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AUTOMATIZATION OF A LOGISTIC PROCESS USING PLATOONING TECHNOLOGY FOR CARGO TRANSPORTATION FROM FINLAND TO SAINT PETERSBURG

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Abstract. The world we live in is changing dramatically through innovation, and the pace of change is accelerating every day. Truck platooning is the linking of multiple trucks in a convoy using communication and sensors between vehicles. Platooning technology can allow vehicles to move completely autonomously. One of Russia's major trading partners is Finland. Active cargo transportation of products is carried out in both directions. Truck platooning can be used on this road. This paper includes the costs analysis of the technology and how it may pay for itself in the future.

Keywords: platooning, cooperative traffic system, highway automation, vehicle to vehicle communication

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АВТОМАТИЗАЦИЯ ЛОГИСТИЧЕСКОГО ПРОЦЕССА С ИСПОЛЬЗОВАНИЕМ ТЕХНОЛОГИИ ПЛАТОНИНГА ДЛЯ ПЕРЕВОЗКИ ГРУЗОВ ИЗ ФИНЛЯНДИИ В САНКТ-ПЕТЕРБУРГ

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Аннотация. Мир, в котором мы живем, резко меняется благодаря инновациям, и темпы этих изменений увеличиваются с каждым днем. Группа грузовиков — это объединение нескольких грузовиков в колонну с использованием связи и датчиков между транспортными средствами. Технология платонинга позволяет транспортным средствам двигаться полностью автономно. Одним из основных торговых партнеров России является Финляндия. Активные грузоперевозки продукции осуществляются в обоих направлениях. На этой дороге можно использовать платонинг грузовиков. Этот документ включает анализ затрат на технологию и то, как она может окупиться в будущем.

Ключевые слова: платонинг, совместная система движения, автоматизация дорог, связь между транспортными средствами

Для цитирования: Малышева Т. Автоматизация логистического процесса с использованием технологии платонинга для перевозки грузов из Финляндии в Санкт-Петербург // Техноэкономика. 2022. Т. 1, № 1. С. 43–53. DOI: https://doi.org/10.57809/2022.1.1.4

Introduction

The world we live in is changing dramatically through innovation, and the pace of change is accelerating every day. Whether it be social, economic or environmental factors, innovators are taking a hard look at the industry's biggest challenges to develop ways to solve them. According to the European Union, three-quarters of domestic freight traffic is transported by road (Nowakowska-Grunt and Strzelczyk, 2019). That amounts to about 1,750 billion ton-kilometres (TBM) of freight. As a result, fuel consumption, CO_2 emissions, traffic congestion, and traffic safety have been significantly affected. To alleviate these problems in the transportation industry, innovations such as platooning and autonomous vehicles have been developed (Bergenhem et al., n.d.).

Truck platooning is the linking of multiple trucks in a convoy using communication and sensors between vehicles (Fan et al., 2018; Zhang et al., 2020). Virtual communication between trucks allows the vehicles to automatically accelerate, brake, and follow each other at closer distances than would normally be possible with unconnected trucks. Platooning can be defined differently by different projects because there are different goals and motivations for platooning, as well as different technical solutions. However, in order for such convoys to be deployed, the behaviour of these vehicles in the convoy must be verified.

There are 5 levels of vehicle autonomy (Fig. 1), and in this paper, I will look in more detail at the third level, since it is currently the most appropriate and its implementation seems the most realistic, given the legislation, the quality of the routes and so on.

The third level, the Advanced Driving System (ADS) can perform and control all required driving functions in some conditions. However, when the ADS receives a warning, the driver must be able to

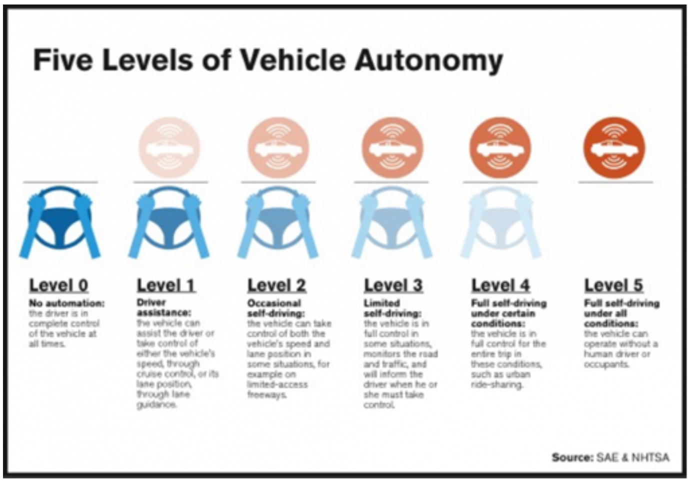

Fig. 1. Levels of Vehicle Autonomy

take over control. In addition, the remaining critical tasks must be performed by the driver (Stehbeck, 2019).

This study aims to explore methods to improve the process of delivery of goods from Finland to St. Petersburg and other nearby cities, by truck platooning.

Materials and Methods

When writing this article, an analysis of the existing literature on the topic of platooning, the principles of the technology, as well as the existing use cases were studied. Also, in order to adapt the use of technology to a specific route and country, the current state of the route was studied, as well as average prices for components and consumables. All calculations were carried out using Microsoft Excel. Also, the documents of the companies-suppliers of trucks using platooning technology, which are open to access, were studied.

Results and Discussion

The freight industry is heavily filled with trends such as digitalization, automation, communications, and electrification. These trends are restructuring the value network of the freight industry by creating new ways of doing business. Through connectivity and data mining, vehicle data can be aggregated and processed to produce data insights that benefit the supply chain. This opens new opportunities for logistics companies to provide new digital, data-driven services beyond their traditional business model (Larsson et al., 2015).

In the long term, leading companies aim to offer logistics as a service with autonomous vehicles directly to shippers by partnering with a digital logistics broker. To achieve this, four major service systems have been developed incrementally and linked with other technologies:

1. Connectivity and data sharing: providing a visible and controlled transportation operation for both carriers and shippers through seamless data orchestration and sharing.
2. Optimize transportation operations: provide sustainable and efficient logistics and transportation management services to customers through data-driven decision making and integration of digital logistics brokerage platforms.
3. Accelerating the EV transition: accelerating the transition to electrified vehicles by providing customers with an easy transportation experience through intelligent routing and charging services.
4. Logistics as a service with autonomous vehicles: transforming towards providing a transportation ecosystem by providing logistics as a service with autonomous vehicles (Chi, 2020).

Platooning technology can allow vehicles to move completely autonomously. In Russia, the use of autonomous transport is currently extremely underdeveloped. But attempts are already beginning to introduce it. For example, the movement of semi-autonomous trucks has been tested along the Moscow-Kazan route. Even the use of technology on the 3rd level benefits both business and society. The benefits will be discussed in more detail in the following sections.

The context of the chosen logistics process.

One of Russia's major trading partners is Finland. Active cargo transportation of products is carried out in both directions. This is not surprising, since the border of the country is located at a distance of just over 1000 km from St. Petersburg. Road, rail, sea and air transport is used for transportation. The fastest and least expensive is road, namely transportation by truck.

The main road junction between St. Petersburg and Helsinki is the E-18 highway (Fig. 2). Highway E18 is a highway of national importance. The increased ties between the EU and Russia, as well as the processes of European integration, predetermined in due time the construction and development of E18. The importance of the highway is that it connects the capitals of Norway, Sweden and Finland with St. Petersburg. The result is an international transport highway between the European Union and Russia. At the moment, repair work is being carried out on a stretch of highway located in the Leningrad region, which is scheduled to be completed by the end of 2023.

A huge amount of time trucks can stand in traffic jams at the border while waiting for cargo clearance. In addition, there is a limited amount of time that, according to the law, a driver can drive a vehicle.

In addition, road repairs slow down the process of transporting goods, as drivers travel a shorter distance because of the lower speed, while the downtime of the truck and the driver increases. This article will look at how autonomous vehicle technology can optimize the process of shipping cargo from Finland to Russia.

The transport process is central to the delivery process. For the most part, it covers the operational level. But looking at the process from a tactical level, transport company managers need to ensure that downtime of company resources is kept to a minimum. According to Russian law, a driver can only drive a truck for 4.5 hours continuously. And a total of 9 hours a day a driver can be at the wheel, thereby creating downtime for the truck. This is the root cause of the downtime problems for vehicles and drivers.

In addition to this, the driver is in the truck while resting. Especially in winter, a huge amount of fuel is wasted warming up the cab. Fuel is also consumed to charge the accumulator so that there is light in the cab at night. All these nuances cannot be circumvented by traditional methods, because rest periods

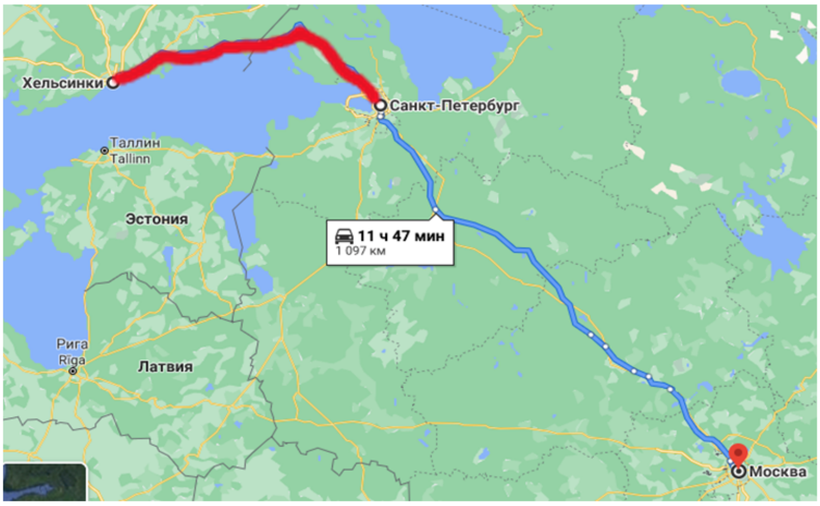

Fig. 2. The Route St. Petersburg – Helsinki

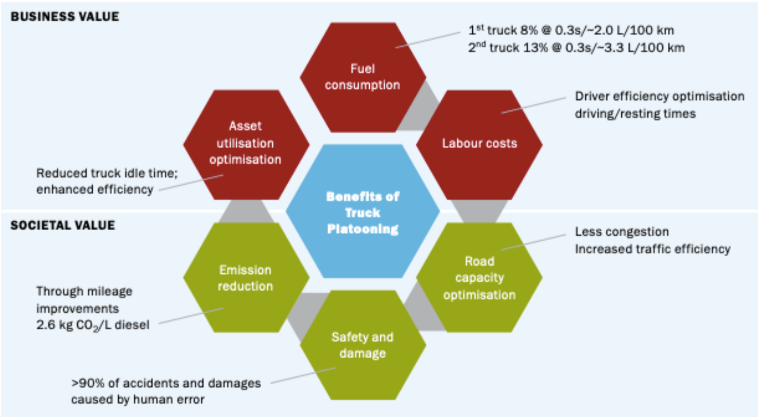

Fig. 3. Benefits of platooning technology (Source: (Boysen et al., 2018))

are legally stipulated. All of these problems can be solved by introducing pay-as-you-go technology, and the next section will describe in more detail how this can be achieved (Alam et al., 2010).

How the logistics process can be improved.

Based on an analysis, the process therefore needs to be optimized so that drivers can rest while driving. There are two solutions. First one – 2 drivers in one truck, which is also inefficient because for the same amount of time, the number of services performed would be half as much, and the second one – introduction of platooning technology.

When there are two drivers per platoon, 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 addition, the technology also has other benefits which are shown in the Fig. 3. Connecting trucks has great potential to reduce transport costs, improve road safety, prevent traffic congestion, and improve cleanliness and efficiency. In some EU countries, 90% of total freight is transported by road and 25% of truck fuel consumption is caused by air resistance (Tsugawa et al., 2016). This has a significant impact on CO_2 emissions, congestion and fuel consumption. The technology reduces transport costs through improved aerodynamics, thus eliminating the need for an attentive driver in a second vehicle. In other words, as the trucks travel at a constant speed within 0.3 seconds of each other, fuel consumption will be reduced as braking and acceleration are autonomously controlled by the system (Santini et al., 2017). Furthermore, 90% of all road accidents are caused by human error. Thanks to this innovative technology, human errors are prevented during convoy driving, which implies fewer accidents and damage. In addition, congestion will be prevented with Platooning, as truck lengths will be reduced due to a gap of 0.3 seconds, which means that road capacity is optimized.

To use the technology more effectively, platforms are created where carriers share their data with other companies in order to find other truck and form a convoy with them. For example, trucks arriving from Moscow and departing from St. Petersburg can form a platoon and travel together (Chen et al., 2020).

Now it is already possible to actively test the technology on some highways in Russia. As, for example, on the new M-11 highway connecting Moscow and St. Petersburg which has also recently been opened. And upon completion of the repair work, it will be possible to organize joint convoys of trucks coming from Moscow and departing from St. Petersburg.

The description of the to be applied technology

To guarantee a coordinated motion of the vehicles in the platoon, cooperative adaptive cruise control (CACC) algorithms are used to compute the acceleration of each vehicle based on on-board measure-

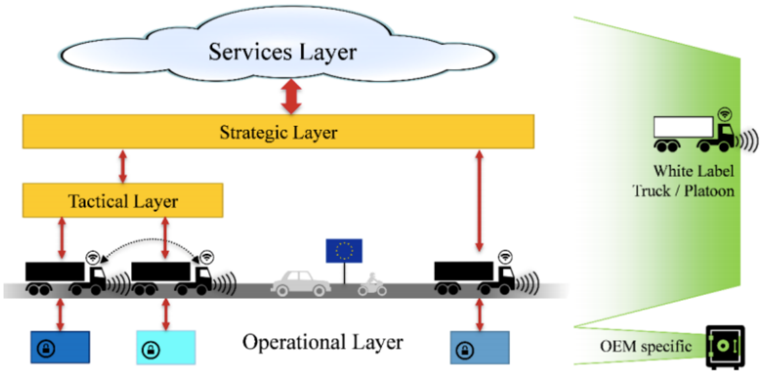

Fig. 4. Platooning layers (Source: (Konstantinopoulou et al., 2019))

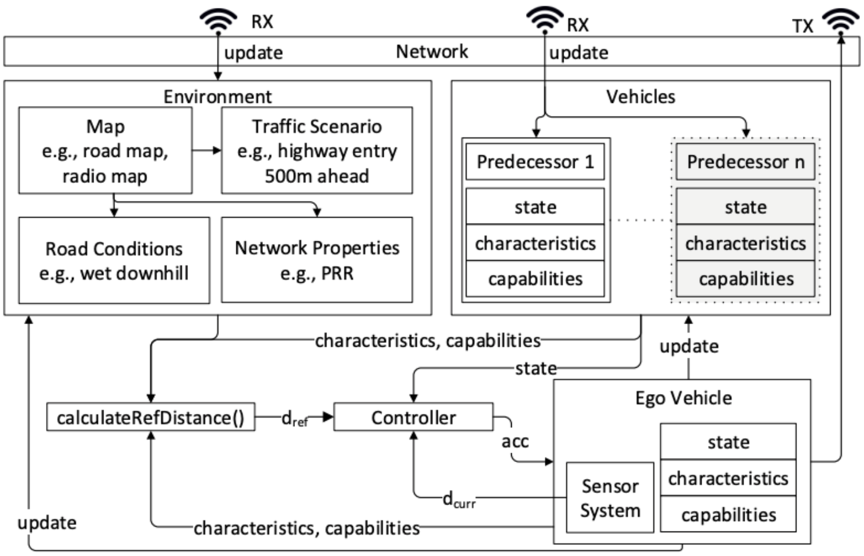

Fig. 5. Following the reference distance (Source: (Renzler et al., 2019))

ments and information gathered from the other platoon members through Vehicle-to-Vehicle (V2V) communication systems ("Cooperative Adaptive Cruise Control (CACC) for Truck Platooning: Operational Concept Alternatives," n.d.). The building blocks of cargo movement in a caravan consist of in-vehicle requirements (longitudinal, sensors, HMI-interface interaction), infrastructure (zone policy), information (starting, V2V and V2I exchange, and data exchange), and movement in a caravan strategy at the tactical level (coordination mode, break formation, dissolve, and mix vehicle) (Lakshmanan et al., 2019).

The tactical layer coordinates the actual formation of the platoon (both from the tail of the platoon and by merging in the platoon) and the disbanding of the platoon.

The tactical level shares information about the state of the vehicle equally within the platoon, as well as the state of the platoon. The setpoint limit / recommendation function will send to the operational level a combined recommended value for a given vehicle speed and time interval, processed based on information from the strategic level and platoon status. The requirements modeling process is supported by first principles modeling in order to perform a reality check on the feasibility and relevance of specifications (Konstantinopoulou et al., 2019).

Miles per tractor per year		110 000	Input fleet data
% of the miles platooning		75%	Input %
Miles per tractor platooning		82 500	Calculated
Costs			
Total Installed Cost			
Collision Avoidance Technology	$	1 500	Input $0 if already in tractor spec
Adaptive Cruise Control	$	250	Input $0 if already in tractor spec
V2V Radios for Transmission	$	250	Input your own data
In-Cab Cameras	$	200	Input your own data
Other material or tech update during ownership	$	400	Input your own data
Labor to install	$	200	Input your own data
Total Installed Cost	**$**	**2 800**	**Calculated**
Other Costs			
Any per truck cost (Annual subscription, etc.)	$	200,00	Input cost per truck per year
Additional maintenance costs per truck per year	$	50,00	Input cost per truck per year
Other ongoing costs?			
Driver and technician training	$	50,00	Input cost per truck per year
Incentivize drivers to platooning ($/mile)	$	0,0075	Incentive per mile if any
Annual Driver Incentive	$	618,75	Calculates annual incentive
Total Annualized Costs	**$**	**918,75**	**Calculated**
Benefits			
Fuel Savings			
Fuel miles per gallon		7,00	Input fleet data
Fuel $ per gallon	$	3,00	Input fleet data
Fuel Expense per mile per truck	$	0,43	Calculated
Total Fuel Expense per year per truck before platooning	$	47 142,86	Calculated
% of platooning miles following		50%	Input fleet data
Estimated % fuel savings following		7,5%	Input fleet data
Fuel expense saved following	$	1 325,89	Calculated
% of platooning miles in the lead		50%	Input fleet data
Estimated % fuel savings while in the lead		3%	Input fleet data
Fuel expense saved in the lead	$	530,36	Calculated
Fuel savings per year per truck	**$**	**1 856,25**	**Calculated**
Repair and insurance costs	**$**	**500,00**	**Zero if already assumed with**
Other Benefits?			**safety equipment**
Total of one time costs	**$**	**2 800,00**	**Calculated**
Total of annualized costs	**$**	**918,75**	**Calculated**
Total of annualized savings	**$**	**2 356,25**	**Calculated**
Payback in months		**23,4**	**Calculated**

Fig. 6. Cost benefit analysis

To ensure interaction with the trucks in the platoon, communication must be established between the platoon members. A decentralized tactical layer running locally in trucks needs information from other trucks (Fig. 4). Requirements for vehicle hardware components specific to platonizing can be grouped into the following categories:

– HMI-driver-vehicle interface and, in particular, the platooning solution

– Longitudinal control system consists of sensors, control computing and communication-control executive components.

The trucks in the platoon try to maintain a predetermined distance to the predecessor. The distance is usually the same for all vehicles in the platoon and is selected to meet certain requirements. Vehicles measure the distance to their predecessor and receive additional V2V communication information from their predecessor (such as acceleration and speed). In connection with driving vehicles, they operate under constantly changing conditions (different road scenarios), and external influences can lead to different environmental conditions (for example, weather, traffic density) (Hjälmdahl et al., 2017).

Network Properties: Only a highly reliable network provides a close inter-transport distance. Relying on cellular networks, latency, data rate, and coverage area vary depending on the current location and data traffic. Low data transfer rates and high latency due to poor coverage are known from radio cards. There, vehicles can plan to increase the distance or prepare the transition to a special network. In ad-hoc networks, reliability mainly depends on the number of transmitting nodes and the load on the network (Hameed Mir and Filali, 2014). Knowing the current reliability of the underlying network allows to update the reference distance.

Fig. 5 summarizes all external influences that contribute to the determination of the reference distance. The following figure shows that cars are constantly updating their vision of the environment: the properties and capabilities of cars are exchanged using CAM, and the distance is measured by the on-board sensor system. Information about network properties, traffic scenarios and road conditions are provided using maps, analyzed by the vehicle itself using cameras and sensors, or received via a communication channel (Renzler et al., 2019).

Cost calculations

There are various costs associated with the implementation of platooning. The table below (Fig. 6) contains the costs of the technology and how it may pay for itself in the future. All prices are notional, as it is not possible to accurately calculate the number of sensors, cameras and other equipment, the price of fuel, as it is constantly changing (Calvert et al., 2019).

Based on the calculations, it can be concluded that the introduction of such technology will pay for itself fairly quickly. Moreover, it will save money, in addition to all the other benefits mentioned above.

Conclusions

In this article, the process of cargo transportation from Finland to Russia was analyzed, difficulties and problems were identified, and as a result how this process can be optimized was realized. The best solution is to organize movement of trucks in a convoy. Connecting trucks has great potential to reduce transport costs, improve road safety, prevent traffic congestion, and improve cleanliness and efficiency.

According to Russian law, a driver can only drive a truck for 4.5 hours continuously. And a total of 9 hours a day a driver can be at the wheel, thereby creating downtime for the truck. This is the root cause of the downtime problems for vehicles and drivers. With platooning, when there are two drivers per platoon, 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).

In section 6, the principle of operation was described in more detail, as well as the systems that ensure the operation of the technology. Of course, only the basics were described, for a more in-depth study it is necessary to devote an entire article. Then the economic efficiency of the system implementation was calculated, which showed that the system will pay off quickly enough.

Summing up, such technologies need to be implemented in the processes of Russian companies. The main problem is the roads, because in order for the column to be convenient to overtake other road users, it is necessary to have at least two lanes in one direction, which is not always the case. Scania had already planned to conduct a test trip from St. Petersburg to Finland, but due to restrictions, the experiment was not completed.

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