PAPER

TRUCKING EFFICIENCY INCREASE BY HORIZONTAL COLLABORATION IN INLAND CONTAINER TERMINAL HINTERLAND OPERATIONS.

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Abstract
The Dutch road transport sector faces increasing pressure from stringent sustainability targets, a growing shortage of drivers, emphasizing the need for higher operational efficiency. At the same time, industry demands resilient supply chains, which conflicts with the limited flexibility of the current transport system. Horizontal collaboration between carriers offers opportunities to reduce inefficiencies such as empty mileage and improve asset utilization. This study introduces a concept for decentralized (federated) decision-making, allowing transport companies to retain control over their own planning while jointly achieving optimization.

A case study involving two inland terminals demonstrates a potential monthly saving of 18,000 km (4% of total distance, 10% of empty mileage), equating to €13,000 in cost reduction and 18 tons of CO_2 savings. The findings highlight that collaboration effectiveness depends on geographical and time-based shipment balance and that scaling up partnerships is essential to realize network benefits. This research provides a foundation for further development of decentralised planning systems and emphasizes the relevance of horizontal collaboration for sustainable and efficient transport operations.

1. Efficiency increase through horizontal collaboration in transport operations

The Dutch transport sector is facing a multitude of challenges in operating sustainable road freight operations. To meet the sustainability goals, the transport sector requires measures that reduce the negative impact of fossil-fuelled road freight. It is the only sector that is not reducing its total CO_2 emissions (CBS, 2024). Additionally there is a growing labour shortage for truck drivers in the Netherlands, which leads to high pressure for the remaining workforce (ING, 2025).

This results in delays and increased costs in transport operations. Road freight carriers struggle to face these challenges, as they are required to operate more efficiently with fewer assets (trucks and drivers) and reduce the fossil fuel consumption and related harmful emissions. Meanwhile, industry has increased its focus on supply chain resilience to prevent major disruptions or minimize their impacts when they occur. Adding resilience measures contrasts with the road transport system, which is already under pressure due to limited spare capacity, systems with limited flexible capacity are more severely affected by disruptions.

The combined challenge of providing a resilient transport system with less asset capacity and using less resources requires transport companies to be more efficient with their assets. The companies are required to further improve operational efficiency and asset utilization to ensure continuous high throughput in their transport networks.

To achieve increased asset utilization transport companies have two objectives:
1. Minimize idling and waiting time for assets and
2. Minimize empty mileage of trucks.

To minimize these objectives, transport companies require efficient decision making and scheduling methods. The set of transport assignments determines how efficiently the transport company can fill their truck schedules. For example, a trucking company with only shipments from A to B will have all trucks return from B to A empty. However, if a transport assignment is available near B that needs to be delivered near A, then the truck can combine its return trip with this assignment, resulting in fewer empty kilometers. Therefore it may be valuable to identify ways to increase transport assignments that result in more efficient truck schedules - for example via horizontal collaboration with other road freight operators.

By collaboratively scheduling shipments and assets, truck operations can become efficient. (Ferrell, Ellis, Kaminsky, & Rainwater, 2025). Efficiency gains by collaboration require geographical balance and other transport conditions, such as product type and delivery time windows. The type of product determines the required truck design, (un)loading facilities, driver requirements for dangerous cargo or even specialized conditions where a truck needs to be cleaned before and/or after use.

Horizontal collaboration in transport to increase efficiency is not a novel concept and has been widely researched and attempted in practice. Also currently there exist many collaboration initiatives1 today, mainly operated through collaboration platforms where transport operators and shippers are connected through a centralised information platform. However, many previous horizontal collaboration initiatives have struggled to scale or have dissolved over time.

These outcomes can be explained by several interrelated factors (Tinoco, Creemers, & Boute, 2017) (Karma, Reinau, & Østergaard, 2021) (Crijssen, van Beest, & Kant, 2023), such as:
• a lack of trust between collaboration partners,
• only a limited inefficient set of shipments is shared,
• not wanting to give operational control to a centralised planner,
• no sustainable governance framework for the collaboration has been setup,
• collaborative schedule improvements are not adopted by the internal planner organisations,
• or the collaborative gains are not fairly distributed.

These reasons illustrate the complexity of successful horizontal collaboration in transport operations, as multiple aspects should be addressed and aligned: collaborative business modelling, secure information handling, collaborative decision making, fair yield distribution and organisational change management. Any aspect not sufficiently addressed to the satisfaction of all of the partners may result in the end of collaboration. In this work we only focus on the collaborative decision making where we highlight the potential efficiency increase of applying collaborative decision making in a use case with two transport companies.

The goal of this work is to present a concept of collaborative decision making without a centralised platform. To ensure transport companies keep control over their own operations we propose a decentralised, or federated, decision making system where transport companies maintain control on the decision outcomes, but the systems objective is to enable collaboration in trucking operations and increase both individual and overall operational efficiency.

By being able to transport all shipments with a smaller fleet of trucks, cost reductions can be achieved for the companies. To quantify the potential savings we use real world data of two transport companies to analyse the potential efficiencies gains when collaborating in trucking operations.

[1] *Examples of such initiatives: Trimble, Uber Freight, CtrlChain, Cargo Exchange, MyDello, Cargopedia, Cargominer, Wtransnet, Trans.eu Platform, 123cargo, express-online, Haulage Exchange, Load Today, Return Loads, Timocom, CargoX, E-containers, U-turn.*

Collaborative truck scheduling use case

The two transport companies both operate an inland container terminal in the Netherlands. Containers need to be transported between the container terminal and client location for (un)packing of the containers. Trucks delivering a container to a client have a next trip that is without load either to a pick-up customer or back to the terminal to load another container for delivery. Preferably these empty trips are minimized and truck schedules are made such that the total driven distance without load is minimized. In case of collaboration there are more customers and therefore there are more opportunities for neighbouring delivery and pick-up customers and more efficient trips might be scheduled. An example of how collaboration can reduce the empty milage is provided in Figure 1.

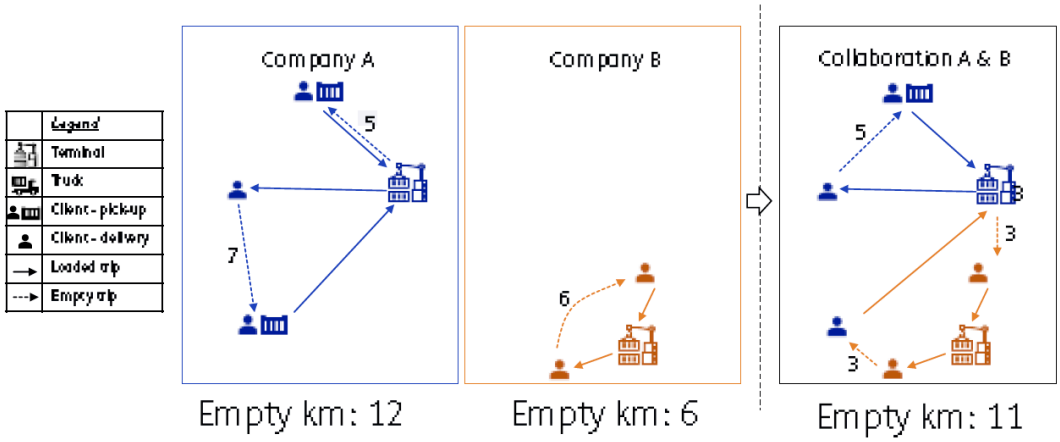

Figure 1: Basic example of reducing total empty mileage from 18 km before collaboration to 11 km in case of collaboration.

The problem described above is known as a truck and trailer vehicle routing problem (TTVRP). The companies have pick-up and delivery of containers with varying origins and destination, where either the trailer with a container is (un)coupled at a customer or the container is delivered to a different terminal where the container is loaded to, or unloaded from, the trailer chassis.

Research outline

This paper presents the results of quantifying the reduction potential of horizontal collaboration between to road freight operators. A brief literature review on the truck and trailer vehicle routing problem and the development of decentralised scheduling approaches for this problem is provided. Followed by a description of the method and performance indicators for the analysis and the results of the analysis. The results and approach are reflected in the discussion section, after which conclusions and next research steps are described.

2. Decentralised fleet scheduling

The idea of decentralising logistic decision making by allowing multiple agents to make decisions is presented by Krauth et al. (Krauth, Moonen, Popova, & Schut, 2005). The concept is further elaborated by Gerrits et al. (Gerrits, van Heeswijk, & Mes, 2023), who describe a system in which agents operate autonomous, thereby automating the logistic system. They refer to this as a Self-Organizing Logistics An example of applying this concept in horizontal collaboration is explored by van Meijeren et al. (van Meijeren, Fransen, van Leeuwen, & Sprenger, 2025). These ideas form the foundation for the proposed federated fleet system, which aims to enable horizontal collaboration among road transport carriers.

The proposed solution is a decentralised scheduling system, in which each company has a scheduler agent responsible for determining which truck handles each shipment (container transport) and at what time. To enable collaboration, the decision making agents should be able to identify potential schedule improvements for each other's fleets by exchanging transport orders between companies. For example, one agent could propose a schedule change to another agent, which then decides whether to accept or reject the proposal.

Each decision making agent therefore requires information on the available truck fleet and container shipments for its company. First each company creates an initial fleet schedule. Secondly, partial information of individual fleet schedules, available trucks, and shipments are shared for the other agents to find possible schedule improvements. An abstract functional design is presented in Figure 2. The type of information to be shared and how to make improvement decisions that lead to better collaborative schedules is still to be researched. The first step is to analyse the potential of collaboration. This to evaluate the relevance of the follow up research and development of the proposed solution.

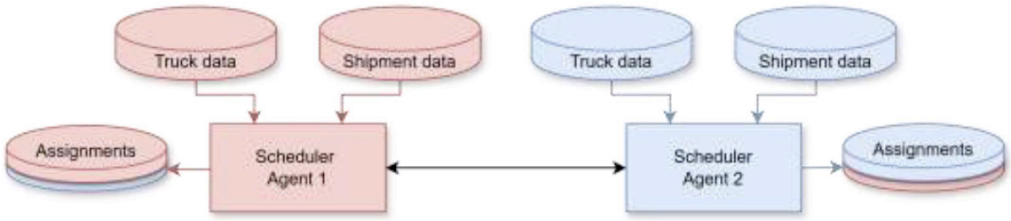

Figure 2 high-level functional design of a decentralised scheduling system.

Reproducing trucking schedule

To quantify the potential of horizontal collaboration we execute scenario analysis which we describe in section 3, in these scenarios we need to determine trucking schedules. In this section, we briefly present a basic greedy scheduling approach that has been used to create fleet schedules for these scenarios.

Scheduling Procedure:

1. Sort container shipments by delivery or pick-up time, from earliest to latest (earliest-deadline-first).
2. Iterate over the sorted shipments. For each shipment:
    a. Identify the closest and available truck, taking into account the need to pick up or from off an empty trailer-chassis.
    b. If a suitable truck is found: assign the shipment to the truck, schedule the truck's departure, and Update the truck's next available time.
    c. If no suitable truck is available: leave the shipment unassigned

This methodology relies on several assumptions. It is assumed that empty trailer-chassis are always available at container terminals and that there is sufficient space to park additional trailers. Driving times are estimated based on as-the-crow-flies distances multiplied by a factor 1.2 to approximate road network distance, using an iterative speed function Furthermore, two types of trucks are considered: terminal tractors, which operate exclusively on local industry area around the terminal, and regular tractors, which can service all customers. To accommodate these constraints, all local industry area container shipments are first assigned to available terminal tractors, and any shipments that cannot be assigned are added to the list for regular tractors.

3. Results

For the case study, the two companies shared data on all container shipments and available truck fleets for a single month in 2024. During this period, company 1 handled 15,000 shipments , while company 2 handled 6,500 shipments.

Data analysis

Not all shipments are relevant for collaboration due to geographical constraints or delivery time restrictions. A selection of relevant shipments is based on the geographical spread of shipments and time of day of shipment execution. Geographically: the a region with overlap in operational area were selected. The selection is illustrated in Figure 3, which shows a heatmap of shipment origins and destinations of the shipments of both companies. Temporally: all night time deliveries were excluded. After applying these criteria, the total number of relevant shipments was reduced to approximately 18,500.

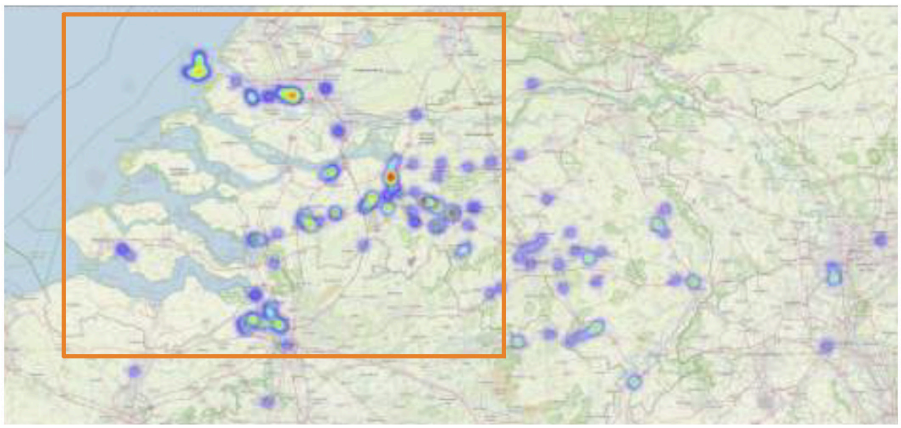

Figure 3 Geographical selection of overlapping delivery regions on the heatmap of shipment origins and destinations in the terminals' hinterland.

Experimental Design

To quantify the potential benefits of collaboration, an experiment was designed in which two scenarios, individual operations and collaboration operations, were compared. The performance indicators considered were total trucking distance (in kilometers), associated trucking costs (in €), and CO_2 emissions. The reduction potential of collaboration is calculated as the difference between the collaborative scenario and the individual operations scenario.

1. Individual schedules – total performance
   a. Company A - individual performance
   b. Company B - individual performance
2. Collaboration schedule - total performance

For each scenario, trucks costs were estimated using a cost factor of €0.75 per kilometer. CO_2 emissions are calculated using an average of 1 kg CO_2 per truck-kilometer, based on the average trucking emission published by the Dutch Emissie Registratie.

Experimental Results

The greedy scheduling method was applied to determine truck schedules for the different scenarios using the real-world truck and shipment data from both companies. From these schedules, the scheduled trucking empty and full kilometers are calculated and used to estimate the trucking costs and CO_2 emissions. The results of this analysis are presented in Table 1.

Table 1. Performance indicator values per scenario and the delta being the potential improvement by collaboration.

Scenario	Trucking km	km – no container	Trucking €	kg CO_2	%
Individual	439,000	169,000	€ 329,000	439,000	100 %
Collaboration	421,000	151,000	€ 316,000	421,000	96 %
Delta	***- 18,000***	***- 18,000***	***- € 13,000***	***- 18,000***	***- 4 %***

On the total month driven distance, fleet collaboration can potentially save around 18,000 trucking kilometres. This is 4% of the total driven km and 10% of the 'empty' km – driven without a container, either with an empty trailer chassis or no trailer chassis attached to a tractor. This corresponds to a cost reduction of €13,000 per month and a reduction of 18,000 kg of CO_2. These numbers are totals for the month, the daily result in kilometres are shown in Figure 4. The reduction potential per day ranges from 0% to 11% reduction of total driven distance, and for the empty kilometres, it ranges from 0% to 27%. This variation shows that the balance of shipments in terms of geographical and time windows can strongly influence the reduction potential for collaboration.

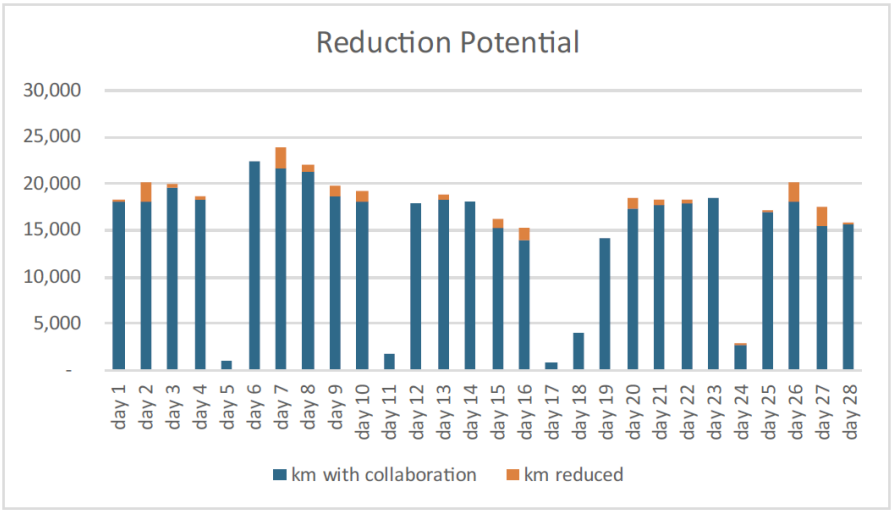

Figure 4: Reduction potential per day in number of trucking kilometres.

4. Conclusion and Discussion

The potential for road transport collaboration for these two companies can lead to a significant cost reduction of 4% in total trucking costs. Relative to the empty mileage the reduction is 11%. Additionally, there is the added benefit of reducing CO2 emissions by a similar 4%. These results have been discussed with the transport companies, who expressed interest in pursuing these reductions and supporting further research to develop the federated fleet system.

The experiments show that the potential for collaboration varies on a daily basis, due to differences in daily shipments with varying origins, destinations, and time windows. On certain days, these variations lead to more efficient shipment exchange, resulting in greater schedule improvements through collaboration. This also underlines the importance of collaborating with transport companies that generate shipment portfolios in which efficient combinations can be made based on geographical, timing and cargo type. In the analysed use case, both companies transport deep sea containers, which can be easily exchanged due to the standardized container sizes, provided that shippers accept shipments handled by a different company's truck. To identify suitable collaboration partners it would be interesting to further analyse the results of this research and investigate which parameters and constraints influence collaboration potential and subsequently determine what properties are relevant for collaboration partners.

The executed analysis used real world data but the availability and quality of the data were still limited. Data cleaning, standardization and quality improvement with assumptions were necessary to enable this potential analysis. Real world data is still very limited and challenging to get good quality data from transport operations. For example, the provided company data did not contain execution logs, so we estimated individual operations using our basic scheduling method to create a truck schedule for both the individual and the collaborative scenarios. The scheduling method used in this study was intentionally simple. More advanced approaches, such as linear programming or heuristic methods like genetic algorithms, could yield additional improvements.

This research focused on collaboration between only two companies, but to gain greater efficiency through collaboration. It would be interesting to scale up in number of collaborations partners and gain network effects in improving each other transport schedules. Next to focusing at the truck-trailer vehicle routing problem, the methods for horizontal collaboration can also be relevant for different variants of horizontal decision making problems with assets sharing. For example with extension to battery-electric vehicle fleets with limited charging infrastructure or even to other domains such as the scheduling of electricity distribution in a shared local energy system.

Acknowledgements

This work has been made possible by Regio Deal Midden-Brabant, klimaatfonds by gemeente Tilburg, innovatiecoality by Province Noord Brabant and by TNO.

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Het project Circulaire Stromen - Next Level Logistics
wordt mede mogelijk gemaakt door Logistics Community Brabant, Midpoint Brabant,
Breda University of Applied Sciences, TNO en Technische Universiteit Eindhoven met subsidies vanuit de
provincie Noord-Brabant, klimaatfonds gemeente Tilburg en de Regio Deal Midden-Brabant.
De Regio Deal Midden-Brabant is een initiatief van Midpoint Brabant, de gemeenten Tilburg en Waalwijk,
provincie Noord-Brabant, Tilburg University, Fontys, Yonder en de ministeries van BZK, I&W en EZ.