Planning of Truck Platoons: a Literature Review and Directions for Future Research

Anirudh Kishore Bhoopalam[a,*], Niels Agatz[a], Rob Zuidwijk[a]

[a] *Rotterdam School of Management, Erasmus University*
Department of Technology & Operations Management
Mandeville (T) Building, Burgemeester Oudlaan 50
3062PA Rotterdam, The Netherlands

Abstract

A truck platoon is a set of virtually linked trucks that drive closely behind one another using automated driving technology. Benefits of truck platooning include cost savings, reduced emissions, and more efficient utilization of road capacity. To fully reap these benefits in the initial phases requires careful planning of platoons based on trucks' itineraries and time schedules. This paper provides a framework to classify various new transportation planning problems that arise in truck platooning, surveys relevant operations research models for these problems in the literature and identifies directions for future research.

Keywords: Truck platooning, Optimization, Transportation, Automated driving, Review paper

---

1. Introduction

A set of novel semi-automated driving technologies, collectively referred to as Cooperative Adaptive Cruise Control (CACC), enable trucks to drive very close together as a platoon. Trucks in a platoon are virtually linked and communicate with each other through wireless communication technology. The leading truck is manually driven at the first position of the platoon and automatically followed by one or more following trucks. This means that the following trucks automatically brake, steer and (de)accelerate based on the leading truck.

Truck platooning has been the subject of heightened interest recently because of the

*Corresponding author

Email addresses: kishorebhoopalam@rsm.nl (Anirudh Kishore Bhoopalam), nagatz@rsm.nl (Niels Agatz), rzuidwijk@rsm.nl (Rob Zuidwijk)

different benefits it provides, both for the individual truck operators and society. Driving close together reduces fuel consumption as it improves the aerodynamics of all trucks in the platoon (Patten et al., 2012; Zabat et al., 1995). Test track experiments suggest savings of up to 6% for the leading truck and 10% for the following trucks (Alam et al., 2015; Lammert et al., 2014).

While less fuel consumption leads to costs savings for the truck operators, it also reduces emissions (Scora and Barth, 2006). These savings may have a significant impact as heavy duty road transport is responsible for a large part of all traffic emissions (European Commission, 2016). Furthermore, platooning can enhance traffic safety by providing significantly lower reaction times and less room for human error within the platoon, which can reduce the number of rear-end collisions. The trucks in a platoon take up less road space than when driving separately, which reduces traffic congestion (Schladover et al., 2015; Van Arem et al., 2006) and therefore, increase traffic throughput (Lioris et al., 2017).

Automated driving has successfully been deployed in closed environments in various logistics and freight transportation settings such as port terminals (Kim and Bae, 2004) and warehouses and factories (Roodenbergen and Vis, 2001). Truck platooning can be considered as a first step towards automated freight transportation in an open and uncontrolled environment. Given the development of automated driving technology, we expect to see a decrease in human involvement in the driving task i.e. in the future, not all trucks in a platoon might require drivers (Kilcarr, 2016).

All major truck manufacturers have developed technologies that allow platooning, and several field tests are planned or are currently taking place in Europe (Eckhardt et al., 2016), the U.S (Peloton Technology, 2016), Singapore (Ministry of Transport - Singapore, 2017), Japan (Tsugawa, 2014) and Australia (UNSW Engineering, 2016). The first road-legal trucks equipped with platooning technology are expected soon.

When a sufficient number of vehicles possess platooning capabilities, it is likely that platoons can be spontaneously formed without planning in advance. However, in the initial stages, when the deployment of platooning technology is not widespread, careful centralized planning is required to create platoons (Janssen et al., 2015). A so-called platooning service provider (Roland Berger, 2016; Janssen et al., 2015) could organize the planning and control of platoons between different fleets. Platoons could be scheduled in advance or planned in real-time during execution.

To establish a platoon, the departure times, travel speeds and the routes of the trucks in the platoon must be synchronized. A truck may, for instance, have to take a different route or make a small detour to join a platoon. Figure 1 depicts an example platoon between two trucks in which one of the trucks makes a detour to form the platoon.

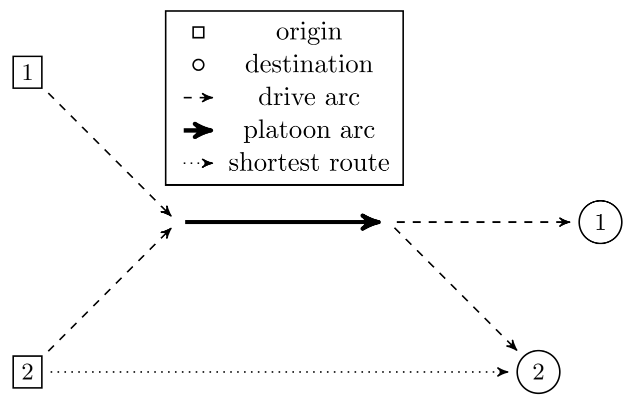


Figure 1: A two-truck platoon

Even when considering platoons of at most two trucks, complex planning problems may arise, especially when we can create multiple platoon matches on a single trip and allow detours. To fully reap the benefits of truck platooning, sophisticated decision support tools are required. While there has been much attention for the technological issues (see Berenghem et al. (2012) for an overview of recent projects), safe manoeuvring of platoons (see Kavathekar and Chen (2011) for an overview), and human factors related issues (for example, Heikoop et al. (2017); Hjamdähl et al. (2017); Yamabe et al. (2012); Larburu et al. (2010)), we are not aware of a paper that systematically reviews the challenges of platooning from a planning and transportation optimization perspective.

This paper aims to fill this gap by classifying the different planning problems that arise in truck platooning, reviewing the emerging literature related to this planning and identifying directions for future research. More specifically, the goal of this paper is fourfold: (1) provide a systematic overview of different forms of platooning; (2) identify and define relevant planning problems to support the different forms of platooning; (3) provide an overview of relevant operations research models and approaches for these and similar problems in the literature and; (4) identify gaps and areas for future research.

This paper focuses on truck platooning but similar issues may arise in the planning of platoons of regular cars and other vehicles not only on the road but also in water (see Lauf (2017); TU Delft 3mE (2017)) and air (see Chen et al. (2015); Richert and Cortés (2012)).

The paper is structured as follows. Section 2 explains the main characteristics of platooning planning. In Section 3, we compare platooning with other collaborative transport systems such as ridesharing and freight consolidation. Section 4 describes different platoon configurations and related static planning problems from the literature. Section 5 discusses planning problems that arise when technology and legislation allow platoons with (partially) driverless trucks. Section 6 discusses the planning of platoons in real-time. Section 7 looks at vehicle routing with platooning. The effects of platooning on network design are discussed in Section 8. Finally, Section 9 identifies some future research opportunities and concludes the paper.

2. Characteristics of truck platoon planning

This section discusses several important characteristics of platoon planning. First, we discuss the planning process and the possible planning dynamics. Then, we present the planning objectives and constraints. Following this, we examine different types of collaboration in platooning.

2.1. Platoon planning process and dynamics

To explain the planning processes, we consider a platooning service provider that creates platoon schedules based on the trip information from different trucks. Each trip announcement specifies an origin location, a destination location, an earliest departure time, and a latest arrival time at the destination. We assume that there is typically some flexibility in the departure time, i.e. it is not necessary to leave at the earliest departure time to arrive at the destination before the latest arrival time. Moreover, there may be different possible routes between the origin and the destination. The trip announcement also specifies the characteristics of the truck and the load and could contain the preferences for the role of leading or following truck.

A platoon schedule specifies (1) which trucks platoon together, (2) where and when the trucks form a platoon, (3) the route the platoon will take and (4) in what sequence the trucks drive within the platoon. Based on these platoon schedules, the different trucks then typically form platoons en-route. A platoon could be formed with one truck waiting for, or catching up to, another truck. For more information about the en-route formation of a platoon while interacting with surrounding traffic, see e.g. Segata et al. (2014); Berenghem et al. (2012).

Depending on when the trip announcements become available, we can distinguish the following situations.

Scheduled platoon planning All trips are announced before the start of the operations. Therefore, all platoon schedules can be created in advance.

Real-time platooning Truck operators announce their trips closely before departure or even when the trucks are en-route. Therefore, trip announcements arrive during the execution of the trips.

Opportunistic platooning Trucks that are in close proximity of each other form platoons dynamically on the road without any prior planning. This type of platooning is also referred to as spontaneous, ad-hoc or on the fly platooning (Janssen et al., 2015; Liang et al., 2014).

When the deployment of platooning technology is not widespread, opportunistic platooning will not lead to many platoons and therefore some form of planning is required. This is supported by Liang et al. (2014) who study opportunistic platooning and compare it to a scenario where some degree of planning is involved and see that the benefits of platooning are much higher when some degree of planning is involved. In the next few sections of the paper, we discuss various aspects of scheduled platoon planning before we go into real-time platoon planning.

2.2. Platooning objectives

To create platoons, a platooning service provider can consider different objectives.

Minimize the system-wide travel cost

This objective aims to minimize the total variable transportation costs (i.e. fuel) of all trucks in the system. To determine the net costs of a platoon, one should not only consider the costs savings that occur within the platoon but also the additional costs incurred to create the platoon such as waiting or additional fuel consumption due to detours or speed changes to catch up with the truck. Liang et al. (2013) using a fuel consumption model, conclude that the platooning distance has to be much larger than the catch up distance for the platoon to be beneficial. The minimization of the transportation costs is the main reason for individual truck operators to participate in platooning.

The objective to minimize fuel costs is equivalent to maximizing the societal benefits of platooning. That is, emissions are directly proportional to fuel consumption (Scora and Barth, 2006). Also, in trying to maximize the fuel savings, longer platoons are automatically preferred as the total savings will be higher with more following trucks in the system. Such longer platoons are also associated with more efficient road utilization since the trucks within a platoon drive closer together. The headway between two trucks could be approximately 90% lower when they drive as a platoon as opposed to driving separately (Queensland Government, 2016; Janssen et al., 2015).

Maximize the number of trucks in a platoon

Instead of minimizing the system-wide travel cost, a platoon service provider could also maximize the number of matched trucks in the system. The increased likelihood of finding a platoon might be an important criterion for truck companies. Furthermore, involving more companies by creating more matches in the initial stages might help spread confidence and trust in the system. The higher matching rate could consequently stimulate larger participant pools by attracting more truck companies in the future. This approach sacrifices short term optimality for the long term sustainability of the system.

2.3. Constraints on platoon formation

Various prerequisites determine whether it is feasible to form a platoon between a set of trucks. One of the most important constraints is the timing of the trips. Since freight transportation typically operates within tight time windows that are specified by the customers, there may be only little flexibility to wait for another truck to form a platoon.

Besides the customer imposed time windows, platoons also have to abide by driving time regulations (Goel, 2014; Goel et al., 2012; Goel and Rousseau, 2012; Goel, 2010). These regulations dictate specific time periods in which trucks need to take breaks. Incompatible break times may render certain platoons infeasible.

Furthermore, it may not be possible to form platoons between certain types of trucks. The platooning technologies of different truck manufacturers are current incompatible, so it is only possible to platoon with trucks of the same brand (Brizzolara and Toth, 2016; Berger, 2016). Close competitors may also not be willing to form a platoon together. Also, the nature of the load (for example, dangerous goods) may preclude a truck from being part of a platoon (Meisen et al., 2008).

There may also be legal limitations on the length of a platoon (Eckhardt et al., 2016). Long platoons might disturb the traffic flow by making it difficult for other vehicles to merge onto highways. Additionally, long platoons could lead to increased wear and tear of road infrastructure such as bridges. This is because of the greater weight of a platoon which certain bridges or roads cannot bear.

Apart from these technical and operational constraints, personal and inter-organizational considerations may also play an important role in platoon formation. That is, not all companies may be willing to platoon with each other because of issues related to trust or competition. Some companies may only want to form platoons within their own fleets or within a restricted coalition of fleets.

Next to restrictions on which trucks can form platoons together, there may be restrictions on the platoon sequence. That is, loading weights, torque ratings and the brake capacity determine safe possible truck sequences in a platoon (TNO, 2016). For example, trucks should be arranged in ascending order of their engine power to mass ratio. This will ensure that lead trucks don't pull away on uphill terrain (Nowakowski et al., 2015). A different consideration could be that of safety. To prevent the following trucks from colliding, the truck with the worst braking performance could be placed in front.

Finally, the infrastructure could impose physical restrictions on the platoons that may be formed. For example, certain roads in the network may not be suitable for platooning as they might be worn out or are too small. Some bridges might be too old and worn out to sustain the weight of a platoon (Janssen et al., 2015). It might be necessary to have dedicated lanes or corridors that are capable of supporting platoon traffic. The communication technology might not be very reliable in tunnels. The physical infrastructure related considerations play a role in the convoy planning problem. For instance, Tuson and Harrison (2005) mention that the gradient of a road plays a constraining role for convoys.

Table 1 provides an overview of the different objectives and constraints that are used in the platooning literature.

2.4. Dividing the benefits of platooning

Trucks that participate in a platoon directly benefit due from lower fuel consumption. However, these savings depend on the position in the platoon, i.e. there are more savings for the following truck(s) than for the leading truck. Moreover, trucks may incur different costs, such as detour costs, in order to join the platoon. This means that it may be necessary to redistribute the total system-wide benefits among the different participant in a platoon. In determining the total benefits, one should not consider the benefits within the platoon but also the costs, e.g. detour and waiting, associated with forming the platoon.

With scheduled truck platoons, simple proportional rules may be an appropriate way to divide the total system-wide benefits. However, this becomes difficult in a dynamic setting in which trucks can join and leave a platoon at any time. This issue is also relevant in dividing the shared benefits in multi-passenger ridesharing (Furuhata et al., 2013). This issue is related to the stream of literature on inter-organizational collaboration (Cruijssen et al., 2007). Much of the research in this area makes use of cooperative game theory which considers scenarios where different parties form alliances that aim to achieve some goals jointly in an attempt to increase their individual profits (see Elkind and Rothe (2016) for more information). Cooperative game theory has been extensively applied to solve various benefit allocation problems in the area of logistics. For examples of applications, see Lozano et al. (2013); Frisk et al. (2010); Krajewska et al. (2008). For a review of studies, see Guajardo and Rönnqvist (2016).

If the same trucks regularly platoon together as in the coalition, they could share the benefits by taking turns as leading truck. Richert and Cortés (2012) consider the similar problem for unmanned aerial vehicles (UAVs). This is also similar to carpool schemes in which different participants act as driver each time, e.g., Fagin and Williams (1983) propose scheduling algorithms to determine which carpool participant should drive in each carpool to fairly divide the workload. In similar fashion, one could assign the more beneficial following positions to the truck that incurs most costs to join the platoon.

Another consideration in centralized planning is that system-optimal solutions are not necessarily optimal for each of the individual participants. A solution is not 'stable' if there exist pairs of trucks that are better off forming a platoon together than with the system assigned platoon partners. Wang et al. (2014) consider this in the context of dynamic ridesharing.

System optimal solutions could also be hindered because of strategic behaviour from one or more companies. The desire to maximize one's own profit means that certain companies or drivers may reveal false information if it means they find a better match. For example, if a freight transporter is aware that a route is frequently traversed by many trucks, he might lie about the destination to make it seem like he needs to travel along the same route for a longer distance than he actually has to. This increases the probability of his truck being allocated a platoon match as part of the "system optimal" solution.

This could be prevented using formal agreements or contracts (see Schwartz and Scott (2003) for information on contract theory). Another way is to create a collaboration mechanism that ensures all the parties act in a way that contributes to system efficiency (Xu, 2013). This is linked to the area of strategy proofness and mechanism design (see Nobel Prize Committee (2007); Parks (2001)). Strategic behaviour could also be prevented by using a reputation system (see Resnick and Zeckhauser (2015); Gupta et al. (2003) for examples, Mui et al. (2002) for an overview) which also incorporates factors such as company and driver trust. These systems could also discourage non compliance from the truck companies and drivers.

Table 1: Overview of platoon planning literature

Author(Year)	**Objective**	**Constraints**	**Dynamics**
Sokolov et al. (2017)	Minimize total fuel consumption	Maximum waiting time, maximum detour length, earliest start time, latest arrival time, fixed speed	Scheduled, Opportunistic
Zhang et al. (2017)	Minimize costs (fuel, travel time and penalties)	Earliest arrival time, latest arrival time	Scheduled
Adler et al. (2016)	Minimize energy consumption and delay simultaneously	Maximum platoon length, maximum waiting time	Real-time
Larson et al. (2016)	Minimize total fuel consumption	Maximum detour length,earliest start time, latest arrival time, fixed speed	Scheduled
Liang et al. (2016)	Minimize total fuel consumption	Fixed route, maximum speed, latest arrival time	Real-time
Van de Hoef (2016)	Minimize total fuel consumption	Fixed route, maximum speed, no waiting, start time, latest arrival time	Scheduled, Real-time
Nourmohammadzadeh and Hartmann (2016)	Minimize total fuel consumption	Fixed speed, latest arrival time	Scheduled
Larsson et al. (2015)	Minimize total fuel consumption	Start time	Scheduled
Liang et al. (2014)	Maximize fuel savings	Fixed route, maximum speed, maximum deviation in the departure time	Scheduled, Opportunistic
Liang et al. (2013)	Platoon savings greater than catch up cost	Maximum speed	Real-time
Larson et al. (2013)	Minimize total fuel consumption	No additional driving time, maximum speed, maximum catch up length	Scheduled, Real-time
Meisen et al. (2008)	Maximize net platoon savings	Fixed routes, maximum waiting time, maximum platoon size, minimum net platoon savings	Scheduled

3. Comparison with other collaborative transportation systems

Platooning entails the collaboration of multiple vehicles to increase the efficiency of the transportation system. As such, it shares some features with other forms of collaborative transportation. In this section, we highlight some of the key similarities and differences between platooning and two other collaborative transportation systems.

3.1. Freight consolidation

Freight consolidation is widely used as a means to facilitate more efficient and frequent shipping by combining large freight flows between terminals through a few links (Campbell, 1990). When multiple trucks with similar routes and time schedules have spare capacity, their loads may be consolidated into fewer trucks. Therefore, freight consolidation requires the matching of trucks with the load they need to pick up and deliver. An overview of the various forms of consolidation and consolidation strategies may be found in Hall (1987).

Triangulation of truck transport or backhauling is a form of consolidation that is, from the collaboration perspective, similar to platooning. In traditional consolidation described above, loads from partially filled trucks traversing similar routes are consolidated. In backhauling, loads are assigned to trucks travelling back and forth between locations so that the number of empty kilometers is utilized (Jordan and Burns, 1984).

Like platooning, freight consolidation is associated with reduced costs, reduced consumption of fuel and consequently, a decrease in the emissions. The key difference between platooning and freight consolidation is that platooning does not involve load transfer between the trucks meaning that loads do not have to be compatible. This means that full trucks could also form platoons. Also, truck platooning is a less "intimate" form of collaboration than freight consolidation since platoons may be formed anywhere in the network whereas freight can be consolidated only in stationary facilities such as warehouses or depots.

3.2. Ridesharing

Ridesharing is the practice of sharing rides as a means of reducing congestion, pollution and personal costs. Ridesharing utilizes the empty seats of passenger cars to achieve the above mentioned benefits. The rationale behind ridesharing is similar to that of freight consolidation discussed above. Instead of load being consolidated into fewer vehicles, people are. A difference with consolidation is that people are less flexible than load specially with regards to pick up and drop off times. However, people are more flexible when it comes to the pick up and drop off locations since they can move.

Traditionally, ridesharing was used by people regularly travelling to the same place at the same time (Levofsky and Greenberg, 2001). The term carpooling is associated with this method of operation. In today's world, ridesharing systems exist where people are dynamically matched with cars, in real time, based on their locations and times. Ridesharing has been studied extensively in literature (see Furuhata et al. (2013); Agatz et al. (2012) for overviews in the area).

In ridesharing, drivers are matched with riders that need to be picked up at their origins and dropped off at their destinations. Similar to freight consolidation, the location of pick up and drop off are fixed at the origin and destination. The service time is determined by the time it takes for this pick up and drop off to be executed.

Both truck platooning and ridesharing have the benefit of reduced costs and consequently, reduced emissions. Both of them involve matching entities with similar routes and time schedules. Both of them operate under certain capacity constraints. For ridesharing, the capacity is the number of seats in the car. For platoons, the length of a platoon will be restricted by legislation. Also like in platooning, drivers part of ridesharing services might have to make some detours or adjust their time schedules to pick up riders.

Table 2 shows the comparison between platooning, ridesharing and freight consolidation.

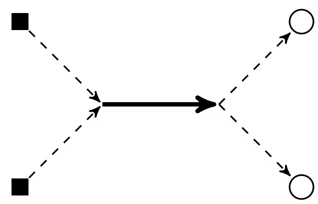
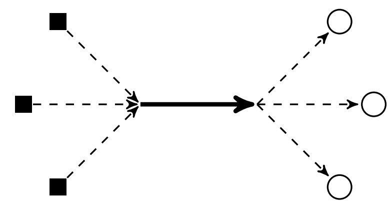
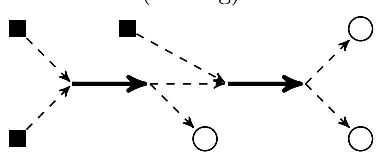
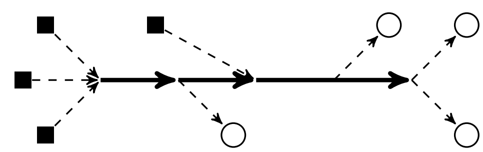
Table 2: Comparison of platooning with ridesharing and freight consolidation

	Truck platooning	**Ridesharing**	**Freight consolidation**
Supply			
Entity	Trucks	Drivers	Trucks
Capacity	Allowed maximum platoon size	Vehicle capacity (no of passengers)	Load weight and volume limits
Demand			
Entity	Trucks	Riders	Load
Location	Flexible	Fixed	Fixed
Service time	Negligible	Pick up and drop off time	Loading and unloading time
Service quality	Detour, excess travel time, success rate	Detour, excess travel time, success rate	Detour, safety, reliability
Benefits			
Individual	Reduced labour and fuel costs	Reduced costs due to shared capacity	Reduced costs due to economies of scale
Societal	Reduced emissions, road utilization	Reduced emissions, road utilization	Reduced emissions, road utilization

4. Basic truck platoon arrangements

As stated earlier, the platoon size in terms of the number of trucks is likely to be restricted by law. We can classify platoon planning based on the number of trucks that can platoon together and also the number of platoons in a single trip. This gives rise to four truck platoon arrangements as shown in Table 3.

Table 3: Basic platoon arrangements

	Two-truck Platoons	**Multi truck (>2) platoons**
Single platoon per trip	Matching trucks (matching) 	Interdependence between matches (routing) 
Multiple platoons per trip	Interdependence between matches (routing) 	Combined setting (less constrained) 

4.1. Two truck platoons, single platoon per trip

On grounds of legislation, trucks may be required to form at most one single two-truck platoon in a trip. For each pair of trucks, a platoon is feasible if it results in net savings for both the trucks i.e. the costs of driving in a platoon are lower than the costs if they were driving alone. This involves solving the routing problem for each pair of trucks. Given all feasible platoons, the assignment that maximizes the total system-wide savings can then be found by solving a general matching problem. Note that, unlike in unit capacity pick up and delivery problems (see Amey (2011); Berbeglia et al. (2007)), this problem does not represent a bipartite matching problem as a truck can be a leader or a follower in the platoon. We are unaware of any research that specifically considers this two-truck platoon planning problem.

We are aware of one study that focuses on the sub problem of determining feasibility of a pair of trucks. Zhang et al. (2017) consider the platoon coordination problem under travel time uncertainty. As part of a cost minimization framework, they focus on determining the savings for a pair of trucks considering fuel related costs, travel time related costs, and penalties for deviating from the planned schedule. When both trucks follow the same path, they observe that above a certain threshold in the waiting time, the vehicles are better off driving alone since the penalties outweigh the fuel savings. They extend this to converging and diverging routes and find that platooning on converging routes is less beneficial due to the extra costs of waiting at the merging point on the network.

The two-truck platooning problem is similar to the ridesharing problem with meeting points in which riders are willing to walk to a meeting point to shorten the detour for the driver. As in truck platooning, riders and drivers have to find the optimal points to start and end their joint trip. That is, both entities that are involved in the combined trip can move independently. Stiglic et al. (2015) design and test an algorithm for large scale ridesharing systems with meeting points. They consider meeting points that are within walking distances of the riders' present locations. A similar setting in the context of buses is considered by Mukai and Watanabe (2005). They allow for flexible pick up and drop off points of the customers and minimize the 'time sequence' of the customer which is the sum of the walking time, waiting time and the riding time.

Ridesharing is a special case of the well-known general pick up and delivery problem. The general pick up and delivery problem (Savelsbergh and Sol, 1995) considers vehicles that need to fulfil transportation requests by picking up goods at their origins and delivering them to their destinations. This can be extended to truck platooning where instead of goods, trucks need to be "picked up". Unlike the traditional pick up and delivery problem, there are no fixed start and end locations defined as both vehicles are mobile. This is linked to the vehicle routing problem with roaming delivery locations. This problem considers the deliveries of shipments to the trunk of a customer's car (Reyes et al., 2016).

4.2. Two truck platoons, multiple platoons per trip

For longer trips, trucks may be willing to participate in multiple platoons with different trucks along their route. This means that a truck could platoon with one truck during the first part of its trip, disengage and then platoon with another truck later in the same trip. This could be repeated multiple times so that a single truck is part of several platoons during a single trip. We are not aware of any papers that explicitly study this platooning arrangement.

In this setting, the start and end locations and time schedules of the different platoon assignments within a trip should be synchronized. If we do not consider detours, it is a scheduling problem, (see Dumas et al. (1990) for an example of a fixed route scheduling problem) i.e. we need to find the departure times of all trucks so that the platoon savings are maximized. When we do consider the detours, the problem is linked to the area of vehicle routing with synchronization constraints. A survey of problems in this area may be found in Drexl (2012). In this area of problems, there is an interdependence in the routes of different trucks. This is also clearly the case in this platooning arrangement. Of the different types of synchronization described by Drexl (2012), *operation synchronization* is specially relevant for truck platooning. Operation synchronization refers to the spatial and temporal offsets allowed for different trucks to begin certain tasks, for example, depart from a depot. This is directly related to the route and time flexibilities.

The problem is also similar to the single rider ridesharing problems in which a driver can sequentially pick up multiple riders in the same trip. Chen et al. (2016) consider meeting points and also rider transfers between drivers. They allow flexible roles for the participants within a car i.e. participants with a car can also ride with others. As a result, return restrictions are also incorporated. In Aivodji et al. (2016), riders can either walk or take public transportation to reach the meeting point. This incorporation of movement of the riders strengthens the link to platooning where both the entities i.e. trucks that need to be matched are moving.

Note that sequentially solving different instances of the single platoon per trip problems may provide a good heuristic solution approach. Such an approach is used by Wark and Holt (1994) who make use of a repeated matching heuristic for the vehicle routing problem.

In such an approach, the end location of one platoon would be considered as the origin for the next platooning instance.

4.3. Multi truck platoons, single platoon per trip

If truck platoons of more than two trucks are allowed, one may still want to minimize the number of platoon arrangements to, for example, make the division of benefits simpler by requiring that the platoon start and end at the same time for all associated trucks. This means that a truck cannot join or leave a platoon en-route. Such dynamic add-ons and split-ups are considered multiple platoons in the trip and discussed in the next subsection.

We are not aware of any study that considers this platooning arrangement. The convoy movement problem is a similar problem and can be seen as a special case of this platooning arrangement. In this problem, all the vehicles have the same origin and destination and certain links cannot be traversed by the convoy due to infrastructure. The convoy movement problem is encountered in the military area where safety and therefore, time are the most crucial factors. For some examples, see Kumar and Narendran (2010); Tuson and Harrison (2005); Chardaire et al. (2005).

Problems conceptually similar to this platooning arrangement are seen in freight transportation. Heeswijk et al. (2016) consider inter-modal networks with terminals where freight coming in by truck is consolidated and moved to a different terminal by barge, rail or truck from where the freight is sent to its destination. If we consider a special case where all the trucks are headed to the same destination, the problem is linked to the merge in transit method of operation seen in parcel deliveries (see Croxton et al. (2003)).

Since the platoon starts and ends at the same time for all the associated trucks, this setting requires the determination of a meeting point for the trucks. Given a set of points on a road, Yan et al. (2015, 2011) describe exact and heuristic algorithms to find the optimal meeting point to minimize the travel costs. We can then route the trucks between from the meeting point to the split up point.

4.4. Multi truck platoons, multiple platoons per trip

In the least constrained case, there could be multiple trucks in a platoon and multiple different platoons can be formed along a route. Planning these platoons requires accurate information about all the trucks throughout their trips.

Meisen et al. (2008) aim to find profitable truck platoons given a set of routes. To determine if a platoon is profitable (has net savings), they consider multiple criteria such as common distance, waiting time, fuel consumption etc. They propose a data mining based heuristic to solve this problem. The trucks are first categorized based on characteristics such as the goods they're carrying. Among these trucks, grouping possibilities are determined based on the trucks' physical characteristics. Within these trucks that are grouped together, platoons are planned based on the overlap in the routes. In addition to the fuel costs, the costs associated with waiting are also considered. They set the maximum size of the platoon to be two and four. To test the algorithm, the authors use synthetic datasets with up to 5000 routes and are able to find profitable platoons. To limit the exponential growth in the number of profitable platoons with an increase in the number of routes, they set limits on the waiting time, common distance and profit per platoon.

Larson et al. (2013) allow trucks to form platoons if the fuel savings are higher than the catch up costs of forming the platoon with the objective of minimizing the total fuel expended. The optimization process is carried out by local controllers that are placed at various junctions in the street by taking into account a truck's speed, position and destination. In a restricted version of the problem, they do not allow trucks to travel for any additional time compared to the shortest path time. For multi truck platoons, they propose a pairwise matching heuristic where platoons with the highest savings are fixed as one unit in the next step of the heuristic and so on. When they allow the trucks to deviate from their shortest time paths, the savings increase further. A similar pairwise matching heuristic is also used by Liang et al. (2016) who also aim at minimizing the fuel consumption given a set of trucks. Unlike Larson et al. (2013), Liang et al. (2016) do not consider any rerouting. In this study, which is a continuation of Liang et al. (2013) (see section 2.2), they allow the lead vehicle to slow down in addition to the following vehicle speeding up to form platoons and conclude that it is more efficient.

Larsson et al. (2015) also aim to minimize the fuel consumption given a set of trucks with their origins, destinations and deadlines. They model this as a graph routing problem and prove that it is NP-hard. They also introduce a simpler version of the problem called the unlimited platooning problem where the deadlines are discarded. They propose two heuristics to solve instances of the problem with more than 10 trucks. Like Larson et al. (2013), they propose a heuristic where they merge the pair of platoons with the highest savings. In addition to this best pair heuristic, they also present a hub heuristic where the problem is broken down into sub-problems. They split the trucks and select hubs for each subset. The problem is then to route the trucks from the origins to the hub and then to the destinations. The trucks are partitioned based on the edge ratings which represent the probability of a truck to drive over that edge. A local search improves the results of both the heuristics and generates near optimal solutions for most instances up to 200 trucks. They also consider a special case where all the trucks have the same origin for which the heuristics work more efficiently.

Larson et al. (2016) consider a similar problem of routing vehicles so that they reach their destinations on time while being as fuel efficient as possible. They formulate a mixed integer programming model with the objective of minimizing the amount of fuel used. The trucks are allowed to wait to form platoons. They declare additional constraints based on results that help reduce the number of variables and the problem size significantly. They perform experiments on a simple grid network and a representation of the Chicago highway network for instances with 25 trucks.

Nourmohammadzadeh and Hartmann (2016) also consider a similar problem of planning fuel efficient platoons while respecting deadlines. They formulate a mathematical model to minimize the total fuel used. They propose heuristics based on a genetic algorithm for good quality solutions for large problem instances. On comparison with the results from a solver for smaller instances of about 10 trucks, the genetic algorithm exhibits similar levels of performance at faster speeds. For larger instances of 30-50 trucks where the solver is inadequate, the genetic algorithm still generates fuel saving results in under a minute.

Van de Hoef (2016) examines a similar problem for a large fleet of trucks. Using truck information, a centralized coordinator computes the vehicle plans for each truck which contain the routes and speed profiles so that they reach their destinations before the deadlines. The trucks are not allowed make detours to facilitate platoon formation. Trucks that have partially overlapping routes may, theoretically, form platoons. A truck may be part of multiple platoons along its route. The problem is to find the set of vehicle plans that minimizes the total fuel consumption. A list of candidate platoon pairs is found taking into consideration the overlap in the routes and the time schedules. With this list of candidate pairs, pairwise plans are computed where one vehicle adapts its speed so that it can form a platoon with the other vehicle. These pairwise plans are all merged together into one plan that contains all the vehicle plans of the trucks. The associated combinatorial optimization problem is shown to be NP hard and a heuristic is presented to solve large problem instances. Then, the timings of platoon formation and split up are adjusted using a convex optimization problem to minimize fuel consumption.

In addition to the specific treatment of the problem in the above mentioned studies, the area of convoy movement provides a special case of such a setting. Valdés et al. (2011) consider the problem where a transportation unit in a city needs to merge with a convoy that is travelling in a circular path across the city. They use dynamic programming to route this transportation unit to the convoy in an efficient way.

Apart from these approaches, a traffic flow perspective could be used in planning platoons. In traffic assignment, having more vehicles on the same arc is unfavourable as it causes congestion. Therefore many traffic assignment models seek to minimize congestion. For examples, see Angelelli et al. (2016), Merchant and Nemhauser (1978). But in platooning, it represents more platooning opportunities and is therefore, at least up to a certain point, favourable. Using this line of reasoning, Farokhi and Johansson (2013, 2014) consider vehicles that decide their time of travel based on their preferred time, average traffic velocity and the congestion tax at that time. But trucks that can platoon have an additional incentive use the road at the same time as other trucks. They model this as a congestion game and study a Nash equilibrium to study how the traffic flow and platooning incentives interact. One of their observations is that as the fuel saving coefficient (which represents the platooning incentive) is increased, more trucks start travelling in similar time intervals.

5. Levels of human involvement in platooning

In this paper, we have considered platoons between trucks that require fully engaged drivers. As technology develops and legislation permits, driverless platoons may become

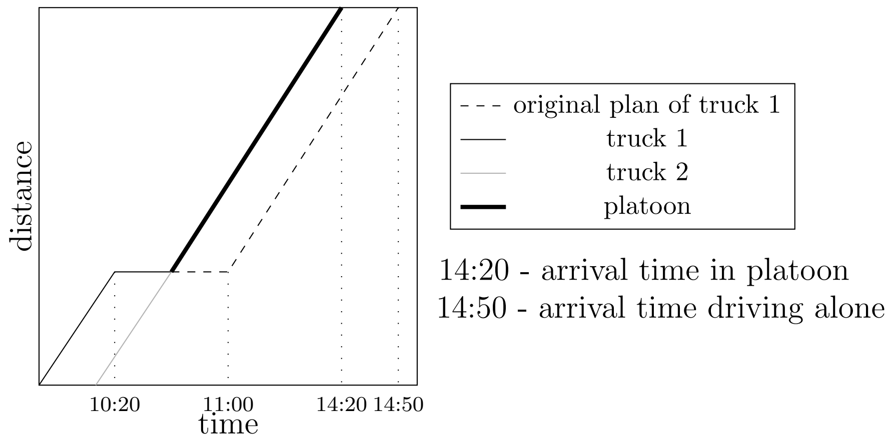


Figure 2: Increased productivity when the driver of truck 1 can take a break in a platoon

reality. The required level of human involvement is likely to gradually decrease. Since the widely used SAE levels of driving automation (SAE International, 2016) focus on individual vehicles and do not consider platooning, this paper develops the following new classification to describe different levels of human involvement in platooning. These different types of platooning give rise to new planning problems that are also discussed in this section.

5.1. Human driven platooning with in-platoon resting

In most countries, truck drivers are subject to regulations on the time that they are allowed to drive before having to take a break. The regulations depend on the type of vehicle and the country. For example, EU regulations state that a driver must take breaks totalling at least 45 minutes after a maximum of 4.5 hours of driving (Government-UK, 2016). Similarly, in the US, a break of 30 minutes is required after at most 8 hours after a driver begins his duty (Goel, 2014). Regulations also prescribe weekly limits in addition to the limitations within a day. See Goel (2014); Goel et al. (2012); Goel and Rousseau (2012); Goel (2010) for a detailed overview of different regulations.

In this type of platooning, the following trucks can handle all the driving tasks which means that the drivers may rest while being in the truck. For this to be implemented in practice requires both technological feasibility and legal clearance. In this setting, the time as part of the platoon would not count as formal driving time for the following driver.

Allowing breaks during a platoon will relax break time constraints and as such improve the overall transport efficiency. In particular, it may help increase the productivity of the drivers as they can cover longer distances in the same period of time. Figure 2 illustrates the benefits of being able to take a break within the platoon. The example considers two trucks that share a portion of their route. Truck 1 starts a 40 minute break at 10:00. Ten minutes into his break, truck 2 arrives at the location. Instead of waiting to finish his break, the driver of truck 1 can now finish the last 30 minutes of his break in the following truck of the platoon. This implies that truck 1 now arrives at its destination at 14:20 instead of 14:50. Therefore, there is an improvement in the transportation lead time in addition to the decrease in labour costs as a result of the shorter driving hours.

The example described in figure 2 considers a two truck platoon where each truck is part of only one platoon in its trip. The same idea can fairly easily be extended to the multi-truck, single platoon per trip case. Just like the example, the change will affect only the trucks in that platoon. It is, however, more complicated when a truck may be part of multiple platoons per trip. The different platoons in a trip are interdependent. Any change made to the break of one truck will affect all the platoons in the trip of that truck. This, in turn, will also affect all the platoons in the trips of the trucks part of the aforementioned affected platoons and so on. Therefore, the problem's computational complexity grows rapidly.

At the same time, there is an additional layer of complexity that needs to be considered in planning the platoons. Since breaks are allowed only for the drivers in the following trucks, the position of a truck in a platoon becomes an important planning decision. For longer trips, we may even consider switching the order periodically so that drivers can take breaks in turn. To plan the timing of switches in the platoon sequence, the timing of breaks, and travel times need to be considered. In these settings, we can also consider minimizing the time to serve all requests as an objective.

5.2. Hybrid platooning

In this type of platooning, only the leading truck requires a human driver and the following trucks can be driverless. This means that the driver of the following truck is no longer required for parts of the trip, which may lead to labour cost savings (Kilcarr, 2016). Unless the leading and following truck have exactly the same itinerary (and following trucks basically serve as trailers), we would still need drivers for the first and last part of the trips.

Drivers could be moved between these pick up and drop off points by taxi. The planning of these taxi rides gives rise to a pick-up and delivery problem of drivers.

The pick-up and delivery problem is a well known optimization problem, see for example, Berbeglia et al. (2010); Savelsbergh and Sol (1995). A special case of pickup and deliveries that involves people is referred to as the Dial-a-Ride Problem (Cordeau and Laporte, 2007). This is also similar to the last/first mile problem seen in scheduled public transit. The first mile problem is similar to the car pooling problem where multiple users are picked up and transported to a common flexible destination which could be any point on a public transportation line (see Minett (2013)). The last mile problem considers the opposite scenario where people are picked up from the public transportation line and taken to their destinations (see Wang and Odoni (2014); Cheng et al. (2012)).

Hybrid platooning also gives rise to new opportunities with regards to driver roles. The drivers may have different duties such as a platoon leader or a last mile driver. Furthermore, during the pick up and delivery of drivers, drivers may swap roles. The driver dropped off may take over as the leading driver of the platoon while original platoon leading driver may take over the decoupled truck and complete its final leg. This is specially relevant for the planning of shifts and breaks. This is linked to the general area of crew scheduling (see Ernst et al. (2004); Raff (1983)). Vehicle routing and crew scheduling has been done in parallel in most of the literature (see Hollis et al. (2006) for an overview). Drexl (2011) mentions that the truck and trailer approach could also be used in this way. The drivers may be considered vehicles which can couple with a truck that is left at intermediate locations.

Apart from being picked up by a driver, a truck could also be picked up by another platoon. Also, drivers could pick up trucks from one location and leave it at another location where the truck is then picked up by another platoon. These two basic arrangements may be combined in any order and form. Therefore, there is quite some flexibility in the planning of hybrid platoons. On that account, following trucks can essentially act as trailers that need to be picked up and dropped off. Therefore, this problem is related to the the truck and trailer problem (see Derigs et al. (2013); Villegas et al. (2013); Chao (2002)) and the swap body vehicle routing problem (see Lum et al. (2015); Absi et al. (2015); Miranda-Bront et al. (2015); Huber and Geiger (2014)). Meisel and Kopfer (2014); Drexl (2011) categorize transport means as active and passive. Active means are also allowed to transfer load onto passive means in addition to picking them up. In this platooning context, a truck could either be active or passive depending on its use at a particular instant.

5.3. Driverless platooning

This form of platooning involves completely driverless trucks which provides a greater degree of flexibility since the platoons do not have drivers that need to go home or take breaks. Planning elements related to the human driver such as break time optimization, pick up and delivery of drivers are no longer relevant in driverless platooning. The planning problems are conceptually similar to the lowest form of platooning but the additional flexibility creates more room for optimization. For instance, the absence of drivers means that trucks do not have to return to a fixed location. This feature is shared by the open vehicle routing problem (see Li et al. (2007) for an overview in the area).

6. Real-time platoon planning

Up to now, we assumed that all the information required for planning the platoons is known in advance and accurate. However, in practice this might not be the case and trucks may continuously arrive and withdraw from the platoon planning system.

The dynamics increases the complexity of the decision making process. It requires real-time information of the states of all vehicles and communication methods to inform the vehicles of any changes. Decisions need to be made quickly as trucks are moving so platooning opportunities at one point in time may no longer be available at a later point in time. This dynamism links this problem to the area of dynamic vehicle routing in which route plans may be adjusted when new information becomes available (see Pillac et al. (2013) for an overview).

Dynamic planning could be carried out in a time-based or an event-based manner (see Agatz et al. (2011)). A well known example of a time based approach is the rolling horizon approach where optimization is repeated after a given time interval. Instead of the optimization being repeated after a certain time, it also could be triggered by an event such as the arrival of a new entity as the system. This is the case with event-based planning and is considered by Van de Hoef (2016) and Larson et al. (2013) who repeat the optimization when new information becomes available.

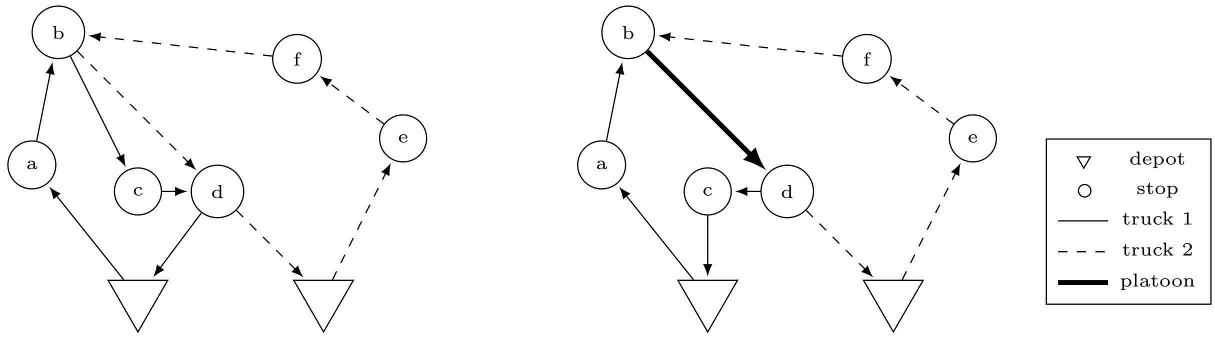
Based on historical information, we may have some probabilistic information about future events. For instance, historical data could provide an indication about trip announcements from freight transporters. For instance, if it is known that some trucks traverse the same route fairly regularly, there is a high probability of them being able to form platoons.

Adler et al. (2016) look at a case of real-time platooning of multi truck platoons from a queueing perspective by considering historical data to model the arrival of trucks. They consider a Poisson-distributed series of vehicles arriving at a particular station and all headed towards a common destination. The vehicles form platoons at this station and drive together as a single platoon to the common destination. Therefore, they allow the formation of multi truck platoons. Vehicles can wait for each other at the station but this will increase the delay. They look at this trade-off between energy savings and delay. Two sets of platoon formation policies are defined - all the trucks at the station leave as a platoon when either a certain time period has elapsed or a threshold platoon size is reached. On comparing these two sets of policies, they observe that the performance is dependent on the size of the platoons produced. The threshold platoon size policies allow an average of one truck more per platoon than the time table policies. As a consequence, the threshold policies perform better in terms of the energy saved for a given delay.

Moreover, the stochasticity of the information links the problem to the area of stochastic vehicle routing (Gendreau et al., 1996). See for example, Bent and van Hentenryck (2004); Powell (1996) for the usage of stochastic information in dynamic settings. Furthermore, the travel times of trucks could be uncertain due to the weather, traffic amongst other factors (van Lint et al., 2008). For examples with stochastic travel times, see Kenyon and Morton (2003); Laporte et al. (1992). This was considered by Zhang et al. (2017) as described in Section 4.1.

7. Vehicle routing with platooning

Instead of planning only single trips from an origin to a destination, one could also consider platooning opportunities in a typical route beginning from a depot and with multiple



No platooning opportunity Platooning opportunity between stops b and d

Figure 3: Changing the sequence of stops to create a platooning opportunity

stops. This provides more flexibility in forming platoons since there is more room to alter the route of a truck by visiting the stops in a different order.

Figure 3 shows an example in which the number of platooning opportunities may be increased by changing the sequence of stops. The figure shows the routes of two trucks with their stop sequences. Initially, there is no common path in their routes and, therefore, no opportunities to platoon. Switching the order of stops c and d on route 1 gives rise to a platooning opportunity between stops b and d.

This combines platoon planning with vehicle routing. There is a large body of research on solution approaches for the vehicle routing problem. Laporte (1992) provides an overview of these different approaches. In the usual variant of the problem, the loads need to be assigned to vehicles subject to the capacity constraints. The trucks could operate out of a single depot or multiple depots (for examples of the multi depot setting, see Crevier et al. (2007); Lim and Wang (2005); Cordeau et al. (1997); Renaud et al. (1996)).

When all trucks belong to the same fleet or company, the problem can be solved by considering a vehicle routing problem that incorporates platooning opportunities. This is different from the standard vehicle routing problem since the routing overlap creates platooning opportunities. We need to consider multiple paths between a pair of points to maximize the platooning opportunities. This is not considered in the traditional vehicle routing problem where the focus is usually on the shortest path.

A more restricted planning problem arises in the setting where the vehicle assignments are fixed in advance but there is flexibility in the routes and the sequence of stops. This would be the case when different fleets are involved. This links the problem to the area of cluster first route second vehicle routing literature (see Prins et al. (2014) for an overview). Here, the customers are clustered together and the customers in a cluster are visited by the same truck. That is, we already have the determined clusters. The routing phase can be treated as solving a travelling salesman problem with time windows within each cluster (Laporte et al., 2000).

8. Network design and platooning

The previous section described how platooning could have an impact on the way that freight is routed through the network at the operational level. Platooning could impact at strategic and tactical level decisions as well.

The strategic level decisions involve long term aspects such as physical network design (Crainic, 2000). For instance, parts of the network might be heavily used by platoons and might require an increase in the capacity. A similar rationale is used in the context of automated vehicles by Chen et al. (2017, 2016). Also, since the starting points of trucks influence platooning opportunities, facilities such as warehouses and depots might move closer to each other. This is similar to the concept of economies of agglomeration (see Glaeser (2007)).

Tactical level decisions relate to service network design. Crainic (2000) provides an overview of research in the area of service network design. A platoon can be viewed as a *consolidation transport mode* (Crainic and Kim, 2007). A platoon could move freight originating from different customers and destined for different locations. This is similar to freight consolidation although the savings are obtained differently. Platooning could prove to be a more economical alternative to freight consolidation since it does not require any additional infrastructure as there is no goods transfer and is so much more flexible. Therefore, platooning may be viewed as "on the fly" consolidation. This means that the service network design is dynamic. This is linked to the dynamic service network design problem (see Dall'Orto et al. (2006)). This flexible formation of a platoon can also be viewed as a switch in the transportation mode instantaneously. This links platooning to the multimodal network design problem (for an example, see Yamada et al. (2009)).

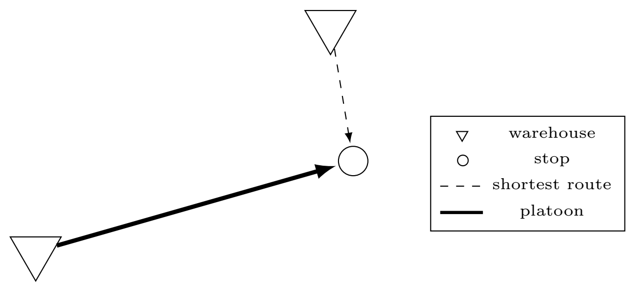


Figure 4: Change in order assignments because of platooning

Platooning can also be the motivation for assigning orders to certain warehouses. Figure 4 shows a simple example of such a situation. Instead of choosing to ship from the warehouse that is closest to the stop, the farther one is chosen because of the platooning opportunities it provides. The flexibility of platooning means that this decision could be made as late as possible based on the platooning opportunities on the different routes. Xu et al. (2009) look at a similar problem in the e-commerce setting citing the dynamic nature of the system.

9. Conclusions and future research

Truck platooning can be seen as the first implementation of automated driving in an open environment. Truck platooning has the potential to provide cost savings and is associated with several societal benefits. To efficiently reap the benefits of platooning requires good planning and optimization approaches.

This paper outlined various planning challenges encountered in platoon planning. Also, the paper provided an overview of relevant operations research models from different areas. Table 4 provides an overview of the platoon planning literature discussed in this paper. From this table, we see that there are several papers that address various sub-problems but an overall and dynamic approach is still lacking specially for the advanced forms of platooning. More specific, the areas for future research include -

Optimization. There are few studies in literature in the area of platoon planning (Larsson et al., 2015; Meisen et al., 2008; Van de Hoef, 2016) that present optimization approaches for the least constrained case where trucks could be part of multiple platoons per trip. These studies all acknowledge that the problem is hard to solve and solve it for moderately sized instances. Assuming a full scale implementation, there would be thousands

Table 4: Overview of platoon planning literature

Platoon configuration	Author(Year)	Decisions	Solution method	Level of human involvement	Multi-stop
Two truck platoon	Zhang et al. (2017)	2	Exact	Human driven	No
Single platoon per trip	Adler et al. (2016)	1,2	Analytical	Human driven	No
and	Liang et al. (2013)	1	Analytical	Human driven	No
Multi truck platoon					
Single platoon per trip					
Two truck platoon	Sokolov et al. (2017)	1,2,3	Exact	Human driven	No
Multiple platoons per trip	Larson et al. (2016)	1,2,3	Exact	Human driven	No
and	Liang et al. (2016)	1,2	Heuristic	Human driven	No
Multi truck platoon	Van de Hoef (2016)	1,2,3	Heuristic	Human driven	No
Multiple platoons per trip	Nourmohammadzadeh and Hartmann (2016)	1,2,3	Heuristic	Human driven	No
	Larsson et al. (2015)	1,2,3	Exact+Heuristic	Human driven	No
	Liang et al. (2014)	1,2	Heuristic	Human driven	No
	Larson et al. (2013)	1,2,3	Exact+Heuristic	Human driven	No
	Meisen et al. (2008)	1,2,3	Heuristic	Human driven	No

(1) which trucks platoon together, (2) where and when the trucks form a platoon, (3) the route the platoon will take (4) the sequence the trucks drive within the platoon

of truck trips to be planned. It is unlikely that these large instances can be solved to optimality in an acceptable time period. Even if they could be, the cost of complexity compared to the added benefits might not make it a worthwhile exercise. Therefore, efficient and fast approaches to deal with these large real life instances are required.

Also, areas relating to real time and stochastic planning are of interest. Dynamic and stochastic planning represent a more realistic scenario but are more complex to solve and implement. Zhang et al. (2017) use stochastic travel times but in a small setting.

Higher levels of automation reduce the level of human involvement and therefore open up a set of new planning problems. To our knowledge, there is no research done in this area. Planning approaches are required before these platoons become 'street legal'.

System sustainability. With a very small number of participants, the chances of formation of platoons go down. To ensure that platooning is sustainable in the long run, several 'special' steps might need to be taken during the initial phases of implementation.

From the planning perspective, maximization of the number of companies involved could be a way to go. Incentive schemes from the government to ensure benefits could also play a role. For examples, these incentives could be to subsidize the technology or provide special cost cuts for platoons. The determination of such measures and their effects on the system are interesting areas to look into.

Also, to ensure system sustainability, ways to ensure fair participation and prevent strategic behaviour are necessary. Participants may try to maximize their own profit rather than contributing to the system benefits. Designing mechanisms such as rating systems etc. to prevent this is required.

Network design. Platooning could have implications for the transport and supply chain network designs. As discussed, parts of the transport network might require upgrading to reap the maximum benefits of platooning. Similarly, supply chain network decisions such as locations of facilities might be made differently with platooning in the scene.

These network changes require significant investments and therefore, the expected costs and benefits will have to be carefully weighed against each other. Moreover, the level of human involvement becomes less, the magnitude of the effects will change due to the additional benefits.

Incentives could again play a role here. Given the societal benefits of platooning, the government might have a motivation to encourage some of the (expected) effects so that forming platoons becomes easier. Additional research into the effects of platooning on the network and their magnitudes will help this cause.

Given the growing recent interest in platooning, and the different planning challenges, it is expected that the literature in this area will grow significantly in the near future.

Acknowledgements

We would like to thank Robbert Janssen and Emiel van Eijk (TNO), and Caspar Chorus (TU Delft) for their feedback and comments on earlier versions of the paper.

Funding: This work was supported by the Netherlands Organization for Scientific Research as part of the ‘Spatial and Transport impacts of Automated Driving (STAD)’ [Project number 438-15-161] and the ‘2-Truck Platoon matching for collaborative planning’ [Project number 438-15-512] projects.

References

Absi, N., Cattaruzza, D., Feillet, D., Housseman, S., 2015. A relax-and-repair heuristic for the swap-body vehicle routing problem. Ann Oper Res.

Adler, A., Miculescu, D., Karaman, S., 2016. Optimal policies for platooning and ride sharing in autonomy-enabled transportation.
URL http://www.wafr.org/papers/WAFR_2016_paper_110.pdf

Agatz, N., Erera, A., Savelsbergh, M., Wang, X., 2011. Dynamic ride-sharing: a simulation study in metro Atlanta. Transportation Reserch Part B, Methodological 45 (9), 1450–1464.

Agatz, N., Erera, A., Savelsbergh, M., Wang, X., 2012. Optimization for dynamic ride sharing: A review. European Journal of Operational Research 223 (2), 295–303.

Aivodji, U., Gambs, S., Huguet, M.-J., Killijian, M.-O., 2016. Meeting points in ridesharing: A privacy preserving approach. Transportation Research Part C: Emerging Technologies 72, 239–253.

Alam, A., Besselink, B., Turri, V., Mårtensson, J., Johansson, K. H., 2015. Heavy-duty vehicle platooning for sustainable freight transportation: A cooperative method to enhance safety and efficiency. IEEE Control Systems 35 (6), 34–56.

Amey, A., 2011. A proposed methodology for estimating rideshare viability within an organization, applied to the MIT community. Annual TRB Meeting 2011.

Angelelli, E., Arsil, I., Morandi, V., Savelsbergh, M., Speranza, M. G., 2016. Proactive route guidance to avoid congestion. Transportation Research Part B.

Bent, R. W., van Hentenryck, P., 2004. Scenario-based planning for partially dynamic vehicle routing with stochastic customers. Operations Research 52 (6), 977–987.

Berbeglia, G., Cordeau, J., Gribkovskaia, I., Laporte, G., 2007. Static pickup and delivery problems: a classification scheme and survey. Top 15 (1), 1–31.

Berbeglia, G., Cordeau, J.-F., Laporte, G., 2010. Dynamic pick-up and delivery problems. European Journal of Operational Research 202 (1), 8–15.

Berenghem, C., Schladover, S., Coelingh, E., 2012. Overview of platooning systems. In: Proceedings of the 19th ITS World Congress, Oct 22-26, Vienna, Austria (2012).

Berger, A., 2016. Sharing gains and pains - service needs for safe and efficient platooning. Tech. rep., Volvo Group Trucks Technology.

Brizzolara, D., Toth, A., 2016. The emergence of truck platooning. In: Baltic Transport Journal, 3rd Edition.

Campbell, J. F., 1990. Freight consolidation and routing with transportation economies of scale. Transportation Research Part B: Methodological 24 (5), 345–361.

Chao, I.-M., 2002. A tabu search method for the truck and trailer routing problem. Computers I& Operations Research.

Chardaire, P., McKeown, G., Verity-Harrison, A., Richardson, S., 2005. Solving a time-space network formulation for the convoy movement problem. Operations Research 53 (2), 219–230.

Chen, M., Hu, Q., Mackin, C., Fisac, J. F., Tomlin, C. J., 2015. Safe platooning of unmanned aerial vehicles via reachability. In: Decision and Control (CDC), 2015 IEEE 54th Annual Conference on. IEEE, pp. 4695–4701.

Chen, W., Mes, M., Schutten, M., Quint, J., 2016. A ride sharing problem with meeting points and return restrictions. Beta Publication series.

Chen, Z., He, F., Yin, Y., Du, Y., 2017. Optimal design of autonomous vehicle zones in transportation zones. Transportation Research Part B 99, 44–61.

Cheng, S.-F., Nguyen, D. T., Lau, H. C., 2012. A mechanism for organizing last mile service using non dedicated fleet. WI-IAT 2012: IEEE/WIC/ACM International Conference on Intelligent Agent Technology, 4-7 December 2012, Macau: Proceedings., 85–89.

Cordeau, J.-F., Gendreau, M., Laporte, G., 1997. A tabu search heuristic for periodic and multi-depot vehicle routing problems. Networks 30 (2), 105–119.

Cordeau, J.-F., Laporte, G., 2007. The dial-a-ride problem: models and algorithms. Ann Oper Res 153, 29–46.

Crainic, T. G., 2000. Service network design in freight transportation. European Journal of Operational Research 122, 272–288.

Crainic, T. G., Kim, K. H., 2007. Intermodal transportation. Handbooks in operations research and management science 14, 467–537.

Crevier, B., Cordeau, J. F., Laporte, G., 2007. The multi-depot vehicle routing problem with inter-depot routes. European Journal of Operational Research 176 (2), 756–773.

Croxton, K. L., Gendron, B., Magnanti, T. L., 2003. Models and methods for merge-in-transit operations. Transportation Science 37 (1), 1–22.

Cruijssen, F., Dullaert, W., Fleuren, H., 2007. Horizontal cooperation in transport and logistics a literature review. Transportation Journal 46 (3), 22–39.

Dall'Orto, L. C., Crainic, T. G., Leal, J. E., Powell, W. B., 2006. The single-node dynamic service scheduling and dispatching problem. European journal of operational research 170 (1), 1–23.

Derigs, U., Pullman, M., Vogel, U., 2013. Truck and trailer routing - problems, heuristics and computational experience. Computers and Operations Research 40, 536–546.

Drexl, M., 2011. Applications of the vehicle routing problem with trailers and transshipments. Tech. rep., Johannes Gutenberg University Mainz and Fraunhofer Centre for Applied Research on Supply Chain Services SCS.

Drexl, M., 2012. Synchronization in vehicle routing - a survey of VRPs with multiple synchronization constraints. Transportation Science 46 (3), 297–316.

Dumas, Y., Soumis, F., Desroiers, J., 1990. Technical note - optimizing the schedule for a fixed vehicle path with convex inconvenience costs. Transportation Science 24 (2), 145–152.

Eckhardt, J., Aarts, L., van Vliet, A., Alkim, T., 2016. European truck platooning challenge 2016, lessons learnt.

Elkind, E., Rothe, J., 2016. Economics and computation. Springer.

Ernst, A. T., Jiang, H., Krishnamoorthy, M., Sier, D., 2004. Staff scheduling and rostering: A review of applications, methods and models. European Journal of Operations Research 153 (1), 3–27.

European Commission, 2016. Climate action.
URL `http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm`

Fagin, R., Williams, J. H., 1983. A fair carpool scheduling algorithm. IBM Journal of Research and Development 27 (2), 132–140.

Farokhi, F., Johansson, K. H., 2013. A game-theoretic framework for studying truck platooning incentives. In: Proceedings of the 16th International IEEE Annual Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, The Netherlands. pp. 1253–1260.

Farokhi, F., Johansson, K. H., 2014. Investigating the interaction between traffic flow and vehicle platooning using a congestion game. In: Proceedings of the 19th World Congress The International Federation of Automatic Control Cape Town, South Africa. pp. 4170–4177.

Frisk, M., Göthe-Lundgren, M., Jörnsten, K., Rönnqvist, M., 2010. Cost allocation in collaborative forest transportation. European Journal of Operational Research 205 (2), 448–458.

Furuhata, M., Dessouky, M., Ordez, F., Brunet, M.-E., Wang, X., Koenig, S., 2013. Ridesharing: The state-of-the-art and future directions. Transportation Research Part B 57, 28–46.

Gendreau, M., Laporte, G., Séguin, R., 1996. Stochastic vehicle routing. European Journal of Operational Research 88, 3–12.

Glaeser, E. L., 2007. Introduction. In: Glaeser, E. L. (Ed.), Agglomeration Economics. University of Chicago Press, Ch. 1, pp. 1–14.

Goel, A., 2010. Truck driver scheduling in the European Union. Transportation Science 44 (4), 429–441.

Goel, A., 2014. Hours of service regulation in the United States and the 2013 rule change. Transport Policy 33, 48–55.

Goel, A., Archetti, C., Savelsbergh, M., 2012. Truck driver scheduling in Australia. Computers & Operations Research 39, 1122–1132.

Goel, A., Rousseau, L.-M., 2012. Truck driver scheduling in Canada. Journal of Scheduling 15 (6), 783–789.

Government-UK, 2016. Driving hours - EU rules. URL `https://www.gov.uk/drivers-hours/eu-rules`

Guajardo, M., Rönnqvist, M., 2016. A review on cost allocation methods in collaborative transportation. International transactions in operational research 23, 371–392.

Gupta, M., Judge, P., Ammar, M., 2003. A reputation system for peer-to-peer networks. In: Proceedings of the 13th international workshop on Network and operating systems support for digital audio and video. ACM, pp. 144–152.

Hall, R. W., 1987. Consolidation strategy: Inventory, vehicles and terminals. Journal of Business Logistics 8 (2), 57–73.

Heeswijk, W. V., Mes, M., Schutten, J., Zijm, W., 2016. Freight consolidation in intermodal networks with reloads. Flexible Services and Manufacturing Journal, 1–34.

Heikoop, D., de Winter, J. C. F., van Arem, B., Stanton, N. A., 2017. Effects of platooning on signal-detection performance, workload, and stress: A driving simulator study. Applied Egronomics 60, 116–127.

Hjamdähl, M., Krupenia, S., Thorslund, B., 2017. Driver behaviour and driver experience of partial and fully automated truck platooning a simulator study. European Transport Research Review 9 (8).

Hollis, B. L., Forbes, M. A., Douglas, B. E., 2006. Vehicle routing and crew scheduling for metropolitan mail distribution at australia post. European Journal of Operational Research 173 (1), 133–150.

Huber, S., Geiger, M. J., 2014. Swap body vehicle routing problem: A heuristic solution approach. In: International Conference on Computational Logistics. Springer, pp. 16–30.

Janssen, R., Zwijnenberg, H., Blankers, I., de Kruijff, J., 2015. Truck platooning: Driving the future of transportation. Tech. rep., TNO.

Jordan, W. C., Burns, L. D., 1984. Truck backhauling on two terminal networks. Transportation Research Part B: Methodological 18 (6), 487–503.

Kavathekar, P., Chen, Y., 2011. Vehicle platooning: A brief survey and categorization. In: ASME 2011 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers, pp. 829–845.

Kenyon, A. S., Morton, D. P., 2003. Stochastic vehicle routing with random travel times. Transportation Science 37 (1), 69–82.

Kilcarr, S., 2016. Driverless trucks: Where they'll work, where they won't. URL `http://m.fleetowner.com/technology/driverless-trucks-where-they-ll-work-where-they-won-t`

Kim, K. H., Bae, J. W., 2004. A look-ahead dispatching method for automated guided vehicles in automated port container terminals. Transportation Science 38 (2), 224–234.

Krajewska, M. A., Kopfer, H., Laporte, G., Ropke, S., Zaccour, G., 2008. Horizontal cooperation among freight carriers: request allocation and profit sharing. Journal of the Operations Research Society 59 (11), 1483–1491.

Kumar, P. R., Narendran, T., 2010. Convoy movement probleman optimization perspective. Innovations in Defence Support Systems1, 79–93.

Lammert, M., Duran, A., Dies, J., Burton, K., Nicholson, A., 2014. Effect of platooning on fuel consumption of class 8 vehicles over a range of speeds, following distances, and mass. SAE Int. J. Commer. Veh. 7 (2), 626–639.

Laporte, G., 1992. The vehicle routing problem: An overview of exact and approximate algorithms. European Journal of Operational Research 59, 345–358.

Laporte, G., Gendreau, M., Potvin, J.-Y., Semet, F., 2000. Classical and modern heuristics for the vehicle routing problem. International transactions in operational research 7 (4-5), 285–300.

Laporte, G., Louveaux, F., Mercure, H., 1992. The vehicle routing problem with stochastic travel times. Transportation Science 26 (3), 161–170.

Larburu, M., Sanchez, J., Rodriguez, D. J., 2010. Safe road trains for environment: Human factors aspects in dual mode transport systems. In: ITS World Congress, Busan, Korea.

Larson, J., Kramer, C., Lang, K.-Y., Johannson, K. H., 2013. Coordinated route optimization for heavy duty vehicle platoons. In: Proceedings of the 16th International IEEE Annual Conference on Intelligent Transportation Systems (ITSC 2013), The Hague, The Netherlands, October 6-9, 2013. pp. 1196–1202.

Larson, J., Munson, T., Sokolov, V., 2016. Coordinated platoon routing in a metropolitan network.
URL `http://www.mcs.anl.gov/papers/P6010-0516.pdf`

Larsson, E., Sennton, G., Larson, J., 2015. The vehicle platooning problem: Computation complexity and heuristics. Transportation Research Part C 60, 258–277.

Lauf, O., 2017. NMT cördineert nieuw maritiem europees innovatieproject ‘NOVIMAR’.
URL `http://maritimetechnology.nl/nmt-coordineert-nieuw-maritiem-europees-innovatieproject-novimar/`

Levofsky, A., Greenberg, A., 2001. Organized dynamic ride sharing: the potential environmental benefits and the opportunity for advancing the concept. Transportation Research Board 2001 Annual Meeting, 7–11.

Li, F., Golden, B., Wasil, E., 2007. The open vehicle routing problem: Algorithms, large-scale test problems, and computational results. Computers & Operations Research 34, 2918–2930.

Liang, K.-Y., Mårtensson, J., Johansson, K. H., 2013. When is it fuel efficient for a heavy duty vehicle to catch up with a platoon? In: 7th IFAC Symposium on Advances in Automotive Control The International Federation of Automatic Control September 4-7, 2013. Tokyo, Japan. pp. 738–743.

Liang, K.-Y., Mårtensson, J., Johansson, K. H., 2014. Fuel-saving potentials of platooning evaluated through sparse heavy-duty vehicle position data. In: 2014 IEEE Intelligent Vehicles Symposium (IV) June 8-11, 2014. Dearborn, Michigan, USA. pp. 1061–1068.

Liang, K.-Y., Mårtensson, J., Johansson, K. H., 2016. Heavy-duty vehicle platoon formation for fuel efficiency. IEEE Transactions on Intelligent Transportation Systems 17 (4), 1051–1061.

Lim, A., Wang, F., 2005. Multi-depot vehicle routing problem: A one-stage approach. IEEE transactions on Automation Science and Engineering 2 (4), 397–402.

Lioris, J., Pedarsani, R., Tascikaraoglu, F. Y., Varaiya, P., 2017. Platoons of connected vehicles can double throughput in urban roads. Transportation Research Part C 77, 292–305.

Lozano, S., Moreno, P., Adenso-Díaz, B., Algaba, E., 2013. Cooperative game theory approach to allocating benefits of horizontal cooperation. European Journal of Operational Research 229 (2), 444–452.

Lum, O., Chen, P., Wang, X., Golden, B., Wasil, E., 2015. A heuristic approach for the swap-body vehicle routing problem. In: 14th INFORMS Computing Society Conference Richmond, Virginia, January 11-13, 2015. pp. 172–187.

Meisel, F., Kopfer, H., 2014. Synchronized routing of active and passive means of transport. OR Spectrum 36, 297–322.

Meisen, P., Seidl, T., Henning, K., 2008. A data mining technique for the planning and organization of truck platoons. International Conference on Heavy Vehicles (HVParis 2008), Heavy Vehicle Transport Technology. ISTE I& Wiley.

Merchant, D. K., Nemhauser, G. L., 1978. A model and an algorithm for the dynamic traffic assignment problems. Transportation Science 12 (3), 183–199.

Minett, P., 2013. Flexible carpooling to transit stations. Tech. rep., Transportation research board of the national academies.

Ministry of Transport - Singapore, 2017. Singapore to start truck platooning trials. URL `https://www.mot.gov.sg/News-Centre/News/2017/Singapore-to-start-truck-platooning-trials/`

Miranda-Bront, José, J., Curcio, B., Méndez-Díaz, I., Montero, A., Pousa, F., Zabala, P., 2015. A cluster-first route-second approach for the swap body vehicle routing problem. Annals of Operations Research, 1–22.

Mui, L., Mohtashemi, M., Halberstadt, A., 2002. Notions of reputation in multi-agents systems: a review. In: Proceedings of the first international joint conference on Autonomous agents and multiagent systems: part 1. ACM, pp. 280–287.

Mukai, N., Watanabe, T., 2005. Dynamic transport services using flexible positioning of bus stations. In: Proceedings Autonomous Decentralized Systems 2002 ISADS 2005. IEEE, pp. 259–266.

Nobel Prize Committee, 2007. Mechanism design theory. URL `http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2007/advanced-economicsciences2007.pdf`

Nourmohammadzadeh, A., Hartmann, S., 2016. The fuel-efficient platooning of heavy duty vehicles by mathematical programming and genetic algorithm. In: Martín-Vide, C., Mizuki, T., Vega-Rodríguez, M. (Eds.), Theory and Practice of Natural Computing. TPNC 2016. Lecture Notes in Computer Science. Vol. 10071. Springer.

Nowakowski, C., Schladover, S. E., Lun, X.-Y., Thompson, D., Kailas, A., 2015. Cooperative adaptive cruise control (cacc) for truck platooning: Operational concept alternatives. Tech. rep., California Partners for Advanced Transportation Technology UC Berkeley.

Parks, D., 2001. Iterative combinatorial auctions: Achieving economic and computational efficiency. Ph.D. thesis, University of Pennsylvania.

Patten, J., McAucliffe, B., Mayda, W., Tanguay, B., 2012. Review of aerodynamic drag reduction devices for heavy trucks and buses. Tech. rep., National Research Council Canada.

Peloton Technology, 2016. Industry report: Platooning systems such as from peloton offer significant fuel efficiency i& safety gains.
URL http://peloton-tech.com/nacfe_release

Pillac, V., Gendreau, M., Guéret, C., Medaglia, A. L., 2013. A review of dynamic vehicle routing problems. European Journal of Operational Research 225 (1), 1–11.

Powell, W. B., 1996. A stochastic formulation of the dynamic assignment problem, with an application to truckload motor carriers. Transportation Science 30 (3), 195–219.

Prins, C., Lacomme, P., Prodhon, C., 2014. Order-first split-second methods for vehicle routing problems: A review. Transportation Research Part C: Emerging Technologies 40, 179–200.

Queensland Government, May 2016. Road rules.
URL https://www.qld.gov.au/transport/safety/heavy/rules/index.html

Raff, S., 1983. Routing and scheduling of vehicles and crews. Computers & Operations Research 10 (2), 117–147.

Renaud, J., Laporte, G., Boctor, F. F., 1996. A tabu search heuristic for the multi-depot vehicle routing problem. Computers & Operations Research 23 (3), 229–235.

Resnick, P., Zeckhauser, R., 2015. Trust among strangers in internet transactions: Empirical analysis of ebay' s reputation system. The Economics of the Internet and E-commerce, 127–157.

Reyes, D., Savelsbergh, M., Toriello, A., 2016. Vehicle routing with roaming delivery locations. Optimization Online, 1–27.

Richert, D., Cortés, J., 2012. Optimal leader allocation in UAV formation pairs under no-cost switching. In: American Control Conference (ACC), 2012. IEEE, pp. 3297–3302.

Roland Berger, 2016. Automated trucks - the next big disruptor in the automotive industry. Tech. rep., Roland Berger.

Roodenbergen, K. J., Vis, I. F., 2001. A survey of literature on automated storage and retrieval systems. European journal of operational research 194 (2), 343–362.

SAE International, 2016. Taxonomy and definitions for terms related to on-road motor vehicle automated driving systems.

Savelsbergh, M., Sol, M., 1995. The general pick-up and delivery problem. Transportation Science 29 (1), 17–29.

Schladover, S. E., Nowakowski, C., Lu, X.-Y., Felis, R., 2015. Cooperative adaptive cruise control (CACC) definitions and operating concepts. Proceedings of the 94th Annual TRB Meeting. Transportation Research Board.

Schwartz, A., Scott, R. E., 2003. Contract theory and the limits of contract law. The Yale law journal 113 (3), 541–619.

Scora, G., Barth, M., 2006. Comprehensive modal emissions model (CMEM), version 3.01. User guide. Centre for Environmental Research and Technology. University of California, Riverside.

Segata, M., Bloessl, B., Joerer, S., Dressler, F., Cigno, R. L., 2014. Supporting platooning maneuvers through ivc: An initial protocol analysis for the JOIN maneuver. In: 2014 11th Annual Conference on Wireless On-demand Network Systems and Services (WONS). IEEE, pp. 130–137.

Sokolov, V., Larson, J., Munson, T., Auld, J., Karbowski, D., 2017. Platoon formation maximization through centralized routing and departure time coordination. arXiv preprint arXiv:1701.01391.

Stiglic, M., Agatz, N., Savelsbergh, M., Gradisar, M., 2015. The benefits of meeting points in ride sharing systems. Transportation Research Part B: Methdological 82, 36–53.

TNO, 2016. Truck platooning vision 2025. URL https://www.eutruckplatooning.com/Workspace/Conference%2BTruck%2BPlatooning%2BChallenge%2B7%2BApril%2B2016/handlerdownloadfiles.ashx%3Fidnv%3D499128+&cd=1&hl=en&ct=clnk&gl=nl

Tsugawa, S., 2014. Results and issues of an automated truck platoon within the energy its project. Intelligent Vehicles Symposium Proceedings, 2014 IEEE, 642–647.

TU Delft 3mE, 2017. Major investment in platooning with autonomous cargo ships. URL http://www.3me.tudelft.nl/en/current/latest-news/article/detail/forse-investering-voor-platooning-met-autonoom-varende-vrachtschepen/

Tuson, A., Harrison, S., 2005. Problem difficulty of real instances of convoy planning. Journal of the Operational Research Society 56, 763–775.

UNSW Engineering, 2016. Western Australia to host truck platooning trial. URL http://www.snap.unsw.edu.au/news/western-australia-to-host-truck-platooning-trial

Valdés, F., Iglesias, R., Espinosa, F., Rodrguez, M. A., 2011. An efficient algorithm for optimal routing applied to convoy merging manoeuvres in urban environments. Applied Intelligence 37 (2), 267–279.

Van Arem, B., Van Driel, C. J., Visser, R., 2006. The impact of cooperative adaptive cruise control on traffic-flow characteristics. IEEE Transactions on Intelligent Transportation Systems 7 (4), 429–436.

Van de Hoef, S., 2016. Fuel-efficient centralized coordination of truck platooning. Ph.D. thesis, KTH Electrical Engineering.

van Lint, J., van Zuylen, H. J., Tu, H., 2008. Travel time unreliability on freeways: Why measures based on variance tell only half the story. Transportation Research Part A: Policy and Practice 42 (1), 258–277.

Villegas, J. G., Prins, C., Prodhon, C., Medaglia, A. L., Velasco, N., 2013. A matheuristic for the truck and trailer routing problem. European Journal of Operations Research 230, 231–244.

Wang, H., Odoni, A., 2014. Approximating the performance of a last mile transportation system. Transportation Science 50 (2), 659–675.

Wang, X., Agatz, N., Erera, A., 2014. Stable matching for dynamic ride sharing systems. Tech. rep., ERIM Report Series Reference No. ERS-2015-006-LIS.

Wark, P., Holt, J., 1994. A repeated matching heuristic for the vehicle routing problem. Journal of the Operations Research Society 45 (10), 1156–1167.

Xu, P. J., Allgor, R., Graves, S. C., 2009. Benefits of reevaluating real-time order fulfillment decisions. Manufacturing and Service Operations Management 11 (2), 340–355.

Xu, X., 2013. Collaboration mechanism in the horizontal logistics collaboration. Ph.D. thesis, Ecole Nationale Superieure des Mines de Paris.

Yamabe, S., Zheng, R., Nakano, K., Suda, Y., Takagi, T., Kawahara, S., 2012. Analysis on behaviors of a driver in the system failure in forming automatic platooning of trucks from manual driving. In: 19th ITS World Congress.

Yamada, T., Russ, B. F., Castro, J., Taniguchi, E., 2009. Designing multimodal freight transportation networks: A heuristic approach and applications. Transportation Science 43 (2), 129–143.

Yan, D., Zhao, Z., NG, W., 2011. Efficient algorithms for finding optimal meeting point on road networks. Proceedings of the VLDB Endowment 4 (11).

Yan, D., Zhao, Z., NG, W., 2015. Efficient processing of optimal meeting point queries in euclidean space and road networks. Knowledge information systems 42, 319–351.

Zabat, M., Stabile, N., Frascaroli, S., Browand, F., 1995. The aerodynamic performance of platoons: Final report. Tech. rep., California PATH project, University of California Berkeley.

Zhang, W., Jenelius, E., Ma, X., 2017. Freight transport platoon coordination and departure time scheduling under travel time uncertainty. Transportation Research Part E 98, 1–12.