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PLATOONS IN CONNECTED AUTONOMOUS VEHICLES

ABSTRACT: The connected autonomous vehicles are in development and will enter into operation gradually so their effect on traffic must be studied under diverse conditions of inclusion. Platforms are one of the ways that autonomous vehicles will connect efficiently. By grouping and generating platoons the spacing between vehicles is decreased even more than what is expected in the autonomous cars, the leading vehicle will have the command of the decisions so that it will be safer, will improve the maneuverability and reaction times.
Additionally, the platoons have economic and environmental advantages due to the aerodynamic effect that occurs when reducing speciation, particularly in the freight transport.
The implementation of the platoons is linked to the timely and real-time exchange of travel data by the operators and how operators will use the information to form them.

Keywords: Autonomous vehicles, Car sharing, connected autonomous vehicles, CAVs, AVs, Platoons, Platooning, Truck platooning, Automated driving, automated vehicles, connected automated vehicles.

INTRODUCTION

The term autonomous vehicles or automated vehicles (AVs) refers to those vehicles that are displaced without the need for a human driver at the wheel. Through the use of new technologies, camera sensors among others. With the use of recognition algorithms, the vehicle can interact with the environment that surrounds it to travel on routes previously loaded in its memory.
Now, this type of vehicle is in development, and although the technology advances very fast, it is not clear when it is that this technology will be ready for its safe use. (Litman, 2018)

Connected Autonomous vehicles (CAVs)

The CAVs are AVs connected to each other through the use of Wi-Fi technology, sharing all the information of the vehicle while it is moving. Also, the CAVs receive system information that may be supplied along the roads such as warnings, traffic signals, real-time data, change in traffic lights and more.
Three essential characteristics of CAVs are the ability to receive real-time traffic information, cooperative management and reduction in reaction time.
This type of technology is already being developed and is partially available in some vehicles such as those that use the cooperative adaptive cruise control system, usually in trucks.
Although the legislation to be followed for its implementation is still unclear, the analyzes for its application and effects are thoroughly studied. Principally on how the interaction between manned

vehicles and CAVs would be during the transition phase until the 100% CAVs traffic flow is achieved.

Among the characteristics that are being studied is mainly connectivity and behavior, through the use of algorithms for the simultaneous interaction between CAVs and manned vehicles. (Hu J. , Kong, Shu, & Wu, 2012)

Platoons

Platooning is the movement strategy in highway traffic by which vehicles travel in groups at the same speed and direction. This mode of travel is highly used in trucks and especially in those who have the cooperative adaptive cruise control system. (Amoozadeh, Deng, Chuah, Zhang, & Ghosal, 2015)

This travel method has several benefits such as:

- Reduce the distance between vehicles
- Reduces fuel consumption or energetic consumption in the case of electric vehicles, due to the aerodynamic effect.
- Share origin-destination displacement information optimizing positions and speed.

METHOD

Google Scholar was used as a search tool for the bibliographic review in the different databases.

The literary revision was based first on understanding the operation of the autonomous vehicles. From this knowledge, we deepened into what are the connected autonomous vehicles and the different bibliography and research reviews available.

Among the significant issues that are found in research in the CAVs is the use of platoons.

Different keywords were used to access the different focusing articles in the autonomous vehicles and the integration and incorporation of platoons.

The references of the articles were also used to expand the bibliographic review and expand the resources available for the literature review of the implementation of platoons in connected autonomous vehicles.

CONNECTED PLATOONS

The connected platoons are being studied and developed as the travel model for CAVs.

Since they facilitate the travel model by efficiently distributing the traffic, the vehicular flow becomes more secure, there are fuel savings due to aerodynamic effects and increases the capacity of a road network by decreasing the spacing between vehicles.

Platoons are being studied primarily in trucks but will also be generated in common vehicles.

Trucks in a platoon

To platoons develop and form efficiently it is essential an effective communication between the trucks and the environment that surround them. The technological research is advancing in a way that all these communications are in real time and efficiently transmitted between all the vehicles.

Enabling the creation of platoons along the road in addition to allowing better maneuverability for other users.

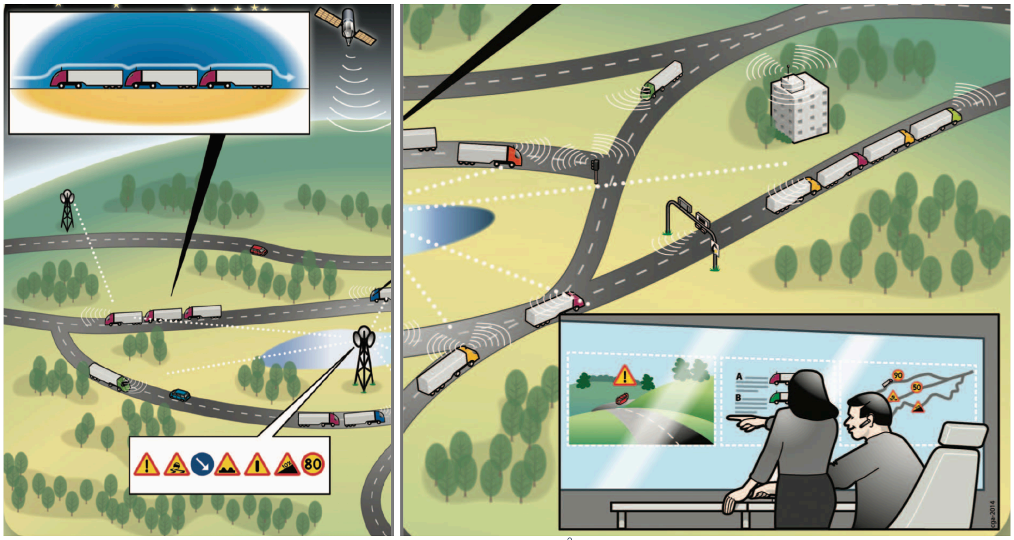


Figure 1CAVs communications (AlAm, Besselink, turri, mÅrtensson, & JoHAnsson, 2105)

To see the efficiency effects in the network through the use of trucks platoons, first, a plan must be developed for its implementation.
It is expected different ways that platoons can be created along the road network.
The network accommodates trips of trucks that travel alone as others that already go platooning as may be the case of courier or cargo companies.
Unrestricted platooning It is defined as that model where trucks can enter and leave the platoon at any time, and there is flexibility in the number of platooning vehicles.

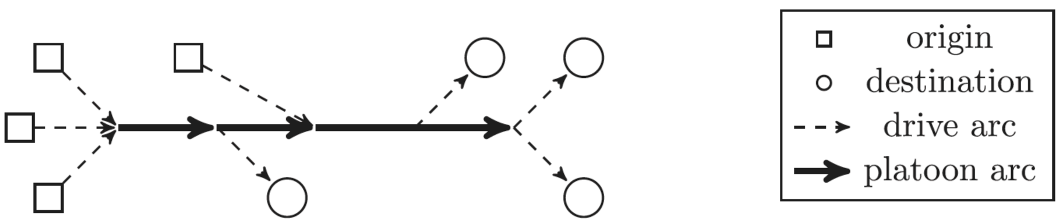
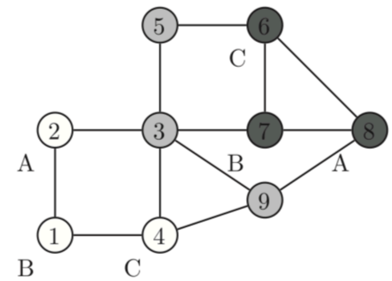


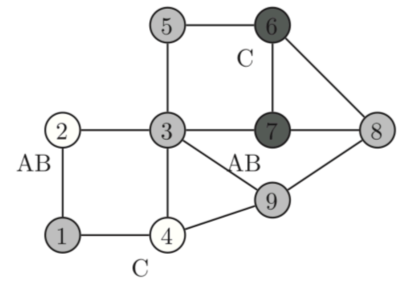
Figure 2 Unrestricted platooning - trucks allowed to join and leave a platoon at any instant (Bhoopalam, Agatz, & Zuidwijk, 2016)

Unrestricted platooning fixed routes the use of this model is expected where the routes of transport are predetermined, and although there is flexibility in the exit and entry of new vehicles to the platoon, there is not in the routes.
So that this model can be efficient and realistic the information needs to be shared in real time, the interaction of the data and routes has to be always updated as well as the number of vehicles and location.
(HOEF, 2016) In Sweden, this method of platooning has already been studied and showed great benefits regarding fuel savings.
It was studied in a theoretical way, but at the same time a real simulation was performed, where the benefits were demonstrated. By creating a coordination center for the operation and coordination of the platoons. It took advantages of the connection mode already developed in some brands of trucks allowing the lead vehicle to be driven manually and the rest to be interconnected and guided.
Unrestricted platooning - flexible routes This model of travel allows trucks to be added and depart with flexibility while allowing the detour to routes even if they are longer allowing to join the nearest platoon with more savings.

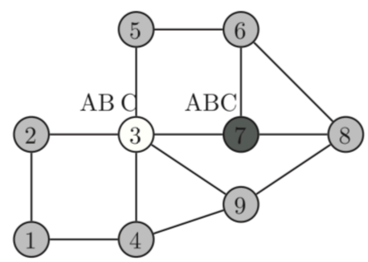
For the deviation to a longer route to be beneficial, the cost per additional length must be less than the savings obtained when entering the platoon and this can be modeled by different algorithms, recalculating the times and generating the costs and savings. Allowing the decision of which route and which platoon must join to incur in savings. Figure 3 shows one of the models to find the best pair for each vehicle.



(a) In the initial state of the Best Pair heuristic all trucks have different starting and destination nodes.



(b) Trucks A and B merge at 2 and split at 7.



(c) Platoon AB and truck C merge at 3 and split at 7

Figure 3 Example run of the Best Pair heuristic. (Larsson, Sennton, & Larson, 2015)

Restricted platooning In this model it is stated that the platoons are closed, that is, they are not allowed to adhere during the route and only during the beginning and end of the route.

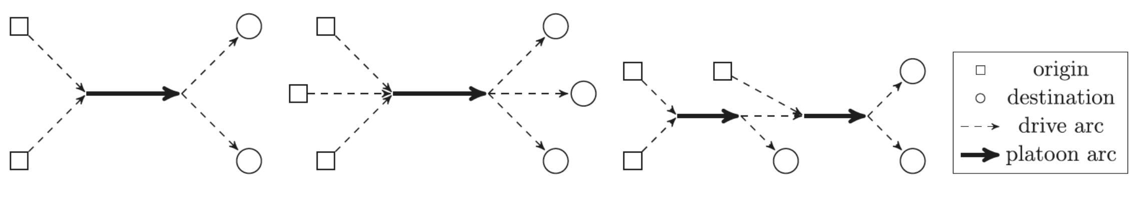


Figure 4Examples of restricted platoon settings - (a) a two truck platoon - single platoon per trip, (b) a three truck platoon - single platoon per trip, and (c) a two truck platoon - multiple platoons per trip. (Larsson, Sennton, & Larson, 2015)

Restricted platooning - fixed routes The routes are fixed and defined from departure to arrival.
Restricted platooning - flexible routes Although it does not allow the inclusion of new vehicles during the journey, it allows a new route, modifying the route when a platoon appears available.

BENEFITS IN TRUCKS PLATOONING

Among the significant advantages as mentioned is the aerodynamic effect that occurs, generating a reduction in fuel consumption and a decrease in inventory gases.
Figure 5 shows the effect that is generated when the trucks travel together and how the pressures are altered as distances vary. Driving tests suggest savings in fuel consumption of 6% for the truck that leads and 10% for the followers. (Lammert, Duran, Diez, Burton, & al., 2014)

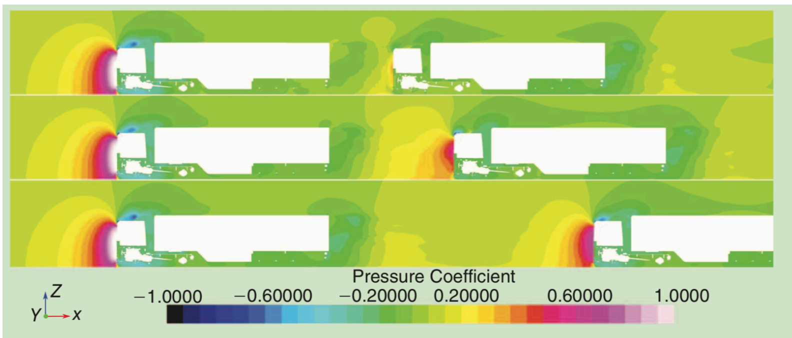


Figure 5The pressure field for a two-vehicle platoon with a spacing of 5, 10, and 20 m (AlAm, Besselink, turri, mÅrtensson, & JoHAnsson, 2105)

As a result of platoons be connected wirelessly the reaction time will decreases, which will generate greater security for the vehicles and users.
(Ma, Li, Zhou, & Ghiasi, 2017) For the platoons to be connected and to determine the speed and spacing harmonization, various algorithms are planted. That will involve vehicles around them, which will provide greater security in maneuverability and decision making for the CAVs.
(Davis, 2017) Real-time wireless communication allows sharing of vehicle information as well as traffic road information. By having real-time data on the road, it will be possible to make decisions regarding the routes to optimize the network and at the same time avoid traffic jams.

REGULAR VEHICLES PLATOONS

The study of platooning in non-heavy vehicles is different and is focused at short distances, optimizing the network and the redistribution in lanes according to the final destinations.
Since the technology is still in development most of the research and algorithmic modeling poses the various ways in which CAVs must react when receiving and sharing information.
(Hu J. , Kong, Shu, & Wu, 2012) The decisions of the CAVs are based on algorithms with conditions, and such decision making has multiple inputs such as sensors, traffic signals, and live road network communication. Under these conditions, the CAVs generate the decisions for each maneuver.
As long as the network is not 100% of CAVs, different conditions and parameters are to be used to interact with the manned vehicles or semi-autonomous vehicles.
(Wang, Daamen, Hoogendoorn, & Arem, 2016) The type of algorithm formulation for the CAVs should be varied as the inclusion increase, and the CAVs platoons will commence forming.
With inclusions of 5% to 10% of CAVs in the traffic flow, human drivers are still in control of the network.

CONCLUSIONS

The implementation of new technologies such as the CAVs in the transport allows reducing costs and time when there is global coordination of the network.

The use of platoons as a freight transport methodology already exists, but it will increase with the inclusion of the autonomous vehicles and their characteristics. Developing economic and environmental benefits.

The wireless connection of the autonomous vehicles will allow sharing all kinds of information optimizing the networks and redistributing the traffic efficiently.

Like the inclusion of the autonomous vehicles increases, it will be possible to begin to perceive the improvements of the system, which is not clear yet what is the point of inflection where the network is still in control of the manned-vehicles.

Although the generation of platoons in the freight transport brings economic benefits in the reduction of fuel consumption, unless explicit models and centers of cooperation and exchanges of information among the transporters are defined, its implementation will be affected by the lack of mechanisms for its adhesion.

FUTURE RESEARCH

Due to the entry into operation of the CAVs the interaction with the distribution facilities is expected to change. The integration of the freight transport with the load exchange sites must improve to allow platooning. There is not much research on how the facilities should be adapted to meet the needs that are going to be generated.

It is not clear the inflection point of the percentage of inclusion where the advantages of the use of CAVs will be seen. As the CAVs begin to be used, platoons will start to appear, but it is also unclear what percentage of CAVs inclusion will allow platoons to be a success in the connected model.

The different models that are being analyzed include algorithms under conditions with assumptions and parameters on particular situations for which it is necessary to integrate all these simulations to understand the effect in the network of all the modelings running at the same time.

As there is not a driver in the autonomous vehicles, the number of cars in the network can increase, this because while traveling to collect the passengers the vehicle could be empty.

Leading to possible network saturation so it is not clear what will be the increase in the number of trips and what percentage of those trips will not have anyone inside the vehicle.

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