is able to perform other tasks or rest while the truck ahead, the platoon leader, controls the flow of the platoon. As platooning emerges and platoon service providers (PSP) originate, the formation of platoons can be orchestrated by these independent PSPs. This will allow easier formation of inter-company platooning, with trucks of different companies which are engaged in long-haul transport and have similar transport destinations. Orchestrated platoon formation is most likely to be adopted by companies which transport their own goods, but are not pure transport companies. These companies, as opposed to transport companies, feel less fierce competition with each other on performing transport but rather in their core businesses, which results in these companies being more willing to cooperate to form inter-company platoons.

In a later stage, on-the-fly platoon formation will become possible. This means that platoons can be formed while driving on public roads without preliminary planning. This will induce an increase in the number of platoons being formed and a reduction of the average distance a single platoon of trucks drives cooperatively. Eventually, when platooning has matured and legislations have adapted accordingly, a single-platoon driver, can steer a platoon of trucks in which the following trucks are driverless. This is expected to become a reality after 2030. Fully autonomous vehicles travelling on public roads are not expected to become reality before 2035.

Benefits for the different stakeholders involved

Truck platooning, when it is well deployed, comes with several benefits for the stakeholders involved: the industry, the public, and government.

The industry stakeholders include all companies that are connected in one way or another with the transportation of goods. Besides transport companies and companies that rely on road freight to transport or distribute their goods, this also includes companies that depend – even if minimal dependency – on road freight for the delivery of inputs for their production process, for example. The second main group of stakeholders are the citizens who are directly affected by road congestion, traffic jams, accidents, and greenhouse gas emissions that are caused by road freight transport. The last main stakeholder group consists of the governments, which are responsible for the wellbeing of their citizens, a sustainable future, and the availability of road infrastructure.

The first important benefit of truck platooning is its capability to reduce the fuel consumption of the trucks forming a platoon due to improved aerodynamics from reduced air resistance and the maintaining of a more constant speed. These reductions range from 2% to 8% for the leading vehicle and from 8-13% for the following vehicles according to the SARTRE project[3]. The fuel savings of a platoon as a whole can thus range from about 5% to 10%. As fuel costs account on average for 30% of a truck’s operational costs, a reduction in it along with the fierce competition in the transport sector, which operates on small profit margins, is an important factor in the adoption of truck platooning. These fuel savings correspond to a reduction of the emission of CO_2 by 5% to 10%.

Although HDVs represent only 4% of the total on-road fleet in the EU, they are responsible for moving 75% of the freight tonne-kilometres and are responsible for 30% of on-road CO_2 emissions[4]. The prediction of substantial growth of freight demand in upcoming decades[5] along with the CO_2 reduction targets of both the transport sector and the EU as a

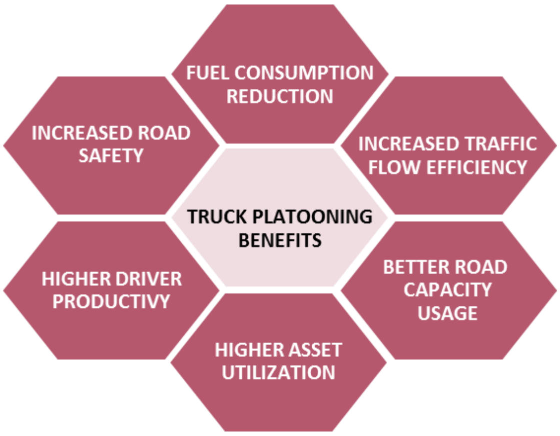
[3] SARTRE, ‘D.4.3 Report on Fuel Consumption’, Applus+IDIADA, 2014.

[4] Overview of the heavy-duty vehicle market and co_2 emissions in the European Union, R. Muncrief and B. Sharpe, icct.

[5] European Commission 2015

whole, also encourage the adoption of truck platooning.

It is estimated that about 90% of all accidents are caused by human error, and one in eight of these crashes is due to driver fatigue[6]. Most of the accidents in which trucks are involved are frontal collisions. Because of the increased automation levels of the trucks that are able to platoon, a lot of these human induced accidents can be avoided. Widespread penetration of platooning has therefore a significantly positive effect on the



The major benefits of truck platooning

number of accidents on the road, and thus on the general road safety. Also, as congestion and traffic jams are often caused by the occurrence of accidents, people will waste less time in traffic jams. This in turn positively affects the overall productivity and fuel usage. Less accidents imply less damage to trucks, infrastructure and humans which should allow the transportation companies to negotiate lower insurance premiums.

On the long term, when the technology has achieved high market penetration, platooning will result in more efficient traffic flows and better road capacity utilisation. More specifically, it is estimated that a market penetration of over 60% is needed[7]. As mentioned earlier, two trucks forming a platoon instead of driving independently limit their road use with c.30%. As road freight transport in the EU is predicted to grow significantly over the next decades, considerable investments in road infrastructure, amounting to 1.5 or 2.5 trillion euro for 2010-2030, are necessary to match the demand for transport.[8] More efficient road capacity would induce limited expansion of the current road network. The budgets that are saved by reducing the necessary road expansion investments can then be used for supporting the development of automated driving, for investing in further CO_2 reductions in the transport sector, and for the adaptation of road infrastructure to the needs of automated vehicles of the future.

When a more advanced level of truck platooning will be used, with level 3 or 4 automated vehicles, the following truck can follow the platoon leader autonomously. In this case the driver of the following truck can take the time to perform other tasks or rest, or the following driver can be omitted totally. When one driver rests while the platoon leader controls the platoon and the drivers take turns in leading the platoon, the distance a platoon can travel at once, without stopping, can increase significantly without violating the regulations regarding driver resting times. Along with the reduced fuel consumption of trucks that are part of a platoon, this increased driver productivity expands the range of 720 kilometres of a single truck by c.30% to a 960 kilometres range of a platoon of trucks[9]. On top, this also releases some of the pressure involved in the job of long-haul driver and might make it more of an attractive job. Platooning with higher-level automated vehicles, and adapted legislation, allows to omit the following drivers completely. Resulting in higher driver satisfaction and attraction, and completely omitting personnel, mitigates the increasing shortage of long-haul drivers. In addition to increased driver productivity truck platooning can also increase the asset utilization – the time a HDV is operating – as trucks can 'hop on' a platoon rather than stand still when the driver has to sleep or take a break for example.

Possible implementation difficulties

Truck platooning may be a promising way of improving several aspects of road freight transport, there are several factors that will possibly oppose the implementation of it. We will provide an overview of the main, general issues

[6] http://www.cnet.com/roadshow/news/freightliner-autonomous-inspiration-truck/

[7] Heavy Truck Cooperative Adaptive Cruise Control: Evaluation, Testing, and Stakeholder Engagement for Near Term Deployment: Phase One Final Report by the Auburn University

[8] European Commission, 2010

[9] Lori Tavasszy (TU Delft) highlighted this increased driver productivity at the conference following the European Truck Platooning Challenge.

that may arise with the deployment of truck platooning.

Investment cost and ROI

A first important possible setback to the implementation of truck platooning is the necessary investments by the shippers – both private companies and transport companies. Haulage companies are known to have limited capital for investments, they require short payback periods and direct net ROI's for technology investments. They usually don't take into account any possible public benefits such as less pollution when deciding whether or not to invest. We expect DATP to require an additional investment of about €5,000 in the early market stage, lowering to about 1,500€ when production has grown. This investment consists of the hardware, software, service fees and driver training. The ROI and willingness of the early adopters – large HDV fleets – depend on oil prices, yearly distance driven, the distance over which platooning can be used, insurance premiums, potential subsidies and possible fuel efficiency standards. In this early stage, the initial investment can almost solely be offset by fuel savings and the payback period is expected to be around 3 years. In a later stage, with level 3 automated vehicles, the initial investment can be offset by both fuel savings and productivity gains, but the initial investment will probably be around €10,000. The market penetration of platooning strongly depends on the willingness of several important transporting companies to be first-movers in order for the investment costs to be reduced by higher production levels. Another barrier for the investment in truck platooning and its deployment might be the competition from other technologies to reduce the fuel consumption and greenhouse gasses. Long Combination Vehicles (LCVs) for example consist of one tractor unit who pulls several trailers, resulting in higher fuel efficiency and higher productivity.

Road infrastructure, technology and service

Current road infrastructure often puts constraints on the possible routes, which need to be sufficiently long for platoons to follow. Unsuited lane markings and bridges are examples of road infrastructure that could block the optimal routing of platoons. Governments need to make sure there are long routes that enable platoons to cross Europe without too much interruptions.

Investment cost and ROI
▪ Shippers have restricted willingness and possibility to invest ▪ Limited first movers' advantage
Practical constraints
▪ Reliability of the used technology ▪ Road infrastructure constraints ▪ Need for independent Platoon Service Providers (PSP)
Political constraints
▪ Need for updated regulation to allow for cross-border platooning ▪ Regulatory framework to support automated vehicles, platooning, PSPs and the insurance sector ▪ Governments' budget constraints for investing in truck platooning and vehicle automation
User acceptance
▪ Limited willingness for cooperation among carriers ▪ Truck driver resistance due to fear for discharges ▪ Negative public opinion due to safety concerns

Main constraints to the emergence of truck platooning

Although most of the technology to enable truck platooning is already available, there still are some technical implications that could slow the deployment of platooning. Improvements to the V2V and V2I communications to make it reliable at all times still need to be made. Also, cybersecurity regarding V2V communication poses an important threat. Extensive testing and improvements to the overall truck platooning needs to be done in order to make sure that the control over a platoon is always maintained under all circumstances. The technology and algorithms need continuous improvement to make sure, certainly towards a more automated future, the trucks can handle increasing traffic and obstacles.

There is a need for independent platoon service providers to coordinate all aspects of platoons. The scheduling or on-the-fly formation, the fair distribution of benefits among the platoon members – there are more fuel savings for the following vehicles and possibly the following driver can rest while the first one needs to control the vehicles. They will need to form a bridge between different shippers as well as between shippers and governments regarding regulations such as border formalities and driver resting times. For the PSPs to do their work properly and to enable the growth of platooning, the shippers will have to provide the PSPs with data regarding their shipment times, destinations, drivers. Also, shippers need to trust the PSPs and be willing to remunerate their platooning partners through the PSPs for the benefits they obtained.

Legal, regulatory and insurance barriers

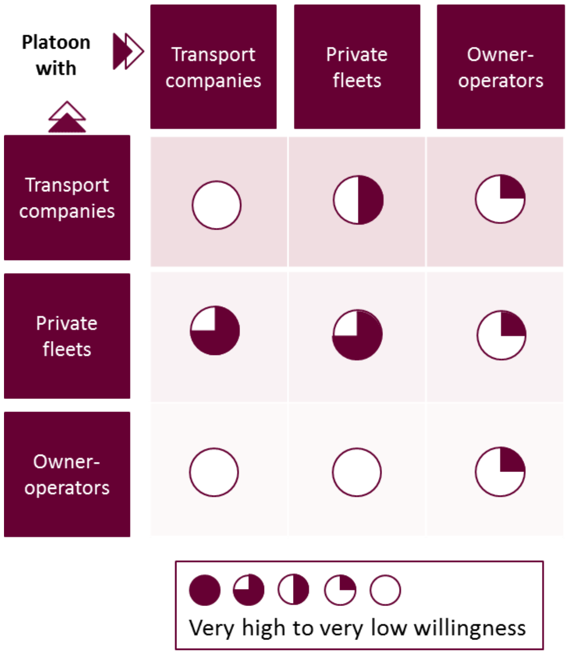
Besides the cost and technology maturity barriers, there are several legal and regulatory barriers to the successful deployment of truck platooning. Legislation concerning driving and resting times of professional drivers need to be reviewed and adapted. There needs to be EU-wide conformity among the legislation regarding truck platooning that allow platoons to cross borders. This is necessary as platooning – certainly in the early stage – provides benefits when trips are sufficiently long, which often involves border crossing. Also, restricted budget may limit the willingness of governments to invest in truck platooning to help the further development and deployment of it. Certainly in the early stage this is an important determinant of platooning's success because first mover advantage is limited and more benefits arise when market penetration rises.

The governments also need to anticipate opposition from truckers as jobs might be lost or drivers will have to perform different sets of tasks. Also, the government should encourage upcoming platooning service providers (PSP) as they will play an important role in the growth of truck platooning by forming a bridge between different fleets.

Also, a regulatory framework regarding the inspection and approval of automated vehicles – which is more complex than that of regular vehicles – should be put in place along with the involved authorities. Adapted driving licenses and training need to be adopted to ensure platoon drivers have the necessary skills. Another big challenge lies in the insurance sector. Insurance companies need to be encouraged to adapt their products to support truck platoon operations and vehicles with higher levels of automation.

User acceptance barriers

A last main concern is that of user acceptance of platooning, this involves acceptance of shippers and drivers as well as all other road users or citizens.



Willingness of different truck/fleet owners to cooperate in order to form inter-company platoons

Carriers need to be willing to adopt platooning technology and work together with other (transport) companies and individual owner-operators. The ATRI industry survey[7] showed that in general there would be willingness to work together, but platooning with trucks from the own fleet is preferred. Owner operators are the least cooperative, followed by the transport companies, while the private fleets are rather positive towards cooperation. Problems that might block cooperation are the competitive environment, data privacy concerns, and the need for cooperative scheduling of the platoons which might cause some of the shippers to delay or put forward some shipments.

Truck drivers might oppose to truck platooning as they might fear the possible changing job content or possible discharge. This could trigger boycotts from driver-representation organizations.

Besides carriers and drivers, a negative public opinion could put a heavy strain on the deployment of truck platooning. This negative public opinion might put pressure on the governments to reduce support for truck platooning.

Predictions for the future

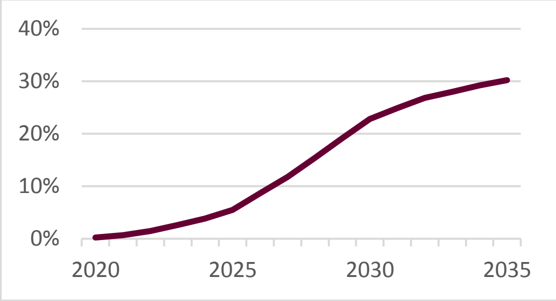
There are already highly automated vehicles being used for purposes such as mining[10] and in ports[11], but these are closed, predictable environments. The future use of level 2 to 4 automated trucks for platooning purposes on public roads is strongly inherent to several variable factors. Some predictions about the future market penetration can be made.

The outlook provided here concerns the EU-15 countries with Norway and Switzerland. Adoption of truck platooning is expected to start in these countries rather than other European countries. The main reasons for this are lack for incentives due to lower driver wages and older fleet age, mainly because of used trucks from Western Europe. For the predictions we used data from Eurostat and EMISIA[12], results from the ATRI industry survey among transporters and fleet managers[7], and our own assumptions and calculations.

The total EU-17 fleet consists of about 4,600,000 HDVs in 2015, expected to grow with 3% annually. Large-fleet transport companies are assumed to possess around 15% of the total EU-17 HDV fleet. The fleet of HDVs has a yearly renewal rate of c. 7%, whereby new vehicles are used more frequently and for longer trips than older vehicles[13]

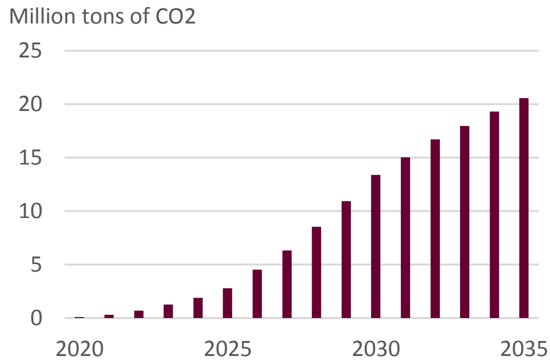
We expect that as from 2019-2020, platoon-enabled vehicles will be bought by large-fleet transport companies, who will use platooning for long-haul transport with routes of well over 300 kilometres that use long parts of big highways, mostly routes using the Trans-European Road Network. More specifically, c. 12.000 platoon-enabled trucks will be sold in the period 2019-2020, under the assumption that regulations will be updated to allow for the use of commercial platooning in 2020. Soon after initial investments, when first movers proofed it viable, we expect companies with large fleets for private use to start to invest in truck platoons. We expect smaller fleets to start investing in platooning as from 2025, when sufficient benefits have been proven in the field.

Taken into account only level 2 automation, a market penetration of c. 1% is expected in 2022, further rising towards a value of c. 5% in 2025. An increase to 10% at the end of 2027 and by 2030 we expect a market share of about 18%, followed by a decrease in growth of the market penetration resulting in about 20% market penetration in 2035. If we take into account level 3 and 4 automation, the market share evolves from almost zero in 2020, 5.5% in 2025, about 22% in 2030 to 30% in 2035.



Prospected market penetration of platooning 2020-2035

The strong rise starting in 2025 is due to the technology to come to maturity, the legislation to adapt, the adaptation by smaller fleets, the increased trust of the shippers and public opinion and the PSPs that are getting well established.



The predicted yearly reduction of CO_2 due to truck platooning in million tons of CO_2 per year

As carriers should be able to form a platoon of two trucks over a total yearly distance of 120,000 kilometres – below the total yearly mileage – and knowing that an average truck uses 35 litres of diesel fuel per 100 kilometres, platooning will reduce the total CO_2 emissions of the EU-17 road freight sector by about 7 million tons of CO_2[14] in the period 2020-2025. This will further reduce the CO_2 emissions with 40 million and 90 million tonnes in the periods 2025-2030 and 2030-2035 respectively.

[10] http://www.mining.com/australias-big-miners-add-more-driverless-trucks-88704

[11] http://www.terex.com/port-solutions/en/products/automated-guided-vehicles/

[12] EMISIA final report about project TRACCS for the European Comission (2013)

[13] According to TRACCS : http://traccs.emisia.com

[14] 2.6 kg CO_2 Per liter diesel fuel. 7.5% fuel reduction

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