Business Models and Roles for Mediating Services in a Truck Platooning System-of-Systems

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Abstract—**Platooning of trucks on motorways has been proposed as a method of reducing fuel consumption. It requires communication between the trucks to control the distance between them. However, this system-of-systems (SoS) cannot only contain the trucks, but also needs to include mediating off-board services for match-making to find suitable constellations of trucks, and for creating platooning incentives by distributing the profit made equally among the constituent systems. This paper analyzes what actors in the SoS would be suitable to operate these services, and also business models that cover the cost for their implementation and operation. It concludes that the truck OEMs have a vital role in creating the mediating services, and that a suitable business model would be based on usage fees for the services rather than upfront payment for platooning equipment.**

Keywords—platooning, system-of-systems, match-making, fuel saving distribution, incentives.

I. Introduction

The transportation sector is continuously trying to improve its energy usage, in order to reduce the environmental impact and save fuel costs. This has traditionally been achieved by optimizing individual vehicles and their propulsion. However, the potential for further improvements of the vehicles is gradually shrinking, and other approaches must be sought.

One possibility is to improve how vehicles are used, and how they interact with others in the traffic environment. This has led to considerable research into truck platooning [1][2]. The idea of platooning is that a lead vehicle, which is driven manually, is followed closely by a number of other vehicles using automated driving. The benefit is that aerodynamic drag can be substantially reduced by shortening the distance between the trucks, leading to lower energy consumption. A key technology is the use of short-range radio communication between the trucks to control their speed, and thus the distance between them.

Truck platooning is a very good example of a system-of-systems (SoS), which clearly fulfils all the characteristics put forward by Maier [3]. Obviously, the trucks themselves are the key constituent systems (CSs) of this SoS, that dynamically form and dissolve platoon constellations over time. Although the common Maier-Dahmann archetypes [3][4] are not always easy to distinguish in a practical case, it is quite clear that platooning is best described as a collaborative SoS. However, recent research has shown that there is also a need for CSs which provide mediating services, that enable a better collaboration [2].

One such mediating service is for match-making, that helps trucks equipped for platooning to find others to join. If such a service is not included, there will be difficulties in forming platoons, in particular in situations with few platooning prepared trucks in the same region, such as will be the case during the early introduction of the concept.

Another mediating service is for allocating the profits from platooning, and this is needed since the gains are unevenly distributed among the participants. Although the leader of the platoon also gets somewhat lower fuel consumption, the followers have much more benefit. Also, during formation some vehicles must wait for others and will thus arrive later at their destination and have a lower utilization, which can be seen as a cost.

The contribution of this paper is a macro-level analysis [5] of how these mediating services can best be organized to maximize the overall benefit of the platooning SoS.

A. Research Questions and Method

This paper addresses the following two overall research questions:

1. Which actor is most suitable to operate the mediating services?
2. What is the best way to finance the mediating services?

The main evaluation criteria when comparing different answers to these questions is what the overall effects will be on the SoS purpose, which is to reduce fuel consumption.

Similar questions are of generic interest to many commercial collaborative SoS, where there are no central authorities like in a directed or acknowledged SoS. Still, some sort of mediating service is commonly needed, and the paper shows an approach to analyzing the organization of such a service in a way that is economically sustainable. This approach can also be applied in other domains.

The research method applied here is a qualitative system dynamics analysis, since platooning has not yet been deployed in practice (with a few exceptions, [6]) and hence little or no empirical data on large scale effects is available. The findings have been validated through reviews by representatives of the different roles in a truck platooning ecosystem.

B. Overview of Paper

The remainder of the paper is organized as follows: In the next section, the actors in the platooning ecosystem will be described, together with the roles they will need to take. Also, some boundary conditions on viable solutions are introduced. In Section III, the alternative value flows and payment streams between the roles are elicited, and this is a foundation for an analysis in Section IV of the possible business models. In Section V, the alternative solutions are evaluated with respect to their effects on the overall platooning rate, which should be maximized to get the most fuel savings out of the SoS. Section VI presents an overview of related research, and the final section summarizes the conclusions of the paper.

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II. Actors, Roles and Incentives

We will now take a look at the different ways in which platooning services can be organized, and in doing so, we will discuss different actors and roles involved. An actor is here assumed to be a concrete organization, or type of organizations, whereas a role is something carried out by an organization. An actor can thus carry out many different roles. By distinguishing roles from actors, we can systematically evaluate different options when it comes to which actor is most suitable to take on the new roles needed in the SoS.

A. Present Actors and New Roles

In the present truck-based transportation ecosystem, there are four different kinds of actors present who have dedicated roles today:

- *Haulers*. The companies that have the role to provide transportation services by operating fleets of trucks.
- *Truck Original Equipment Manufacturers (OEMs)*. The companies whose role it is to produce trucks and deliver them to the haulers.
- *Infrastructure providers.* Public authorities or companies that have the role to operate the road and telecom infrastructure necessary for the haulers.
- *Third-party service providers*. Companies that have a role to assist haulers to make their operations more efficient.

Each of these actors is a candidate for taking on the additional roles needed in the platooning SoS, which are to operate mediating services for fuel savings sharing and match making.

Apart from these actors, there are also beneficiaries, that are affected by the operations, and these include *transport service users* and *society at large*. Since they are the parties gaining, they must also be the ultimate source of funding.

B. Net Present Value

When trying to find appropriate solutions to operating the mediating services, it is important to realize that a viable business model requires that all actors in the SoS gain more than their costs over time. This constraint can be expressed more precisely by stating that all actors must have a positive net present value (NPV), where:

$$\mathrm{NPV} = \sum_{t=0} \frac{R_t}{(1+i)^t}$$

Here, t is time; R_t is the net value flow over the time period (income – cost); and i is the discount rate, i.e. the return that can be earned on alternative investments with similar risk.

C. Evolutionary Stages

The benefit of NPV is that it makes it possible to consider both short term and long-term value flows in a reasonable way. The need to do so becomes apparent when the evolutionary stages of this SoS are identified:

1. *Establishment (E).* Actors make initial investments required to provide the basic products/services. No value can be created before this stage is completed, and hence there are no incomes.
2. *Growth (G)*. Products/services are available, and an increasing number of users start joining the SoS. There are investments to enhance capacity.
3. *Steady state (S)*. Usage growth has reached a plateau. There are investments in maintaining equipment, and in rationalizing operations to reduce costs.

A viable ecosystem must provide a positive net present value for all involved actors, and the initial investments must eventually pay off, otherwise the actor has no incentives to join the SoS.

III. Value Flows and Payment Streams

To analyze the research questions introduced in Section I.A, it is necessary to systematically assess what the consequences are if any of the present types of actors take on the new roles to provide match-making and fuel savings sharing. The analysis of this will start by first describing what value each role creates for each of the other roles. Then, it is investigated what costs are related to this value creation. Finally, the possible payment streams are described.

A. Value Creation

To systematically investigate all possible value flows between roles (including beneficiaries), an N^2 diagram was used. Based on that, a number of value flows resulted that are enlisted in the left part of Table I. As can be seen from the table, several values are provided to the haulers, which result in an increased platooning rate and hence overall reductions in fuel consumption and environmental effects. This leads to reduced transportation cost for the users, which in turn also benefits economic growth. Finally, the infrastructure providers create a value for both haulers and the service providers.

B. Costs

Value creation normally requires some production resources, such as material, staff, or information, and gaining access to these incurs a cost for the value provider. These costs can be divided into fixed cost and variable cost, where fixed costs are one-time investments and variable costs are dependent on volume of production. The costs may also be related to the different evolutionary stages described in Section II.C above.

The right part of Table I describes the costs associated with creating each of the value flows identified in the previous section. As can be seen, there are investments in engineering, equipment and infrastructure in order to prepare for the platooning SoS, and these costs occur in the Establishment [E] phase, and also to some extent in the Growth [G] phase (to scale capacity). These investments are carried by the truck OEMs, the service providers, and the infrastructure providers. For the haulers, the investments are related to buying prepared trucks, and thus occur during the Growth [G] phase, and also during Steady State [S] to replace old trucks.

The variable costs for all roles relate to equipment maintenance, operations staff, and possibly service fees.

The transport service users do not carry any costs, but the value it provides to society in the form of economic growth is a side effect of the value it gets from reduced transportation costs.

TABLE I. VALUE FLOWS BETWEEN ROLES AND POTENTIAL ASSOCIATED COSTS OF VALUE CREATION

Role		Value	Potential provider costs per evolutionary stage	
Provider	***Beneficiary***		***Fixed***	***Variable***
Transport service user	Society at large	Economic growth	None	None
Hauler	Transportation service user	Reduced transportation cost	Investments in trucks prepared for platooning [G, S]	Service fees for match-making, fuel savings sharing, infrastructure [G, S]
	Society at large	Reduced environmental footprint		
Truck OEM	Hauler	Trucks prepared for platooning	Investments in engineering, production equipment [E]	Purchased parts, assembly staff, equipment maintenance [G, S]
Fuel savings sharing service provider	Hauler	Predictable cost reduction for all platooning participants	Investments in service engineering, IT equipment [E, G]	Equipment maintenance, service fees for communication [G, S]
Match-making service provider		Cost reduction by increasing platooning rate		
Infrastructure provider	Hauler	Road & communication infrastructure prepared for platooning	Investments in road infrastructure, IT and telecom equipment [E, G]	Infrastructure maintenance and operation [G, S]
	Fuel savings sharing service provider	Communication infrastructure prepared for platooning		
	Match-making service provider			

C. Payment Streams

A viable business model requires that all actors have a positive net present value, and this means that after the roles are distributed to actors, all the costs have to be covered. It is thus necessary to find and evaluate potential payment streams.

A few things are worth noting about payment streams:

- Just like costs, payment streams can be fixed or variable. For instance, it is possible to buy a truck (a fixed cost) or pay for a service on a per-use basis (a variable cost).
- A role that receives a value is more likely to be willing to pay for that value, and hence the most likely candidates for payment streams are the reverse of the value streams shown in Table I.
- Eventually, all payments need to come from the beneficiaries of the SoS, i.e., in the platooning case the transport service users and society at large.
- A payment from one role must be matched with an income of another role, to ensure a consistent analysis and a closed system model.

To systematically elicit the potential payment streams, we once again employed an N^2 diagram. The payment streams thus identified are presented alongside the costs for each role in Table II.

It should be emphasized that the payment streams are potential, and there is thus a choice to make which ones of these should actually be implemented as part of the business model. This will be discussed further in Section IV below. To ensure that no possible options were left out, the payment streams considered cover a broad range. Since all incomes to a role must be matched with a cost for another role, this leads to additions of some possible costs that were not present in Table I, which focused only on the inherent costs of value creation.

These added costs include entry fees for the mediating services, meaning that a truck OEM may need to pay a licensing fee to be able to prepare its products for using that service. They also include costs, and incomes, related to the potential role that public authorities can play to stimulate the development of a platooning SoS with the benefit of reduced environmental effects. This includes subsidies, which can reduce the entry threshold for companies to develop and use platooning, and also taxes, both for funding subsidies and also for creating incentives for beneficial behavior on the market (e.g. a tax on fuel would stimulate reduction of fuel consumption, and hence encourage platooning).

Some of the incomes are in fact reduced costs compared to the current situation. In particular, reduced fuel consumption due to platooning will lower the cost for the haulers, which in turn may lead to reduced costs for the transport service users.

IV. VIABLE BUSINESS MODELS

Based on the identification of values, costs, and incomes of the different roles, we can now study different options for allocating the new mediating services to the actor organizations. As a first step, it will be discussed if the two services should be kept separately or merged into one. Then, the pros and cons of different allocation alternatives are evaluated.

A. Same or Separate Services?

In the evaluation of costs and incomes, summarized in Table II, it can be seen that the two mediating services for fuel savings sharing and match-making have identical characteristics. In principle, they can still be separated, but there are some clear benefits in keeping them together:

- It is easier from a user's perspective to only connect to one service, since only one business relation is needed.
- There are economies of scale, where most of the IT infrastructure is similar and can be reused and some of the development costs can be shared.
- It becomes less important that each of the services carries its own cost, but it is enough that they together have a positive balance.

TABLE II. POTENTIAL COSTS AND INCOMES PER ROLE AND EVOLUTION STAGE COMPARED TO TODAY'S SITUATION

Role	Potential costs		Potential incomes	
	Fixed	***Variable***	***Fixed***	***Variable***
Transport service user	None	None	None	Reduced transportation service fee [G, S]
Hauler	Investments in trucks prepared for platooning [G, S]	Service fees for match-making, fuel savings sharing, infrastructure [G, S] General tax on transportation, fuel, vehicles [E, G, S]	Subsidies for buying platooning equipped trucks [G, S]	Transportation service fee [G, S] Subsidies for using platooning trucks [G, S] Reduced fuel consumption [G, S]
Truck OEM	Investments in engineering, production equipment [E] Mediating service entry fee [E]	Purchased parts, assembly staff, equipment maintenance [G, S]	Subsidies for developing platooning equipped trucks [E]	Truck purchase [G, S] Service fee for platooning usage [G, S]
Fuel savings sharing service provider Match-making service provider	Investments in service engineering, IT equipment [E, G]	Equipment maintenance, service fees for communication [G, S]	Service entry fee [E] Subsidies for devoloping or operating service [E, G, S]	Service fees [G, S]
Infrastructure provider	Investments in road infrastructure, IT and telecom equipment [E, G]	Infrastructure maintenance and operation [G, S]	Service entry fee [E] Subsidies for devoloping or operating service [E, G, S]	Service fees [G, S]
Society at large	None	Subsidies for developing, buying, or using platooning equipped trucks [E, G, S] Subsidies for developing and operating mediating services [E, G, S]	None	General tax on transportation, fuel, vehicles; VAT [E, G, S]

Due to these benefits, we recommend that the services are packaged together, and this is the option considered in the rest of the paper.

B. Alternative Allocations of Service Roles to Actors

As described in Section II.A, there are four existing role types that will also be present in the platooning SoS. We will now describe what the consequences are if the joint mediating services are assigned to each of these roles and discuss what payment streams can be used to ensure that those solutions are viable over time.

1) Haulers: The hauler market is very distributed, with a large number of companies active even within a single country. Some of them are large, and already utilize advanced fleet management systems to plan and execute their operations. However, having one mediating service per hauler would fragment the market, and reduce the possibilities to let trucks from different haulers platoon together. Therefore, a federated solution would be needed, and this is equivalent to having a third party service provider funded by both an initial entry fee for investments in creating the services, and a running service fee for operation.

2) Truck OEMs: If the services were connected to a particular truck brand, the same interoperability problem would occur as if the services were operated by the haulers, but on a much smaller scale. This is due to the fact that the global truck market is controlled by less than ten major brands. It would thus be easier to let them agree on a federated service that sets a global standard, not the least since they already need to agree on technical standards for short-range communication between the trucks. It is again equivalent to having a third party operator, except that the OEMs would jointly pay investments through an entry fee. However, the payment stream from the haulers would now go through the OEM, and this opens possibilities for the OEM to use part of that service fee to balance other costs.

3) Third party service provider: The mediating services may be operated by a third party, as a separate organization. As explained above, the haulers or the truck OEMs could jointly create that organization, but it could also be an independent company. The benefit of this is that a centralized solution can be found, but there is also a risk that competing services are founded leading to a situation where platooning with trucks connected to different service providers will be difficult. If the service is not backed by OEMs or haulers, the provider has to make the initial investments during establishment themselves, which has a considerable risk that there will not be sufficiently many trucks joining the service to cover those costs.

4) Infrastructure providers: The final option is to have infrastructure providers expand into mediating services, and it seems most likely that the road administrations would then take this role. Since these are public services in most countries, the services could be funded by taxes, road tolls, or similar. However, there is a large risk that the services would be per country, which would make it difficult for the fairly common cross-border long-haul transportation.

V. EFFECTS ON EMERGENT PROPERTIES

The objective of the platooning SoS is to maximize overall fuel savings, since this creates both an economical room for the necessary investments and also benefits the environment and thus society at large. To some extent, the amount of saved fuel depends on optimizations on a micro-level [5], i.e. within a platoon constellation. On the macro-level [5] studied in this paper, the amount of fuel savings is proportional to the platooning rate, i.e. how often trucks are able to platoon [2].

A. *Maximizing Platooning Rate*

Since the fuel savings are directly dependent on the platooning rate, this rate should be maximized, which involves the following three components:

1. *Maximize number of prepared trucks*: It should be as attractive as possible for haulers to invest in platooning equipped trucks, and hence the cost difference should be minimal. Here, the optimal solution is to have the equipment installed on all trucks, i.e., no cost difference.

2. *Minimize number of service providers*: If there is a fragmentation, where only some trucks can platoon with each other, there will automatically be a reduction of the platooning rate as a consequence of Metcalfe's law or its variants [7]. The optimal solution here is to have one global service provider.

3. *Maximize incentives for platoon formation*: A system that can distribute costs and benefits among constellation participants can improve these incentives considerably, but it is also necessary to keep all service costs low, such as a running cost for connecting to a constellation through the mediating services, if such a cost is considered.

B. *Uncertainties and Risks*

In all these factors, there is an element of uncertainty, and hence of risk. As can be seen in the equation for NPV in Section II.B, the risk is related to the discount factor i, where a higher risk would reduce incentives to join the SoS.

During the early establishment of the platooning SoS, there is a very low probability of finding platooning partners, and thus a low value of the SoS as a whole. Haulers could then be hesitant to buy prepared trucks if they are more costly than unprepared ones, which provides an uncertainty whether the SoS will grow or not. This creates a game theoretic situation [13] where actors need to speculate on the decisions of other actors.

When it comes to the number of service providers, a situation with several competing offers creates an uncertainty what their market shares will be, and a risk of making the wrong investment, which could also lower the incentives for joining the SoS.

C. *Recommended Solution*

Based on this analysis, we arrive at the following recommended business set-up to maximize platooning rate:

- The OEMs should jointly set up a service provider for match-making and fuel savings sharing, since this is the fewest number of actors that can create a single global service solution.

- The OEMs should have platooning equipment as a standard offer on their trucks, since this will guarantee the shortest possible transition through the evolution phases.

- The OEMs should charge haulers based on a per km usage fee, which is invoked whenever a truck joins a platoon. This can be combined with the fuel saving sharing, and possibly also for sharing waiting costs, so that the net fee is sometimes negative (e.g. for a platoon leader) and sometimes higher (e.g. for a follower). The fee should in any case be much smaller than what the hauler gains from joining the platoon.

- The hauler only has a business relation to the OEM where it bought the truck, and hence just extends an already existing relationship. In this way, communication with mediating services can be handled through the on-board equipment and an OEM server, with no needs for third parties to interface to the physical trucks. The OEMs can distribute payments between them on behalf of their users, if there is a multi-brand constellation.

D. *Discussion*

The recommendations are viable in the sense that all actors will have a chance to get a positive NPV, although the exact calculation requires more quantitative data than we have available today. They reach the optimum solution on the first two criteria mentioned in Section V.A above, but not on the third since there is a running fee for connecting to a constellation. However, this running fee will only be charged in situations where the haulers have an income and is thus risk free to them.

The solution also has the benefit that the OEMs have a very strong incentive to create effective services for match-making, since it will directly affect their incomes, and this will have a positive effect on overall savings.

In this set-up, society at large is a free-rider, with no involvement. However, it can optionally be added a government intervention through taxes and incentives. For instance, an extra tax on fuel would give a steady income and create further incentives for reducing consumption, and the income could be used to give subsidies to development of technologies such as platooning to reach those reductions.

VI. Related Research

Vehicle platooning is a problem that has been studied over several decades, but the emphasis has been on longitudinal control algorithms [8]. When it comes to the cost-benefit analysis, a few papers have studied the reduction in aerodynamic drag [9] and in fuel consumption [10], with results pointing to a reduction of about 5-10%, depending on the position of the vehicle in the platoon. These results are useful input to our analysis since it quantifies the value potential that underlies the business case.

Regarding platoon formation and match-making, one proposed solution is to use controllers at major intersections that will give speed advice to drivers so that they can meet up at the same time [11]. The consequence is that a vehicle may need to increase its speed in order to catch up with others, and the cost of this has also been investigated [12]. The effects on platooning rate of having access to the plans of other vehicles is investigated in [2], which thus motivates the need for a mediating service for match-making. The paper also shows the importance of the number of prepared trucks on platooning rate, thus motivating the introduction of the evolution phases used in the present work.

There are few commercial examples of platooning systems on the market, with Peloton being the noteworthy exception [6]. This differs from the SoS described above in that it is an add-on solution to the trucks, and it uses its own mediating services, thus being similar to the third-party option of this paper. However, the business model of the company is not presented in the paper.

Applying a combination of game theory, network models and simulation for SoS analysis has been suggested in a number of previous studies. A summary of research in this area is provided in [13], and this provides a foundation for possible extensions of the present research involving more detailed investigations of dynamic effects.

VII. Conclusions

In this paper, we have studied possible business models for a truck platooning SoS, with the objective of reducing fuel consumption. In previous work, it has been found that mediating services that help in the formation of constellations within the SoS, and that can compensate for uneven distribution of benefits among the constellation members, are important to make this SoS work. The topic of this paper was therefore to analyze which actors are most suitable to create those services, and how it can be financed. Through an analysis of values, costs, and possible payment streams, a solution was proposed where the truck OEMs would jointly create the services, and let the haulers pay for it by sharing some of the profits they get from the reduced fuel consumption.

The results are not only relevant for this particular application, but it also provides a method for analyzing business models and incentives for SoS in general, based on identification of value, costs, payments, and risks.

As future extensions of this research, the qualitative analysis could be extended with quantitative data and dynamic simulations, to get a more detailed understanding of required costs. This could also include sensitivity analyses to deal with some of the uncertainties in the predicted data and ensure that the OEMs who would carry the entire risk in the proposed solution, are likely to get a positive result over time. Another extension is to generalize the work to provide a generic process and method for SoS business analysis.

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