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Collaborative logistics and fierce competition - the path to sustainable freight transport

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COLLABORATIVE LOGISTICS AND FIERCE COMPETITION

- the path to sustainable freight transport

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Collaborative logistics and fierce competition
- the path to sustainable freight transport

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Introduction

Empty running and half-empty trailers have been a headache for logistics service providers for years. The European Commission estimates that more than one fifth of all driven trailer kilometers is empty running, while the World Economic Forum finds that most trailers are not fully loaded.

Managers have tried to reduce this problem by introducing new technology, through company mergers and through ad-hoc collaboration with competitors.
Dispatchers often use their informal networks with colleagues in other transportation firms to solve day–to–day problems of empty running and excess freight. Older dispatchers often mention their little 'black book' of personal contacts, while younger dispatchers join several informal email lists.

Despite the advantages provided by new technology and the dispatchers' individual attempts at problem solving, empty running still presents a major challenge for the industry as well as for the environment.

In 2016, a group of researchers and industry professionals joined forces on an innovation project to provide a solution to this problem. The idea was pretty straightforward: to develop a system that automates the ad-hoc collaboration by matching available goods to excess capacity. This resulted in a project that developed a 'Databased REal-time CollaboraTive Logistics sYstem' - we call it the DiRECTLY project.

By reducing empty running and increasing load utilization on trailers it should be possible to reduce some of the negative impacts of road transport, such as CO_2 emissions, congestion and air pollution. However, achieving this in practice was far from straightforward.

This book tells the story of how we tried to develop the system. It has turned out to be a story not only about technology, but also about competition, organization, data, learning and much more besides.
Did we succeed in solving the problem? Yes, but developing the system turned out to be only the first step on a longer and necessary journey.
This is not a story of how to develop technology, but of how to change companies in an industry characterized by fierce competition, short deadlines, and high complexity.

This book is not only about collaborative logistics, it is also about how to move the road freight industry forward through new technology, exemplified through a focus on collaborative logistics.

PHILIPS

Chapter 1 **Chaos, mayhem and buckets of coffee:** another day at the dispatching office

It is the sunny morning of Tuesday the 2nd of April 2019. The dispatchers at Danske Fragtmænd Transport A/S (DFT) near Aarhus have arrived early as usual. They sit in an open office space. Next to them is a line of smaller offices and a coffee room. On the adjacent side, panoramic windows provide a view of the freight terminal and of trucks arriving and departing.

The coffee machine provides a steady supply of black coffee. A small door opens into a rooftop platform, a popular place for smoking cigarettes. Coffee and nicotine supplies are important for the dispatchers, some of whom will be working for 10 to 12 hours today.

During the night and early morning, orders from customers across Denmark have been added into DFT's IT system. The task of the morning is to plan trips to get all the orders to move, some of them the same afternoon.
Dispatchers are matching orders with trucks and planning trips, taking into account all kinds of constraints, from a specific driver's period of availability to whether a lift is needed to load and unload a specific order. Efficiency for the dispatchers means getting the orders fulfilled using as few trucks and drivers as possible. Empty or partially empty trucks equals lack of profit.

While the dispatchers are busy planning trips, they are also keeping an eye on the progress of the trips planned the previous afternoon and evening. These trips are currently being executed by drivers across Denmark. In their system the dispatchers monitor the status and position of each and every truck. Are they on schedule? Have there been delays? What can be done with trucks that are falling behind? Phones are ringing constantly as the drivers report their status and issues to the dispatchers.

In the middle of this sits an outsider, a researcher from Aalborg University, associate professor Kristian Hegner Reinau. He is observing the dispatchers and their work as part of the DiRECTLY project.

To understand the importance of this book, let us take a look over his shoulder and at

the notes he made that very morning. All observations have been recorded exactly as they were made that morning, only the names of the dispatchers have been changed.

One of the dispatchers at work this morning is James. He has decades of experience. It is 10:15 in the morning, and he is sorting out the last trips scheduled for the afternoon. In front of him are three computer screens. One shows his email inbox, one shows the orders and the last one shows the trips.

He picks up his phone and calls a driver who is driving to a DIY store. James tells the driver what route to take, which crates to pick up, and reminds him to pick up those that have been filled with refuse and leave a few empty crates behind. After hanging up the phone James jokes to the other dispatchers around him: "I think (name) is soon going to get tired of driving to Zealand, he has been driving back empty for two days, this should make him more manageable". The surrounding dispatchers laugh.

Kristian asks James to elaborate on the comment. James explains. This particular driver has been working for DFT for ages, hauling orders for one specific customer. And he has been complaining non-stop about the trips he receives from the dispatchers, arguing that they are annoying, boring, and basically that everyting is wrong. However, James and the other dispatchers know that this particular driver likes to get back home by the end of normal working hours, i.e. in the afternoon.
To annoy the driver, James has deliberately been planning trips for the driver to DIY stores in Zealand, forcing him to drive back with an empty truck and arrive home late in the night for two consecutive days now. James knows that after a while of having to take these late-night trips the driver will stop complaining in order to avoid being given these trips by James. A colleague listening in on the conversation laughs and calls James a sadistic dispatcher.

James quickly picks up the phone, calls another driver and asks where he is, and if he knows exactly what to do. Immediately after hanging up, another driver calls James to report his status. Kristian asks James if this is a busy day. James answers with a smile that every day is fucking chaotic.

James opens a spreadsheet and starts planning trips for another customer. The list contains all the customer's shops and how much freight has to be delivered to each of them. James inserts a new column in the file and calculates the amount of loading metre to each shop. A semi-trailer can hold up to 13.6 loading metre. He then adds another column and starts

calculating the amount of trailers he needs to deliver to each shop. He swears while he works. Some of the dates in the file he received contain errors that he now has to correct.

While James works on the list, his phone rings again. One of his drivers did a pickup at a supermarket, but failed to collect the entire shipment. Now James has to locate the specific order in the system, split it into two, and figure out how to reroute a truck with spare capacity to get the last part of the order fulfilled.

An email arrives from another transport company. While James is reading it his phone rings again. After listening briefly, James instructs to the driver on the line to wait for a few hours, and call him back when he starts driving again. Turning to the others around him, James says in a defeated tone: "I think we will be fucked tomorrow".

Once again his phone rings, and James tells another driver "Well for fuck's sake, then you can't pick up a full load, can you?" A pause, and then: "Well, just leave the shit and load whatever you can."
The phone rings again. "God damn it," mutters James as he picks it up. "This is James, now what?"

While the phone keeps ringing, an email pops into James' inbox. The subject line is "Herning-Ikast-Brande", the names of three Danish cities. Kristian asks James if that is an offer from his network regarding an order to be transported? James explains that, yes, one of his contacts needed some freight driven on that route, but he has to decline. James is already 20-30 loads behind schedule today.

"He wouldn't have paid shit for it, if I know him right, and then he would have wanted it even cheaper afterwards anyway. That is something you only do on the days you are bored."

Clive sits next to James. He is getting increasingly frustrated as he faces the same issues as James. Kristian asks James if this is an ordinary Tuesday. James explains that Tuesdays are normally not this busy, but Wednesdays are. And this is annoying, because normally James starts planning the trips for Wednesdays on Tuesdays, but now he is behind schedule. This means that he will also be behind schedule tomorrow. And that's why, tomorrow they will be fucked. Then the phone rings, and James is busy again.

This snapshot of James from 10:15 to 12:00 on this specific Tuesday, highlights why col-

laborative logistics assisted by a decision support system is necessary for logistics companies - and also why getting such a system to work is extremely difficult.

James is highly experienced and - according to colleagues and his manager - an extremely skilled dispatcher. But even with his experience and large network built up over decades of work in the industry, he faces an uphill battle this Tuesday.
There are several drivers' issues for James to tackle under extreme time pressure. Even a man with his amount of experience is struggling.
He will eventually get the trips planned, but only by pulling 10 to 12-hour workdays and potentially having to work Saturdays and Sundays as well. However, the details, such as the possibility of finding 3-4 pallets in his network for a trip with excess capacity, or selling 3-4 pallets to avoid running a poorly loaded truck are, in James' own words, something you only do as a dispatcher on the days you are bored. This is not one of those days. Not many days are.

So the problem remains: some trucks have a few free pallet spaces when the trips are planned, and at the same time, other small orders do not fit into the trips planned.

This is exactly why there is a need for a collaborative logistics decision support system that can help dispatchers by automatically telling them whether a competitor has an order that fits the trip the dispatcher is planning. Or, in the reverse case, whether the order a dispatcher is struggling to find space for, can be sold to a competitor, who has a trip on the right route with available space.

The starting point of the research project described in this book was based on a simple idea: Can we make a collaborative logistics system which receives real-time information about all the orders and trips planned by the participating logistics companies, match these, identify opportunities for sharing and relay this information back to the companies? In other words: can we tap into the information that James and his colleagues are looking at, and do the same with all the Jameses and Clives in other logistics companies, and provide them with information that they can use, in an easy way, to fill up the trucks more efficiently, even when they are under pressure?

Developing such a system was the objective of the DiRECTLY project. And the glimpse into James' working day reveals why this was no simple task. People unfamiliar with the logistics industry tend to assume that planning trips can be done automatically.
After all, why not? It's simply a matter of matching orders with pickup and delivery lo-

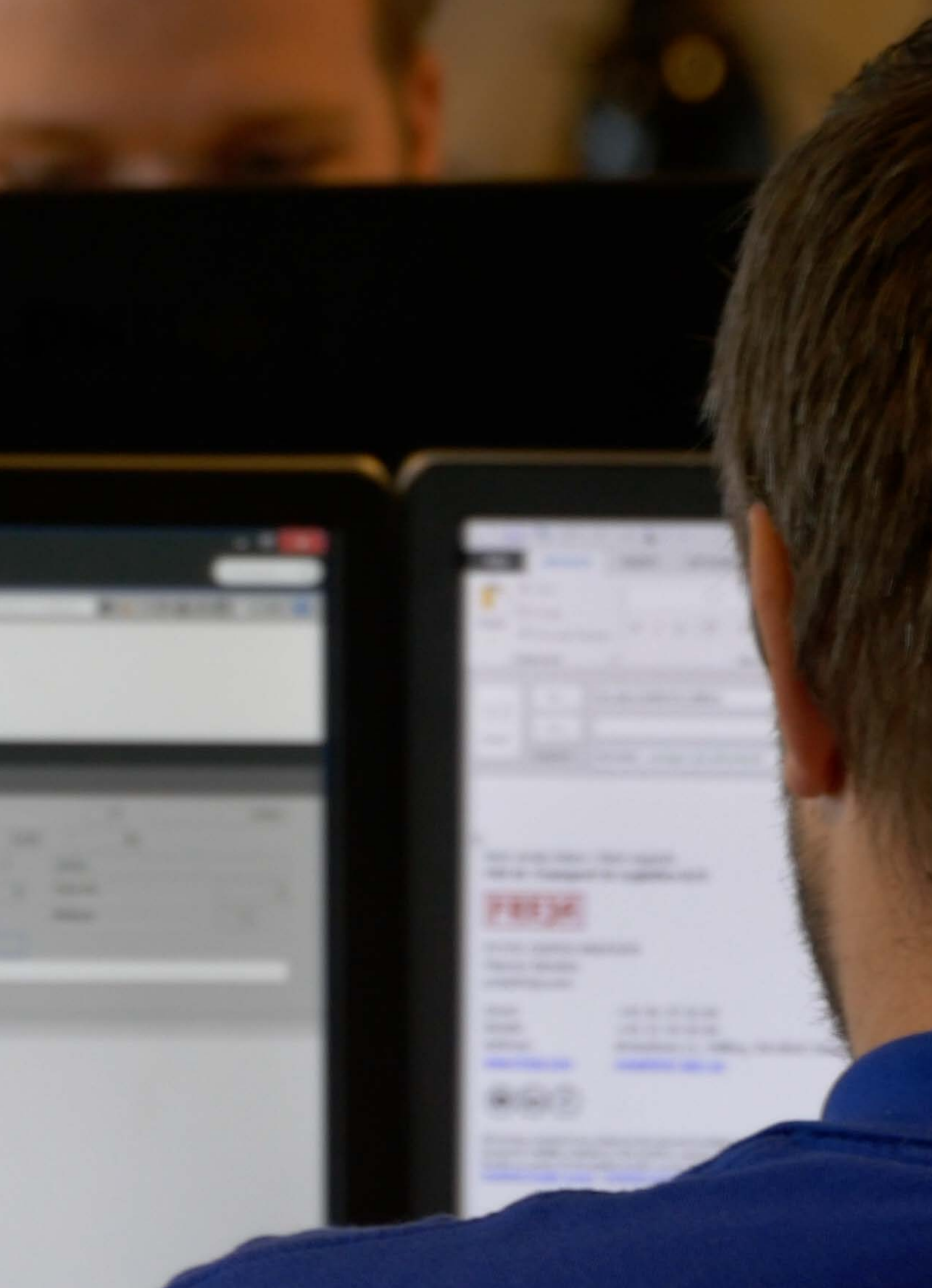
cations to a number of trucks moving on a road network – it all seems like a typical IT optimization problem, right?
In reality the work done by the dispatchers is complex and involves multiple issues, such as driver management, as we saw in James' "education" of the complaining driver, constant replanning and handling of data errors.

These are just a few examples of the challenges a dispatcher faces during a working day. Obviously, a fair share of the trips can be planned automatically, but not all of them. The human dispatcher is still highly needed.

Right. How does this all add up, then?
How do you build a system that incorporates the knowledge, creativity, *fingerspitzgefühl*, brash humour and and intuition of human dispatchers alongside effective algorithms that divide the world into 0s and 1s?

In this book we retrace our steps back to the initial studies to avoid reinventing a leaking bowl (chapter 2), to the action research of embedding ourselves among dispatchers, planners, drivers and lawyers to understand the turbulent nature of the freight transport industry and eventually build the foundations of a fully operational decision support system (chapter 3).

If you don't really care what we did with whom, when and how, but only want to know what we found out and how to apply our knowledge yourself, feel free to jump straight to chapter 4 where we present the findings, barriers and recommendations of the project. The fifth and final chapter contains our ideas and visions of how to integrate a system that can potentially save money, time, CO_2, cigarettes, coffee, outbreaks of mayhem and the occasional swear word.



Chapter 2 Collaborative freight transport: theory and implementation challenges

Before setting out to build a system for freight transport collaboration, we knew from previous studies that the benefits of such a system were already widely recognized.

Horizontal collaborations established amongst companies whose transportation networks partially overlap have the potential for significant shared gains (Frans Cruijssen, Dullaert, et al., 2007; Leitner et al., 2011). A recent review of 10 collaborative logistics studies by Allen et al. (2017) reports that horizontal collaborations amongst logistics operators can lead to 16 percent lower distance-based costs, 24 percent lower environmental costs and a 25 percent increase in business volume. However, the estimates of these benefits are subject to considerable variability depending on specific case studies' contexts.

However, in spite of the theoretical benefits pointed out in the academic literature, the potential of collaborative partnership amongst carriers has never been thoroughly exploited in practice (Creemers et al., 2017). While the theoretical mechanisms for collaborative freight transport are quite well developed, implementation challenges still exist.

In this chapter we give a brief overview of the theoretical developments known from literature and of the implementation challenges that we knew we had to face as we embarked on our journey with the DiRECTLY project.

A BRIEF INTRODUCTION TO ROAD TRANSPORT COLLABORATION THEORY

The academic efforts towards developing systems for horizontal collaboration in road transportation can be broadly divided into three strands.

The first focuses on formulating collaboration mechanisms as mathematical problems. In particular, mathematical optimization problems are solved to decide which orders to share or whether to share capacity so that joint revenues are maximized.

Other approaches to making such decisions are based on auctions. An auction is "a market institution with an explicit set of rules determining resource allocation and prices on the

basis of bids from the market participants" (McAfee and McMillan, 1987). This allocation of resources (i.e. orders and capacities that collaborating companies are willing to share) and the cost of exchanging such resources amongst collaborating companies are also results obtained from the formulation and solution of auctions as mathematical problems.

The second strand looks at the mechanisms of how to fairly divide the benefits and costs of collaboration between collaborating partners.

The third and more widely applied strand looks at how collaboration opportunities can be identified based on spatial and temporal overlap of operational data across the collaborating companies. Below we briefly introduce each of these knowledge strands.

COLLABORATION MECHANISMS IN THEORY

Road transportation companies that provide logistics services within the same geographical territory are natural competitors. Given that these companies operate on the same level of the supply chain, any form of cooperation they may engage in is a form of horizontal collaboration. Verdonck et al. (2013) surveyed 50 studies and identified two different approaches to horizontal collaboration amongst logistics operators: order sharing and capacity sharing.

Order sharing involves sharing or exchanging orders from customers, in order to increase efficiency by optimal re-allocation of orders amongst collaborating partners. Typically, homogenous demand is aggregated to increase utilization of vehicles.
Capacity sharing focuses on supply. Instead of pooling orders, transport companies share assets, specifically vehicle capacities. Order sharing and capacity sharing mechanisms identified by Verdonck et al. (2013) are listed in Table 1 and are described below.

Order sharing	Capacity sharing
Auction mechanisms (AM) for specific orders	Joint fleet assignment
Bilateral Lane Exchanges (BLE), i.e. exchanges of full truck loads in direct movements	Auction mechanisms for free capacity
Information Secured Swapping (ISS) of orders	
Shipment Dispatching Policies (SDP) for expiring delivery deadlines	

Common order and capacity sharing mechanisms, Verdonck et al. (2013)

Verdonck et al. (2013) highlight a number of implementation modes for order sharing: Joint Route Planning (**JRP**), Auction Mechanisms (**AM**), Bilateral Lane Exchanges (**BLE**), Information Secured Swapping (**ISS**) and Shipment Dispatching Policies (**SDP**).

Joint Route Planning involves pooling orders from all partners and formulating and solving appropriate vehicle routing problems. For an agent (i.e. a carrier or a transportation company) order sharing with AM involves first identifying which customer requests should be exchanged, e.g. solving cost minimzsation problems including route planning etc. The agent then informs the collaborating partners that the identified orders are open for bidding.

Bilateral Lane Exchanges means that full truck loads with specific origin-destination pairs are exchanged.

With Information Secured Swapping entails transport companies swapping orders to minimize the total travel distance, while ensuring that an absolute minimum amount of information is shared.

Shipment Dispatching Policies mean that a carrier with an expiring shipment deadline, which is only partially loaded picks up relevant orders from collaborating companies to increase its load level.
In the shipping industry, capacity sharing implementation usually involves solving mathematical programming problems to optimally allocate routes to a fleet provisioned by all collaborating carriers (joint fleet assignment).

In road freight transport, the vehicle allocation problem is more dynamic (Verdonck et al., 2013). As an alternative to solving programming problems, negotiations based on AM have also been adopted in capacity sharing, whereby a carrier offers transport capacity to collaborating carriers that other carriers are free to accept or negotiate (Fischer et al., 1996).

Order sharing requires exchanging customers' order data amongst collaborating partners; but when engaging in capacity sharing, collaborating partners theoretically do not share customer information (Verdonck et al., 2013). In practice, however, even in capacity sharing, it seems very difficult for the "marketing partner" (i.e. the partner who sold the shipping service to a customer) to fully protect order information from being shared with the

"operating partner" (i.e. the partner delivering the shipment), given that the latter will have access via vehicle telematics to vehicle position and load.

Accordingly, any form of order sharing or capacity sharing needs to provision for a trust building mechanism and incentive system that allows for and supports a high level of trust between the partners.

THE REVENUE SHARING PROBLEM

One crucial aspect of collaborative transportation is deciding how to share the benefits and costs of collaboration. The airline industry has a long tradition of horizontal collaboration between companies. They refer to this problem as **revenue sharing**. Guajardo and Rönnqvist (2016), who recently reviewed 55 scientific articles, identify at least 40 methods for allocation of costs amongst collaborating transportation companies. Many of these methods have their theoretical foundation in cooperative game theory.

One of the most widely used popular allocation methods from cooperative game theory is the so-called **Shapley value**. In a given set of companies between which coalitions can be formed, the Shapley value is the average of the costs implied by a company entering a coalition across all the possible coalitions that can be formed (Shapley, 1953). The Shapley value ensures each member of the coalition gains at least as much or more than they would have had they not collaborated, and has been demonstrated to generate fair allocations.

Another popular allocation approach is the **proportional method**, whereby the share of the costs incurred by a player are proportional to the total cost of the coalition. The constants of proportionality for each player must sum to one by definition and can be defined by different criteria. For example the shares can be defined based on demand quantities for each player or standalone costs.

While there exists a large body of theoretical analyses and simulation studies, the translation of theoretical principles and mathematical formulations into practical solutions is still a minefield. From a computational perspective, the identification of allocations guaranteeing fairness and stability is extremely challenging when there are a large number of players, due to the combinatorial nature of the problem (Allen et al., 2017).

Additionally, the compensation mechanisms need to be tested in practice, because, while the benefit-sharing mechanisms may be designed to compensate fairly within the alliance, the external marketplace may be more competitive. As a result, potential collaboration

opportunities within an alliance may be lost to outside carriers offering more favourable conditions (Dahl & Derigs, 2011).

IDENTIFYING OPPORTUNITIES THROUGH OPERATIONAL DATA

Identifying suitable partners and collaboration opportunities is at the core of collaborative logistics. Finding suitable partners and opportunities depends on two sets of factors (Creemers et al., 2017): *Tangible factors*, such as geographical, temporal and shipment type compatibilities and *Non-tangible* factors such as trust between partners. Most applications of collaborative logistics systems have essentially been designed based solely on tangible factors only. Further research and development is needed to address non-tangible factors in collaborative logistics platforms.

As shown in the preceding two sections, literature reviews in collaborative logistics over the past 15 years have systematized collaboration frameworks and their associated mathematical formulations into optimization problems, studied what barriers exist to collaboration, and analysed cost and benefit sharing mechanisms.

However, the practical problem of identifying potential collaboration opportunities has received little attention. Only a handful of studies describe the data analytics methods and search algorithms required in order to mine order and capacity data from transportation companies to generate potential collaboration matches.
Below are three examples of such studies.

Deng (2014) proposes an approach for automated discovery of collaboration opportunities between logistics companies based on a hierarchy of rules to match available vehicle capacity and required consignment movements.
The idea is that in large alliances or in market facilitation systems where postings of available capacities or shipments are published, the manual search involved is inefficient. This is particularly true in dynamic markets where demand, supply and prices are volatile.

Deng's approach identifies vehicles and shipments that have overlaps in:

1. pickup and delivery times,
2. origin and destinations,
3. vehicle type (empty or non-empty), and shipment type,
4. available tonnage and shipment weight, and
5. available space and shipment size.

The sequence of this list sets out the order in which the overlaps are checked by Dengs' algorithm: higher order checks are carried out only if overlaps are found based on lower order checks. The author tested the algorithm using historical data from transportation companies. While this automated search is likely to significantly cut the costs and times entailed by manual searches, Deng does not provide any evidence that any other hierarchy of rules would improve the number of matches or the search speed.
Furthermore, the search algorithm does not take account of any cost preference.

Creemers et al. (2017) present a matching procedure to identify potential collaboration partners purely based on the geographical compatibility of respective shipments. The procedure (named **BBaRT**) does not consider any other criteria than spatial matching.
Therefore, BBaRT can be used only to identify potential partnerships, rather than specific collaboration opportunities. BBaRT has been adopted by Tri-Vizor, a third party logistics company.

Historical shipment data from logistics companies' databases are homogenized so that they have a unique OD pair. Shipments are clustered so that bundling, round-trip, and collect-and-or-drop opportunities are identified.
Potential collaborations are evaluated based on a number of KPIs, such as ratio of shared distance to total distance, ratio of shared volume to total volume, and ratio of shared tkms to total tkms. A user then assigns a weight to those KPI in according to his preferences; so that a utility for collaboration can be assigned and the potential collaboration can be ranked.

Ilie-Zudor et al. (2015) developed a decision support system (DSS) for logistics companies that enables the integration of artificial intelligence and human expertise. Rather than being a tool for discovering horizontal collaboration opportunities, the system facilitates vertical collaboration in a *hub-and -spoke* network.
It provides a data-sharing platform, analytics for short-term demand prediction, and uses cognitive modelling to capture human expertise in operational decisions.
A cognitive model is an artificial system that behaves like a natural cognitive system. Put simply, what Ilie-Zudor et al. suggest is to use structural models of human decision-making to enhance purely data-driven machine learning models.
Incorporating human knowledge and modelling behaviour as part of a decision support tool is also important for horizontal cooperation. It may make it possible to capture non-tangible or latent factors affecting adoption of collaboration opportunities and provide adaptability in situations where purely data-driven systems fail.

Algorithms for identifying collaboration opportunities overwhelmingly focus solely on tangible factors - mainly geographical compatibility of transport networks, but also shipment compatibility.
Non-tangibles tend to be excluded even though they have been found to be critical in the formation of partnerships, particularly when it comes to trust. Unobserved factors - some of which may reflect attitudes towards partners - could be captured by behavioural models of the agents involved in the decision to accept collaboration opportunities.
They might also be identified based on tangible factors and valued using agreed revenue sharing mechanisms. A DSS for horizontal collaboration in logistics should integrate models for human behaviour and algorithms to identify potential collaboration opportunities, adopting the approach proposed by Ilie-Zudor et al. (2015).

CHALLENGES IN TRANSLATING THEORY INTO PRACTICE

As we embarked on the DiRECTLY project, it was clear that despite the wealth of academic knowledge on collaboration mechanisms, the implementation challenges that lay ahead were still extremely significant; especially in terms of translating collaboration mechanisms and cost-sharing approaches into workable business models and applying more straightforward data-driven approaches to collaboration identification in real-life situations.

In this section we summarize the findings of the past and current research in terms of daunting obstacles to an idea that, on paper, is undoubtedly viewed positively by academics and the industry alike; as demonstrated by the enthusiastic reaction of DiRECTLY's industrial partners when the academic team initially presented the project concept. The following findings are based on our work (Ahmed et al., 2021b).

BUSINESS MODEL CHALLENGES

The limited success of a collaboration is often the result of the underlying business model, as this is fundamentally responsible for several operational challenges in day-to-day planning decisions (Klaas-Wissing & Albers, 2010).
In addition, regulating policies defined in the business model can impede efficient alignments of companies and the alliance's interests - thus reducing the willingness of companies to join and maintain a collaborative network.
Baron et al. (2017) note that there are two types of collaborative business models: **contracted** and **non-contracted** business models.

Contracted business models are adopted in collaborative logistics networks (**CLN**s) that

are based on long-term partnerships.
In the literature, long-term partnerships are called *alliances* or *coalitions* and are based on formal agreements among partners for managing and maintaining the CLN - such as policies for sharing profits and resolving disputes.
On the other hand, **non-contracted business models** are often adopted by online freight exchange platforms such as TIMOCOM freight exchange, which enables collaboration in the spot market without the need for long-term agreements (TIMOCOM, 2020).

In what follows, we will look at the six dimensions of business models proposed by (Schmoltzi & Marcus Wallenburg, 2011) and illustrate the barriers that arise in each of them.

Bowersox et al. (1992) states that "uneven commitment to the logistics partnership is one of the reasons a logistics partnership fails". Lydeka et al. (2007) report that some partners do not pay compensation on time, which results financial loss for other partners and reduces their willingness to collaborate further.
One way of ensuring the commitment of partner carriers is to define an operational governance mode in the business models (Klaas-Wissing & Albers, 2010). Without well-defined agreements between partners, various disputes may arise in the CLN when partners or coordinators fail to meet pre-determined service levels (Verstrepen et al., 2009a, 2009b).
Collaborative agreements typically take one of three different forms: **verbal agreements**, **written contracts**, and **elaborated handbook procedures** (Raue & Wieland, 2015; Schmoltzi & Marcus Wallenburg, 2011).

Written contracts have been cited as a reliable means of defining the partners' mutual rights and obligations. They ensure that all players fulfil their duties, i.e. the collaborative transportation planning, privacy of shared information, fair profit allocation and alleviation of the risk of opportunistic behaviour (Klaas-Wissing & Albers, 2010; Reuer & Ariño, 2007; Steinicke et al., 2012).
However, the formulation of contractual agreements between large entities might be prohibited by competition laws/antitrust authorities (Basso et al., 2019).
Some countries may permit the establishment of CLNs where there is a trustee party in place to ensure that the collaboration complies with competition laws and that the shared data remains strictly confidential (F. Cruijssen, 2013; Dahl & Derigs, 2011; Vanovermeire & Sörensen, 2014).

In some cases, collaborating companies may prefer joining CLNs that adopt elaborated processes (e.g. handbooks and standard operating procedures) rather than contractual agreements due to the sheer number of expensive lawyers involved in the latter (Raue & Wieland, 2015).

A challenging question that should be addressed when formulating the business model is how to share the expected profits of collaboration in a way that is accepted by all partners (Guajardo & Rönnqvist, 2016).
Lydeka et al.(Lydeka & Adomavičius, 2007) note "*As long as cooperative venture provides benefits, logistics companies are willing to continue it*".
Although the literature proposes a wealth of profit-sharing approaches, real-world applications show that specifying a profit-sharing policy is often problematic.

The difficulty here is that no sharing policy can capture the exact contribution of each partner to the collaboration. For example, one of the most frequently applied policies is the proportional policy whereby benefits are shared among partners in proportion to only one factor. This could for instance be the number of customers served, the distance travelled for each carrier's orders, the number of orders, the total load shipped and so on.

While this rule is simple, it clearly ignores the fact that small loads may be the most significant contributors to the total distance travelled by the shared truck. In this case, the proportional allocation rule does not reflect equally the contribution of all collaborating partners (J. F. Audy et al., 2012).
In practice, each partner estimates the collaboration profit using its own accounting system and service prices, and then compares the self-estimated profit to the profit estimated by the coordinator. Considerable differences between these estimates will inevitably increase the level of distrust.
Ultimately, it may be difficult for partners to agree on specific allocation procedures - and even if they do, it is too complicated a task to develop an accurate mathematical formula for practical applications (Frisk et al., 2010).
It may also be that the collaboration facilitator imposes a specific rule without consulting the partners. This also makes partners less motivated to join the network (J.-F. J.-F. Audy et al., 2007).

Successful business models require the identification of a coordinator who creates collaborative opportunities, takes responsibility for the operational executions, and helps the partners achieve the best possible benefits (J. F. Audy & D'Amours, 2008).

Furthermore, the coordinator plays an important role in restricting the amount of shared information and ensures that the collaboration process does not violate competition law (Vanovermeire & Sörensen, 2014).
While it may be possible to identify a coordinator to lead the collaboration, it may nonetheless be difficult to reach a consensus between all the partners as to who this should be. Partners are often in doubt whether the coordinator will treat them fairly and ensure that their shared information remains confidential (J.-F. J.-F. Audy et al., 2007; Vanovermeire & Sörensen, 2014; Verstrepen et al., 2009b).

The **collaborative strategy** describes the way in which partners are required to collaborate. This needs to be defined in the business model and accepted by all partners.
There are two main collaborative strategies: **request pooling** and **freight exchange**.

Request pooling means that the coordinator receives all information about delivery requests, service costs, and freight vehicles from partner carriers. The coordinator then plans the collaborative delivery routes for all partners (Montoya-Torres et al., 2016). Additionally, request pooling requires a shuttle service to exchange delivery shipments among the depots of collaborating partners (Buijs et al., 2016).

Freight exchange requires only carriers to share information regarding their inefficient transport requests and delivery vehicles with the coordinator (Dahl & Derigs, 2011). Compared to request pooling, freight exchange does not require full information sharing and is conducted in a decentralized manner, in contrast to request pooling which is coordinated in a centralized manner (Dahl & Derigs, 2011).

According to Pan et al. (Pan et al., 2019) freight exchange requires a large number of carriers, while request pooling is more suitable for two or more carriers. It is worth noting that each of the strategies mentioned above can be further classified on the basis of geographical scope (Buijs & Wortmann, 2014).

Some studies indicate that the geographical scope of a collaboration may not be agreed upon by all partners (Klaas-Wissing & Albers, 2010). Geographical scope may be local, regional, national, multinational, or global. Collaborative strategies and geographical scope are among the most important factors that attract companies to join a network and the most difficult for all partners to reach a consensus on (Gonzalez-Feliu et al., 2013; Klaas-Wissing & Albers, 2010).

From a synergy-based perspective, several modelling approaches show that increasing the number of partners in a network leads to a greater pooling of resources and orders. This in turn results in a higher degree of collaboration synergy (Frans Cruijssen, Bräysy, et al., 2007).
From a management perspective, however, increasing the number of partners leads to a more problematic and costly coordination process and may result in smaller benefits from the collaboration (J. F. Audy et al., 2012; Lozano et al., 2013).

Another issue is that as more companies join the CLN it becomes more difficult to reach a consensus on fundamental parts of the business model. For example, Föhring and Zelewski (Föhring & Zelewski, 2015) report that "it proved to be a big challenge already in the early stages of the prototype development to reconcile contradictory opinions of potential users about single functions and processes."

Another example is documented by (Frisk et al., 2010): in 2004, eight foresting companies investigated the benefits of establishing collaborative transport and found the savings in their transport costs to be around 14.2 per cent.
However, they were unable to agree on a method to share such savings. As a result, only three of the eight companies agreed to collaborate. In addition, large networks may give rise to legal issues due to the competition laws (Serrano-Hernandez et al., 2018).
The fewer and more varied the size of participants, the more difficult the collaboration will be under competition law (F. Cruijssen, 2013).

Palmer et al. (Palmer, A., Slikker, M., De Kok, T., Ballot, E., Pan, S., Herrero, D., Gonzalez, E. & M.J., Lu, 2013) state that finding the right partners is one of the main barriers to collaborations.
Combined Logistics Networks typically start out when the coordinator contacts a group of carriers who are willing to collaborate. In many cases, this group may not have a transport synergy, which leads to collaboration failure.
The majority of NLCs have synergy issues, which results in inefficiency with regard to their collaborative transport planning (Klaas-Wissing & Albers, 2010). Accordingly, partners should be selected in a way that increases the synergies among them. Collaboration synergies depend on many factors such as the geographical location of companies and their customers, order sizes, company sizes, freight flow balance, and shipment compatibility (Frans Cruijssen, Bräysy, et al., 2007).

For example, collaborative delivery is feasible when the geographic locations of logistics

companies are close to each other and there is a freight flow balance between their regions. Flow balance means that the amount of goods moving from one region to another is equal to the amount moving in the opposite direction.
Shipment compatibility is also a source of synergy and opens up the possibility of consolidating several orders within the same vehicle.
Other synergy sources are smaller shipment sizes compared to the vehicle capacity, and overlapping customer areas.

THE INFORMATION SHARING PROBLEM

Collaboration entails a commitment to share some information with competitors to achieve a mutual benefit. However such a commitment is contrary to normal business instincts. Freight carriers believe that sharing their information will most certainly reduce their market shares (Kale et al., 2007).

In order to make effective collaborative decisions, partners should supply the collaborative decision support system (**CDSS**) or the coordinator with their complete set of logistics information. Shared logistics information describes the minimum amount of data for each transport request - such as transport requirements and specifications of the vehicles required (class, capacity, handing equipment etc.). In reality, the majority of these details are rarely documented and dispatchers often use their experience to decide on delivery and pickup times and the specifications of the vehicles required (Chow et al., 2007).

Consequently, a complete set of information is not available for all transport requests in the companies' databases. Thus, the information that is conveyed automatically to the DSS does not include important details. This would inevitably result in many infeasible collaborative decisions that would not be accepted by the partners.

The flow of information from some partners to the DSS can at times be slow or become unavailable (Buijs & Wortmann, 2014). In this case, the CDSS has to wait for the delayed logistics information, which in turn impacts the efficiency and validity of decisions (Ulmer et al., 2017). Additionally, some companies may not have updated their logistics information. In this case, a lot of incorrect matches will be sent to the partners.

Collaborations can only succeed if they are based on trustworthy data. Even if partners supply the CDSS with the required information, it is essential that the shared information is correct in order to ensure collaborative decisions of a high quality (Stefansson & Russell, 2008).

In many cases, incorrect information results in the wrong collaborative decisions being taken and completely random estimates of profits and costs (Ilie-Zudor et al., 2015).
Some partners may use different units of measurement (e.g. loading metre versus cubic metre). In this case, the CDSS obviously requires format unification that might lower the information inaccuracy.

According to Buijs and Wortmann (Buijs & Wortmann, 2014), efficient collaboration requires that partners use advanced information systems such as transport management systems (**TMS**s), warehouse management systems (**WMS**s), barcode systems, route-planning tools, fleet telematics systems, and a geo-fence tool. These systems enable partners to share reliable information, provide better visibility of the collaborative decision making and improve the level of service (Belzer, 2002).

THE H FACTOR

Human behaviour of is often an obstacle when it comes to setting up a collaboration - or a sticking point once the machinery is in place.

Some logistics companies may have pessimistic attitudes based upon previous collaboration initiatives. A good example of this is the CLN of eight forest transport companies referred to earlier. Although theoretical calculations indicated an overall cost reduction for the network, some companies were unwilling to collaborate as they did not consider the benefits great enogh (J. F. Audy et al., 2012).

It frequently happens that one partner cheats in order to maximize its own benefits at the expense of the other partners, which leads to instability, and dissolution of the collaboration (Lydeka & Adomavičius, 2007).

Most studies agree that **trust among partners is the single most challenging barrier to a successful collaboration** (Jeng, 2015; Lydeka & Adomavičius, 2007; Reuer & Ariño, 2007). The willingness of companies to share their logistics information depends on the degree of trust between them.
When partners build trustful relations, they open themselves up to each other by sharing sensitive information and working closely together (Kwon et al., 2004; Tate, 1996).

In a CLN, some partners may not trust that the service costs provided by other partners are correct or that other partners will provide service at high enough levels (Lydeka & Adomavičius, 2007). This lack of trust icreases when partners collaborate on their core

business functions, which is the case in carrier collaboration (Islam et al., 2019).

Furthermore, partners do not always have faith in the collaborative systems, i.e. th coordinator and the methodologies, of CDSS (J.-F. J.-F. Audy et al., 2007; Vanovermeire & Sörensen, 2014; Verstrepen et al., 2009b).

Many logistics collaboration initiatives have deteriorated or disintegrated because partners did not believe that coordinators applied fair profit sharing or kept their information confidential (Frans Cruijssen, Cools, et al., 2007).

OPERATIONAL BARRIERS IN COLLABORATIVE TRANSPORT PLANNING SYSTEMS

As we have seen, the scientific literature is ripe with studies that have made significant contributions to the development of advanced collaborative planning approaches based on the vehicle routing problem (Gansterer & Hartl, 2018, 2020).
However, the literature on operational approaches for enabling technologies for real-time information, developing easy to understand user interfaces and predictive analytics is far more limited, despite the clear interest the industry has in these issues.

Among the operational barriers is the huge number of matching emails that dispatchers receive daily (Dahl & Derigs, 2011). As a consequence dispatchers can sometimes spend an hour or more reviewing proposals and checking their trucks' delivery schedules. In addition, as the day goes on, more proposals are generated continually by the CDSS and sent via email (Tools, 2018).

Approximately 1.6 billion new data items are handled every month in logistics networks (Ilie-Zudor et al., 2015). This necessitates the use of efficient algorithms for operational planning through shared information processing. These algorithms need to identify exchange proposals and email them to the corresponding partners within the space of a few minutes (Dahl & Derigs, 2011; Sprenger & Mönch, 2014). However, efficient systems are constrained by heavy investment costs, and even where funding is available, systems may not perform as expected (Fawcett et al., 2007).

A particular operational issue is the communication tool that relays proposals to the partners and facilitates communication within the network. Only very little attention is paid to this issue in the scientific literature. By contrast it receives ample attention on electronic freight exchange platforms.

A few studies demonstrate how partners can go about communicating. For example, websites were used in (Chen et al., 2010; Eriksson & Rönnqvist, 2003) while an email server client as well as a website were used in (Dahl & Derigs, 2011). With a dynamic increase in data, traditional communication tools such as phone calls and emails are certainly unsatisfactory and can impair the collaborators' efficiency.

Pilot studies indicate that integrating companies' internal information systems with the CDSS is necesary to ensure efficient operational planning (Dahl & Derigs, 2011). According to Fawcett et al. (Fawcett et al., 2007), lack of connectivity between the partners' information systems represents a barrier to collaboration success. Similarly, this barrier exists where there is no connectivity between the CDSS and the partners' transport management systems.

Collaboration failures due to lack of system integration have been reported in some studies in the supply chain (Lieb & Miller, 2002)

MARKET AND REGULATION

Business contexts, e.g., manufacturing and logistics, have different market characteristics. These include regulations, the number of companies, the market share of the largest companies, the degree to which the business is vertically integrated, the extent of service differentiation provided by companies, and the turnover of customers (Brush, 1976; Gonenc & Nicoletti, 2011). Collaboration success may be directly linked to characteristics of the market in which logistics companies operate.

Some markets have regulations (such as the competition law in Europe) that can act as legal barriers to horizontal collaboration. According to the European Union Antitrust Act (The Council of the European Union Commission, 2013), agreements and business practices which restrict competition are generally not allowed.

These regulations are primarily concerned with collaborations between large companies, and as such there are many exceptions when small and medium-sized logistics companies collaborate, or when a trusted party leads the collaboration and ensures that the collaboration does not violate competition laws and that the shared data remains strictly confidential (F. Cruijssen, 2013; The Council of the European Union, 2009; Vanovermeire & Sörensen, 2014).

In practice, many shippers outsource their freight transport via long-term contracts to

logistics companies (Chan & Hu, 2001; Özener et al., 2011). This provides shippers and carriers with a range of advantages; shippers ensure the privacy of their customer information, and carriers have a stable, large share of the transport market.

Collaboration may be impeded by any vertical integration which necessitates that freight transport be carried out by the carrier's private fleet, and where the shipper is not permitted to exchange freight with other carriers (Özener et al., 2011).

Some transport markets have a high level of regional imbalance in freight flow. Various markets may have economic areas from which goods vehicles run fully loaded to other areas from which they return partially or completely empty. This may result in fewer opportunities for shipment consolidation.

In recent years, hauliers have been shifting from contracting to establishing their own logistics companies (one-truck company), and this in turn has led to a high degree of market fragmentation and severe competition.

In general, freight transport in Europe suffers from a high level of fragmentation. The road freight industry in Western Europe has more than 300,000 carriers that range in size from multibillion-Euro-companies to one-truck companies.

The market share of the largest company is only about 2.1 per cent (Jens Riedl, Andreas Jentzsch, Nils Christian Melcher, Jan Gildemeister, Daniel Schellong, Christopher Höfer, 2018). The Netherlands and Belgium have around one company per 1,800 inhabitants (Frans Cruijssen, Bräysy, et al., 2007).

Although many studies agree that collaboration is a promising solution for small companies operating in highly fragmented markets, these companies often have only a limited interest in joining long-term pertnerships. Instead, they prefer CLNs based on non-contracted business models.

Public authorities can encourage collaborative practice in the freight transport market through funding for research projects and initiatives. This is an important role, as collaboration requires relatively large investments to develop advanced planning systems.

In recent years, the European Union and many European countries have provided significant funding for a variety of projects encouraging collaboration in the logistics sector.

For instance, the city of Zurich as well as the municipality of Aalborg have funded projects to evaluate collaboration benefits among logistics companies in city logistics (Karam et al., 2020; Schmelzer et al., 2016).
As a result of these funded projects, research on collaborative logistics has been an active trend in the scientific literature.

FREJA
TRANSPORT & LOGISTICS

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Chapter 3 DiRECTLY: developing a Decision Support System (DSS)

In the early February 2016 Associate Professor Kristian Hegner Reinau from Aalborg University travelled to London to visit the internationally renowned professor of transport research John Polak at the Centre for Transport Studies at Imperial College London. The two had been collaborating for some years on how tracking data is transforming the transport field, and Kristian had previously visited John's research environment as a guest researcher.
On this grey winter afternoon they met in Polak's office on the top floor of the Skempton Building in South Kensington. The meeting would mark the beginning of the DiRECTLY project.

Kristian Hegner Reinau had previously researched personal transport and realized that a gap existed in the Danish transport research environment: nobody in Denmark was conducting any significant research into freight transport. He had been contemplating filling this gap for some time, having previously done research on how personal tracking technologies and data have transformed the transport field. He was now pursuing the theory that the same might be true for freight transport, and had already begun discussing this idea with the CEO of Gatehouse Logistics A/S Michael Bondo Andersen and the CEO of Port of Aalborg Claus Holstein.

That afternoon in London the discussion focused around how new tracking data could be used to transform the freight transport field. At one point, Professor Polak leaned back and said "Well, if we want to do something really interesting, we should set up a project on collaborative logistics." The two realized that very few research projects focused on implementing collaborative logistics in practice, and then it dawned on them: Nobody had ever built a system aimed at large competing logistics suppliers. After all, if the industry is going to become more efficient, big companies have to start using collaborative logistics.

The conclusion was clear. On Wednesday the 10th of February 2016 at 8:06 in the morning, Kristian wrote an email to Michael Bondo Andersen:

Hi Michael,

The application for tracking freight that we talked about has come much further. In short, it will be about collaborative cargo, and Gatehouse will have a very central role. The goal is to develop a collaborative cargo system and estimate what savings it can provide carriers, based on tracking data. I was in England last week discussing the project with John Polak and the discussion gave rise to this idea, I really think this is "the project". (...) The Innovation Fund has a deadline around the first of May), so it's a bit urgent.

Do you have time for a short meeting this afternoon?

Best regards
Kristian

Michael replied quickly, and the same afternoon the two met in Michael Bondo Andersen's office in Nørresundby. After this, things started moving at a fast pace, a long series of urgent meetings followed, and the project team took shape. It was clear to Kristian, John, Michael and Claus, that the success of the project relied on gathering a team with the right competences.

From a research perspective it was evident that the project would require the expertise of three research fields: transport, economics and logistics.

AAU Civil Engineering, with associate professor Kristian Hegner Reinau as project leader for the entire project, and ***the Centre for Transport Studies*** at ***Imperial College London*** with Professor John Polak in the lead, supplied the transport research competences. ***Aalborg University Department of Business and Management,*** with Professor Christian Richter Østergaard at the helm provided the economic research competences. ***Aalborg University Department of Materials and Production*** led by Professor Hans Henrik Hvolby, provided the logistics research capabilities.

From a practical perspective, the project needed two large competing logistics companies to develop and test the system. ***Danske Fragtmænd A/S*** (with CIO Ulf Preisler at the helm), and ***FREJA Transport & Logistik A/S*** joined (led by VP Lars Bakkegaard).

It was also clear that a neutral third-party IT company was needed to run the system and

to handle the data. This became the role of ***Gatehouse Logistics A/S*** for whom CEO Michael Bondo Andersen acted as partner representative. During the course of the project Gatehouse Logistics A/S was acquired by the American company ***Project44***. Following the acquisition General Manager Jørgen Brøndgaard Nielsen from Project44 took over from Bondo Andersen.

Bringing two large competing logistics companies together in a project about sharing data entails several legal issues: competition laws, transport laws and data legislation. Therefore, the law firm ***Bech-Bruun*** joined the project, initially with lawyer and partner Charlotte Bagger Tranberg acting as partner representative. Later another partner at the firm, Johannes Grove Nielsen took over.

Port of Aalborg's CEO Claus Holstein and Chief Technical & Sustainability Officer Mette Schmidt also joined the team. They appointed the port's development company ***Center for Logistik og Samarbejde (CLS)*** to provide logistics consultancy competencies. Over the course of the project the role of CEO chair for Center for Logistik og Samarbejde, and of partner representative, was filled by three different persons: Peter Høy, Frans O. Hoyer and finally Ole Svendsen.

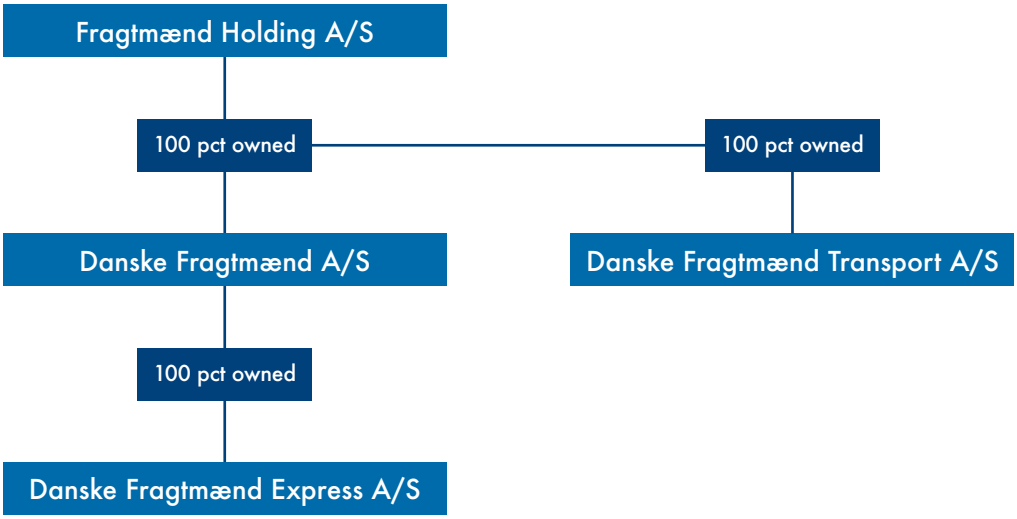
The ***Danish Camber of Commerce*** also joined the project with Director of Policy for Transport and Infrastructure Jesper Højte Stenbæk as partner representative, to provide a contact to the wider logistics industry in Denmark.

The team was assembled, and after several truckloads of meetings and a lot of late-night work, an application was submitted to Innovation Fund Denmark. By the end of 2016, the project - with a budget of DKK 15.1 million - was awarded funding, contracts were signed. On the 1st of January 2017 the research project officially got underway

Reading scientific journals and books one can get the impression that knowledge development is a linear process: researchers start out with a thesis, examine theory, collect data, analyse, and ultimately reach a conclusion. In reality, however, the process is almost always circular. This too was the case for the DiRECTLY project.
The idea was simple, and the solution complex. The DiRECTLY system, presented in the latter part of this chapter, builds partly on the theory presented in the previous chapter and partly on several years of studies, observations, meetings, workshops, surveys etc. conducted at the two participating logistics companies, all aimed at understanding how they operate and how a system can make the task of filling their trucks more efficient.

THE LOGISTICS COMPANIES

FREJA Transport & Logistics A/S and Danske Fragtmænd A/S are two major players in the logistics industry in Denmark. As a consequence of the historical background of the two companies Danske Fragtmænd is focused on the Danish transport market, whereas FREJA operates on the European market.



Organisational chart of Danske Fragtmænd, 2020

Danske Fragtmænd A/S handles the transports that pass through terminals while Danske Fragtmænd Transport A/S handles the direct transports, i.e. truckload and less-than-truckload (LTL) transports that do not pass through terminals. To make sense of this, we have to look at the difference between terminal-based trips carried out by drivers at Danske Fragtmænd A/S and non-terminal-based trips carried out by drivers at Danske Fragtmænd Transport A/S.

When the drivers at Danske Fragtmænd A/S arrive at work, their working day starts at a gate in the terminal. Here, a pile of freight awaits the driver. The goods have arrived at the terminal the day before (if sent locally) or by line-haul during the night from other terminals.
During the early morning hours, staff at the terminal sort the freight according to the areas it is destined for, and each gate receives the freight for a given area.
When the driver arrives at the gate, he or she goes through the freight and decides what route to drive and in what order in order to carry out the deliveries most efficiently.
The decisions regarding the route, delivery and pickup sequence can either be made by the driver on the spot or by the dispatchers working for Danske Fragtmænd A/S, depending

on the route and the freight.
The driver then loads the truck with the freight sorted according to this plan. During the delivery run, as the truck gradually empties, the driver starts collecting freight that has to go back to the terminal. And then the cycle starts again, the incoming freight is sorted, some of it stays at the terminal and some is put on line-haul routes to other terminals.

§

NEUTRAL GATEKEEPING

It is important to have compliance with competition regulations in mind when competitors collaborate in a project like DiRECTLY.

A number of initiatives have been implemented in order to ensure that both the process during the project as well as the finished product comply with competition regulations.

First of all, a "gatekeeper" function was initiated at the start of the project to ensure that all meetings with participants from DFT and FREJA were conducted in accordance with the relevant regulations.

Additionally, steps were taken to ensure that no individualized commercially sensitive information was shared between competitors, neither during the project nor in the finished product. Information from competitors has been handled in such a way that it was renderes no longer commercially sensitive.

At Danske Fragtmænd Transport A/S this work is carried out somewhat differently. A team of dispatchers plan the routes. They are in perpetual contact with the drivers and constantly monitor the progress of the trucks. It is frequently the case that trips don't return back home in the evening, and many drivers start their trips on Sundays or Mondays and sleep in their trucks until they return home Thursday or Friday. These are the dispatchers we met in the first chapter.

FREJA is one of the largest players in the Danish logistics industry. In recent years several acquisitions and mergers have altered the company significantly, and we shall refrain from going into the details of its organizational structure here. The key factor is that the way FREJA's trucks operate in Denmark is comparable to that of Danske Fragtmænd Transport A/S.

Due to the similarities between the operations it was decided that this project would only focus on full and less- than-truckload (LTL) loads and not terminal driving trips.
The LTL market is huge in Europe, and if the DiRECTLY system were to prove that it is possible to share loads/capacity on LTL transports with relatively small geographical distances and timeframes for trips in Denmark, the system would in theory be applicable to all LTL logistics providers across Europe.
In other words: given the geographical distances in for instance Germany, the time horizons entailed in planning LTL transports in Germany are larger than those for equivalent transports planned in Denmark. It logically follows that if the system works with small time horizons in Denmark, it will also work with the larger time horizons in Germany.

THE DISPATCHERS AND THEIR WORK

Chapter 1 gave a glimpse into the day-to-day work of the dispatchers in Danske Fragtmænd Transport A/S. As we saw, the challenge for the dispatchers is to take the incoming orders, match them with available capacity, and plan trips to get the orders delivered on time as efficiently as possible.
The challenges faced by the dispatchers are mainly related to time pressure and data availability.

Dispatchers at both companies work under extreme time pressure. James' phone is constantly ringing. Dispatchers have to plan future trips and simultaneously follow up on trips that are in the process of being executed. When plans have to be changed, as they constantly are, the dispatchers have to be able to react immediately. Consequently, dispatchers rarely have time to look at new technologies and innovative ways of doing things.

Both companies utilize IT systems that help the dispatchers carry out their work. Although the two companies utilize different systems, the overall functionality is the same: systems supply dispatchers with an overview of orders and available capacity in the vehicles, and make it possible to monitor the current status and position of each vehicle.
The studies carried out at the two companies indicated that even when a new IT system functionality was introduced, dispatchers would keep relying on old ways of doing things.

To give an example, handwritten notes on a printed excel file were circulated among the dispatchers during the day - with notes being added continually. Even though the dispatchers had an IT system in which they could update the trip status for trucks, the dispatchers found it easier to print out an A4 page, and then simply add handwritten notes as plans changed through the course of the day.

Another example is the use of IT systems to monitor the progress of the trips. At one company the dispatchers had access to an IT functionality that displayed the real-time location of trucks on a map. The relatively unexperienced dispatchers would look at the map to check the progress, whereas their more experienced colleagues would continually be on the phone to drivers to check whether they were on schedule, and ask them to to report their status at specific waypoints in order to update their work plan.
In practice this meant that some IT applications would only be opened occasionally, usually when a manager was nearby so that it would appear as if the dispatchers were using the system even if they were not.

Working under time pressure is made even more difficult for the dispatchers by the fact that they appear to be working on the basis of relatively incomplete data. It became evident through interviews and observations that the dispatchers use more data when they do their planning, than can be found in the orders entered in the IT system.

To be able to plan and replan, the dispatchers rely on a vast amount of knowledge about all sorts of details acquired through experience. As an observer, you could point to an order and ask 'what do you know about this order?'
The answer would often be something like: "Well, it doesn't have any delivery time, but this company normally needs to have it delivered at (a specific time), and we know that they need a lift to unload it", etc.
In other words, the poor data quality in the orders was made up for by the knowledge accrued by the dispatchers through experience. The same applies when it comes to solving problems with empty running.

The interviews and observations clearly show that one of the things that make experienced dispatchers valuable to the companies is their network within the industry. If an experienced dispatcher has an empty space on a truck, he or she knows which other logistics companies operate in the area and reaches out to them to see if they might have available orders that can fill the truck.
Likewise, if a dispatcher has too much freight on a trip, he or she may contact another logistics company in the network and try to sell it off. This happens constantly, both via emails between dispatchers and through phone calls. This is one of the reasons why experienced dispatchers are more efficient: they have access to a larger network within the industry and a better knowledge of which companies operate in which areas with various types of freight and vehicle capacity.

Often the dispatchers don't see any point in entering missing data into the system. The data they need is already in their head, they are under pressure to get the tasks completed, and now *please stop bothering me, okay?* This means that developing an IT system to assist the dispatchers becomes extremely difficult, since it has to operate on very limited data.

An example of how data quality becomes compromised on a daily basis was observed when a truck made several stops without picking up any freight, and then suddenly, at one stop, appeared to be completely full and carrying several orders.
It turned out that the driver found it more efficient to load all the orders at the various stops and then - at the end of the process - scan all the orders simultaneously and register them in the system. It may have been efficient from the driver's point of view, but it made optimizing the IT system very difficult, as the system received inaccurate load information.

What compromised the data quality even further was the fact that some orders are received electronically, others by phone or email and all orders are then entered into the system manually, in the process generating a variety of potential errors.

After extensive interviews, observations and discussions with the dispatchers, it became evident that since the system would need to be used in situations where time pressure was the norm, and data so limited that it would be impossible to decide which orders to share, the system could only supply ***options*** to the dispatcher, who then, based on his or her experience, could make the decision whether or not to share.

This is the reason why the DiRECTLY system ultimately became a decision ***support*** system, and not a decision system.

With the current quality and availability of data in the industry it would appear to be an impossible task to make a decision system that takes decisions on what to share. A human dispatcher with experience has to make that call, but the system has to support this decision by supplying the right information at the right time.
That was how this system took shape.

THE DEVIL IS IN THE DETAIL

Given that DFT and FREJA are direct competitors, compliance with competition law has been highly prioritized throughout the process.

According to competition law, it is illegal to share commercially sensitive information with competitors such as FREJA and DFT.

Information that enables one competitor to determine the future strategic behaviour of another competitor is considered commercially sensitive.

The exchange of such information can however be accepted if the information is historic or has been aggregated to such an extent that it is no longer possible to determine the parties' strategic behaviour.

As such the precise nature of the information shared was of central importance to ensuring the legality of the system.

ORGANIZATION, PLANNING & WORKFLOW

The respective operational divisions of the two companies' organizations have different structures but the same functions:
Head of department, dispatchers (including a team leader) responsible for a specific region or specific customers, and support functions (customer service, planning, pallet department, administration).

In a system that enables the sharing of transports between DFT and FREJA respectively, the hierarchy of the planning process and system is very important. The sooner the information is made visible to both companies, the sooner it will be possible to take all transports into consideration.

Most of the orders are received on the same day ('day zero') or before. On day zero most transports are pre-dispositioned to pre-dossiers. On day one, the planner re-dispositions the transports based on information supplied by the truck drivers, new orders, and the forwarding agent's expectation or knowledge of other orders.

FACTORS AFFECTING THE PLANNING DECISIONS

- **Resource** (trailer, truck and driver) attributes:
  - Types of cargo that can be freighted: frozen, dangerous, 'long cargo', etc.
  - Location
  - Capacity availability
  - Statistics
  - Daily rest period (an overview of this has not been entered into system)
- **Cargo**:
  - Cargo type
  - Cargo location
  - Expectations/knowledge of transports that haven't been booked yet
- **Customer demands**:
  - Delivery time / slot
  - Quality
- **Supplier demands**:
  - Pick-up time
- **Revenue/costs**

§

AGGREGATE SENSITIVE INFORMATION

The exchange of prices between competitors is often deemed particularly problematic, since it is widely accepted that this information enables the competitor to predict the company's future behaviour.

Furthermore, the exchange of information relating to cargo, location and expectations/knowledge about future transports can be problematic from a competition law perspective.

It is therefore highly important to aggregate such information until it is no longer commercially sensitive.

As part of this process, the forwarder decides whether a transport should be planned by the forwarder him or herself or by other departments, whether the transport should be sold off or whether the forwarder should buy cargo from other external forwarders to gain profit.

The most important parameter when making this decision is profit. There is no hard and fast rule for when forwarders choose to sell transports off internally or externally. It may depend on costs, resources (e.g., capacity) and whether a transport is geographically poorly located.

The trucks start driving in the morning and the drivers obviously need to know where are going. As late as the early hours of the morning customers may still be placing orders that have to be carried out the same day.

Additionally, trucks may experience interruptions and delays on their routes, and as such it is important that routes are constantly planned and monitored. It may become necessary to replan routes over the course of the day if trucks experience delays or other obstacles.

When orders are received at a typical company, they can be seen by all departments. The orders are then processed by multiple teams of forwarders - with the first team planning a certain percentage of the transports.

Transports that do not fit into the schedule are then shared with the other groups. In the IT-system, planning hierarchy orders are received. These are then translated into transports (production orders), allocated to dossiers and designated to trucks.

OPERATIONAL & STRUCTURAL CHALLENGES FOR THE COMPANIES

As we have already established, day-to-day planning is a daily battle and a very hands-on process. Most of the work demands know-how, knowledge and experience.
During our studies and interviews with key persons at the companies we became aware of challenges in integrating data and technology in the chain between customer (order giver) and the logistics company as well as internally within the logistics company.

Reliable data from customers would go some way to solving this challenge with the help of electronic data transfers and internally-integrated systems.
When data is received from the customer it is sometimes transferred manually from the

booking system to the dispatch system. Daily route planning is also carried out by the dispatchers. Trailer booking is then set up in a system in which it is possible to monitor the capacity utilization on the trailers. Each trailer is equipped with a GPS tracker allowing the trailer to be tracked online.

The right data and the interdependency of the technology is crucial to developing the company's business. This process presents a number of potential technology and data challenges:
Incorrect or missing data from customer; data quality is hard to improve, lack of transparency, poor connection and integration between systems.

There are numerous examples of dispatchers spending extra time on simple data issues, (*e.g. the customer has only supplied a postal code when the dispatcher requires the full address; pick-up and delivery time have not been entered in the right order; the order codes are incorrect, etc.*). In addition, late data creates added pressure before dispatchers are able to complete their work for the day.

These challenges are all part of a normal work day. According to dispatchers, the challenges they face are related to technology and poor data quality. As a result, huge amounts of resources are wasted on things that could be solved with better technology and better data quality.

An obvious challenge is that the investments in new technology and system integration risk favouring larger, financially secure companies and leaving smaller companies to fall behind. Nevertheless, given the rapid pace of app and technological development, all logistics companies – management and employees alike – need to stay in touch with the latest development and plan how to integrate them into how they go about organizing their business operations.

Technological innovation and high data quality are essential for companies to compete.
However, as we saw earlier, logistics companies rely to a large extent on the knowledge possessed by their dispatchers, who are under pressure. Dispatchers need to be able to juggle multiple manual processes: stressful time pressure during the day; the brief time interval between order intake to delivery time; coordination between dispatchers and trailers/drivers and difficulties maintaining an overview of the utilization of trailers (as a consequence of the manual process).

Additional complicating factors are imbalances between freight production and consumption, i.e. the ***freight balance*** in Denmark. A greater volume of freight is transported to Copenhagen and Eastern Zealand than in the other direction. This presents the dispatchers with a constant headache: How to fill up the trucks that are heading back to Jutland?.

Companies enter orders into the system in various ways depending on the customer. Direct deliveries of large orders appear differently in the system, prior to being assigned to trips.

Certain major customers' data may not be shared under any circumstances. However, it is difficult to identify major customers in the DiRECTLY system. There is no facility to exclude specific customers by name or customer number. This is difficult to achieve without manual intervention.
A formalized process would make it easier for the dispatchers to achieve an efficient workflow.

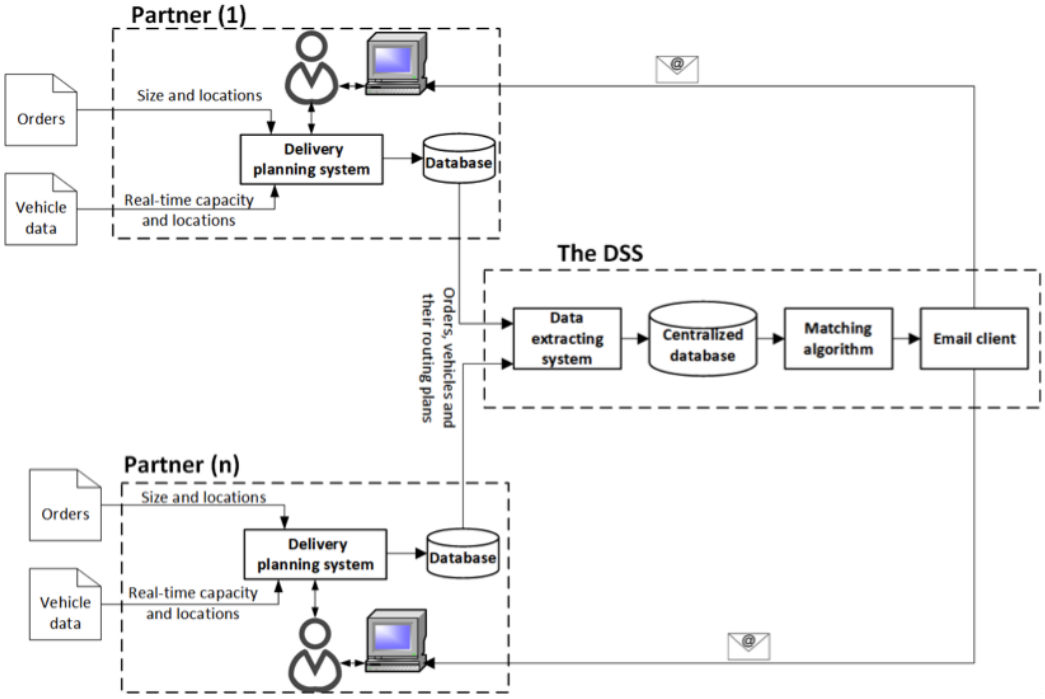
§ **MAINTAIN CUSTOMERS' ANONYMITY**
Information that has the potential to reveal the identity of a major-customer may also be deemed problematic from a competition law perspective.

Teams of dispatchers are made up of very experienced employees. Many of them started out as drivers, often at the same company. They work hard and have extensive knowledge of the areas in which they operate.

They spend many hours at the company and as one of the dispatchers remarked, it is *easier to do the job than to hand it over to another person*. They typically get the job done, and because there are many bugs and shortcomings in the systems and in the data, they are constantly busy.
They typically work in teams, sharing information and supporting one another.
Some work during the weekends in order to fulfil orders from specific customers. They do this in order to optimize the trailers in the best possible way.

THE DiRECTLY DECISION SUPPORT SYSTEM

Based on the observations and discussions with representatives of FREJA and DF the project team developed the DiRECTLY DSS taking into consideration the requirements specified by both companies. The diagram below shows the architecture of the decision support system, which consists of a centralized database, matching engine, and email client.



The DiRECTLY DSS architecture (Ahmed et al., 2021a)

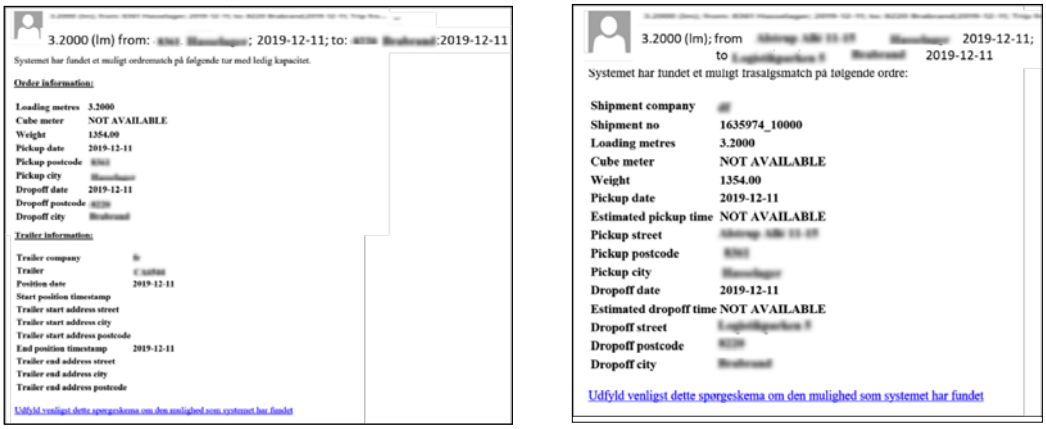
The proposed DSS facilitates automated freight matching, meaning that no human element is required, since logistics data automatically flow from carriers' systems to the DSS, and all possible matches are automatically identified.

The DSS entails interactive information flow in chronological order as follows:
Beginning in the early hours of the morning, the logistics data are shared with the centralized database system. A matching algorithm then processes the shared data to determine feasible insertions of pick-up and delivery locations of orders into the planned routes of trailers or trucks. An email client then acts as a central interface for composing and sending out emails with identified matches.

The idea is not to 'merge' the two companies but to utilize excess capacity through collaborative transport. Accordingly, the companies specified the requirement that the DSS be able to identify and send two types of matches: order matches and trailer matches.

If a transport order is matched to the route of a trailer, the order owner (the partner who has the order) receives an order-matching email while the trailer owner (the partner who has the trailer) receives a trailer-matching email.
In other words, the respective partners receive order-matching emails for transport orders and trailer-matching emails for trailer routings.

Based on the carriers' requirements, the project team designed email templates that provide sufficient (but no sensitive) information to allow the dispatchers to make a decision on whether to accept or reject a match.



3.2000 (lm) from: [redacted]; 2019-12-11; to: [redacted]:2019-12-11

Systemet har fundet et muligt ordrematch på følgende tur med ledig kapacitet.

Order information:

Loading metres	3.2000
Cube meter	NOT AVAILABLE
Weight	1354.00
Pickup date	2019-12-11
Pickup postcode	[redacted]
Pickup city	[redacted]
Dropoff date	2019-12-11
Dropoff postcode	[redacted]
Dropoff city	[redacted]

Trailer information:

Trailer company	[redacted]
Trailer	[redacted]
Position date	2019-12-11
Start position timestamp	
Trailer start address street	
Trailer start address city	
Trailer start address postcode	
End position timestamp	2019-12-11
Trailer end address street	
Trailer end address city	
Trailer end address postcode	

Udfyld venligst dette spørgeskema om den mulighed som systemet har fundet

3.2000 (lm); from [redacted] 2019-12-11; to [redacted] 2019-12-11

Systemet har fundet et muligt frasalgsmatch på følgende ordre:

Shipment company	[redacted]
Shipment no	1635974_10000
Loading metres	3.2000
Cube meter	NOT AVAILABLE
Weight	1354.00
Pickup date	2019-12-11
Estimated pickup time	NOT AVAILABLE
Pickup street	[redacted]
Pickup postcode	[redacted]
Pickup city	[redacted]
Dropoff date	2019-12-11
Estimated dropoff time	NOT AVAILABLE
Dropoff street	[redacted]
Dropoff postcode	[redacted]
Dropoff city	[redacted]

Udfyld venligst dette spørgeskema om den mulighed som systemet har fundet

Screenshots of trailer-matching email (left) and order-matching email (right) (Ahmed et al., 2021a)

Each email template is made up of three main elements: subject line, content, and a hyperlink.
The subject line describes data items for the identified match. A hyperlink at the bottom of the template allows dispatchers to communicate their interest in the match with their partners.

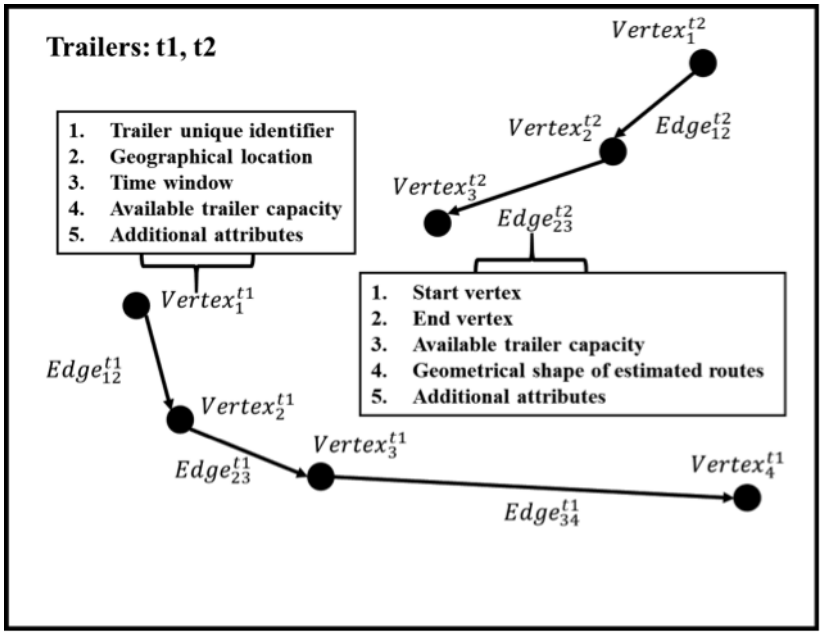
After developing the first version of the DSS, a verification test was conducted to ensure that the DSS configurations operated without bugs and that the email system worked correctly.
A pilot test was then planned in order to test the DSS under real-world conditions and investigate how easy to use dispatchers found the DSS to be in practice. This also enabled early detection of flaws in the DSS before the full release.

THE MATCHING ALGORITHM: THEORY, CONSTRAINTS, AND DESIGN

A shipment and a trailer trip can be matched as a collaboration opportunity if the pair satisfies both fundamental constraints and additional constraints. Fundamental constraints are constraints that each collaboration opportunity must satisfy, including spatial and temporal proximity of a shipment and a trip as well as trailer capacity constraint. Additional constraints are constraints that consider special preferences and requirements stipulated by companies, such as goods types allowed on certain trailers.

The definition of a trailer capacity graph (TCG)

In order to identify a collaboration opportunity, we define a TCG, a directed multigraph that describes the spatial-temporal status of trailer capacity based on the planned trailer trip data. The TCG can then be matched with shipments based on fundamental and additional constraints. The figure below illustrates the definition of a TCG.



An example of a TCG containing two trailers.

For each company, a TCG is defined as a set of vertices that represent the waypoints of all the trips made by the company's trailers as well as a set of directed edges that represent all sections of the trailers' trips. An edge connects the consecutive vertices (waypoints) of a trailer.

A given company's TCG provides the real-time spatial-temporal capacity of all trailers belonging to that company.

Each trailer in a TCG has a number of vertices. Each vertex has five different attributes:

1. The unique identifier of the trailer;
2. Geographical location (coordinates);
3. Time window when the trailer will be at the vertex, which is a the period of time between the earliest arrival time and the latest departure time;
4. Available capacity of the trailer at the vertex;
5. Additional attributes that correspond to additional constraints.

The unique identifier of the trailer is used to specify which trailer will visit the vertex.
The time window of a vertex is defined as the time between the trailer's arrival at the vertex and the processing or stopping time of the trailer at the vertex.
The start of the time window is the earliest estimated arrival time of the trailer at the vertex, and the end of the time window is the sum of the latest estimated arrival time and the stopping time of the trailer.
The available capacity of the trailer at the vertex is the trailer's capacity after the trailer has completed all scheduled loading and unloading actions at the vertex. Note that a trailer can only pick up and/or drop off shipment goods while it is at a vertex, and as such, the available capacity of a trailer will only change at a vertex.

Each edge in a TCG likewise has five attributes:

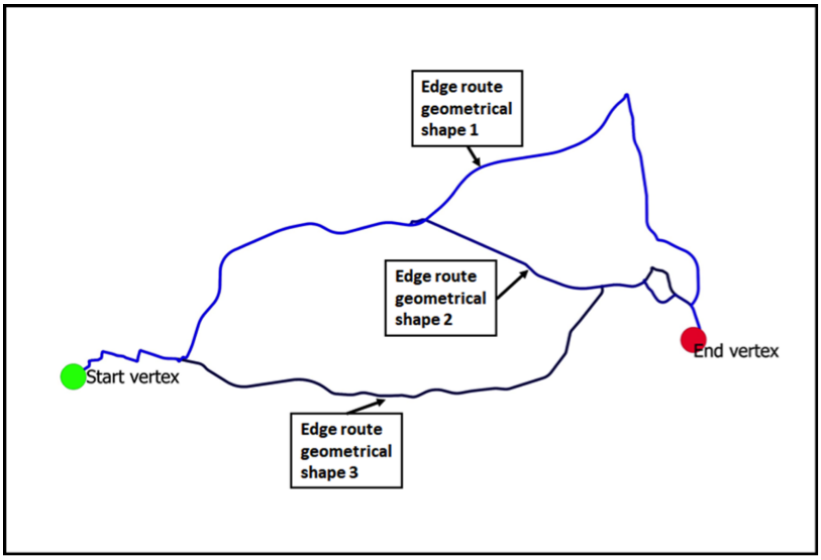
1. The start vertex of the edge;
2. The end vertex of the edge;
3. The available trailer capacity over and above the edge;
4. A set of maximum M geometrical shape of estimated route alternatives for the edge;
5. Additional attributes that correspond to additional constraints.

Since end vertices also function as attributes of an edge, the edge will inherit the attributes of the vertices. The start vertex of an edge is the vertex with the earliest time window, and the end vertex is the vertex with the latest time window.

Since the capacity of a trailer will only change at a vertex, the available trailer capacity over and above this edge will be the same as that of the start vertex. An edge may have multiple route alternatives/ shapes because it is likely that the trailer trip plan data does not include the actual route and geometrical route shape information for a trip section or a trip. Consequently, it is necessary to estimate the actual route and route shape.

In order to increase the probability of correctly estimating the trailer route and matching shipments and trips, multiple feasible route shapes are estimated for each edge.

The TCG below shows an edge with three estimated route shapes. An edge with multiple route shapes may be understood as equivalent to multiple edges connecting the same pair of vertices. As such, a TCG is essentially a multigraph. Nevertheless, a trailer can only choose one of the route shapes of an edge. This means that a shipment's origin and destination can only be matched with the same route shape of an edge.
Moreover, an edge in a TCG is merely a section that connects a pair of consecutive vertices of a trip; for this reason, TCG essentially converts all of a trailer's trips into a single pseudo-trip that consists of of all the sections of its actual trips. Finally, even though vertices of different trailers may overlap both spatially and temporally, the vertices of different trailers are not connected by any edges.



An example of the multiple route shapes of an edge starting from the green vertex and ending at the red vertex.

Traditionally, multigraphs are used for vehicle route planning with attributes such as the travel time or cost of an edge (Andelmin and Bartolini, 2019; Lai et al., 2016; Soriano et al., 2020). The main difference between a TCG and the other types of multigraph used for transport planning is the addition of the geometrical representation of an edge: the route shapes of an edge.

The route shapes, combined with shipment locations, can be used to efficiently calculate the spatial distance between a trailer trip section and the shipment location. For each trip

section, this enables identification of shipments that are close to the section's start or end points as well as to the route as a whole.
This gives the TCG a clear advantage over conventional OD-based approaches that are only able to identify shipment locations that are close to the start or end point of a trip section.

Constraints for matching shipments with trailer capacity graph

In order to match a shipment with a trailer trip described by a TCG, companies must define the shipment with six attributes:

1. The geographical pick-up location;
2. The geographical drop-off location;
3. The time window of its pick-up;
4. The time window of its drop-off;
5. The load of its goods;
6. Additional attributes that correspond to additional constraints.

Once the TCG and shipments have been defined, collaboration opportunities can be identified by matching shipments and TCG edges based on fundamental constraints and additional constraints.
In this case, since the additional constraints are unknown without knowing the preferences of individual companies, we will only be focusing on matches based on fundamental constraints: spatial and temporal proximity of a shipment to the trip sections as well as trailer capacity.
In total, for each pairing of trailer trip (TCG edge) to shipment, there are five specific fundamental constraints:

1. Temporal constraint: the pick-up/drop-off time window of the shipment must overlap with the estimated time window of the trailer's arrival at the shipment location;

2. If the trailer fulfils a matched shipment, it must still satisfy the original required time windows of its succeeding vertices;

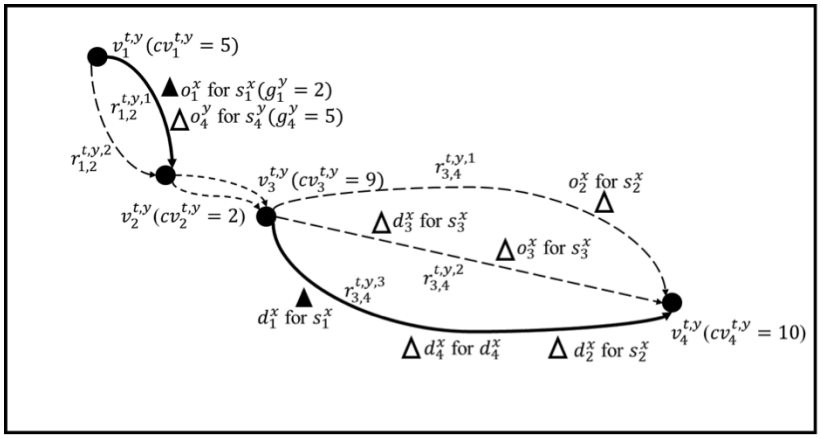
3. Spatial constraint: the diversion distance of the trailer must be smaller than a threshold. The diversion distance is the additional distance that the trailer needs to travel to get to the pick-up and drop-off locations of the shipment;

4. If the pick-up and drop-off locations are close to the same edge, the route

shape matched with the pick-up and drop-off locations needs to be the same, since a trailer can only travel via one route of each edge;

5. In terms of trailer capacity constraint, the available trailer capacity at any given vertex between the pick-up and drop-off edges must not be smaller than the load of the shipment.

Since additional constraints, such as permitted goods type over edges, are essentially either literal values (e.g. food, chemicals, metals, etc.) or numeric values (e.g. product type codes), the evaluation of additional constraints can easily be accounted for by comparing the corresponding attribute values of edges and shipments.



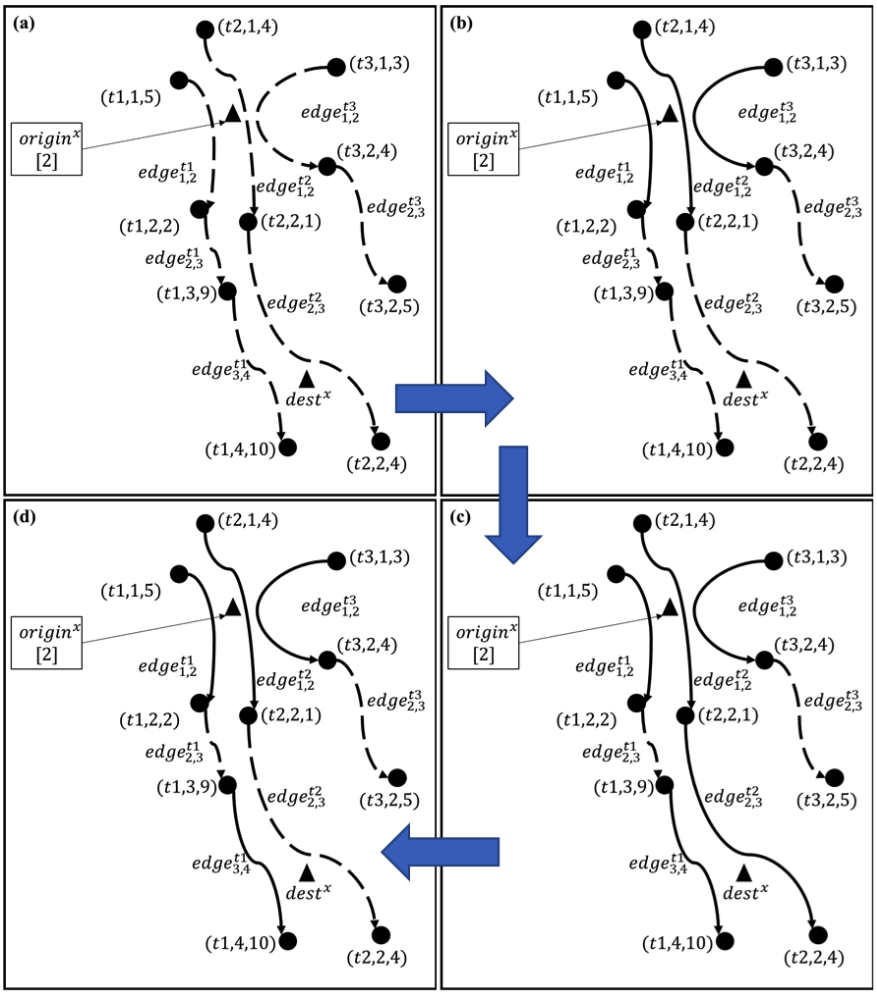
An example of the matching of shipments using the TGC.

The figure above shows an intuitive example of the matching of shipments using the TCG. The dotted lines and the solid lines represent, respectively, unmatched and matched route alternatives for the edges of a trailer trip.
Black and white triangles mark the locations of matched shipments and unmatched shipments.
The trip made by trailer t belonging to company y has four vertices ($v_1^{t,y}$, $v_2^{t,y}$, $v_3^{t,y}$, $v_4^{t,y}$) and three edges ($e_{1,2}^{t,y}$, $e_{2,3}^{t,y}$, $e_{3,4}^{t,y}$), and there are four shipments (s_1^x, s_2^x, s_3^x, s_4^x) belonging to company x.
It is assumed that the temporal constraints are satisfied by all shipments and edges.
In this example, only s_1^x and edges $e_{1,2}^{t,y}$, $e_{3,4}^{t,y}$ form an opportunity, where $e_{1,2}^{t,y}$ is the pick-up edge and $e_{3,4}^{t,y}$ is the drop-off edge.
Shipment s_2^x cannot be matched since its pick-up and drop-off locations are close to different route alternatives of the same edge $e_{3,4}^{t,y}$, and the total diversion distance is too

great.
Shipment s_2^x cannot be matched since its diversion distance is too great.
Shipment s_4^x cannot be matched since its goods load is 5, which is larger than the available capacity at $v_2^{t,y}$ ($k_2^{t,y}$=2) between edges $e_{1,2}^{t,y}$.

Opportunity identification algorithm

The main purpose of the algorithm is to reduce the number of evaluations of the spatial and temporal constraints, which are among the most computationally expensive processes when searching for qualifying pairs of shipment and TCG edges.
Firstly, the destination of a shipment is only matched spatially with TCG edges belonging to trailers that have edges spatially matched with the shipment origin. This reduces the



Example of the opportunity identification algorithm.

number of evaluations of the spatial constraint.
Secondly, since the evaluation of the temporal constraint involves updating the time windows of trip edges to conform to the pick-up edge, this is as the final step in the process in order to minimize the number of time window updates required.
Specifically, this algorithm consists of three main steps, as shown in the figure on the previous page.

In step 1, shipments are broken down according to their shipment origin and shipment destination.
Each origin or destination contains the following attributes:

1. Geographical location;
2. Time window;
3. Load of goods;
4. Additional attributes.

In step 2: for each shipment, the algorithm identifies a set of TCG edges ($edges_1$) that occur on the same day as the shipment's origin and satisfy the spatial constraint. The algorithm then identifies edges ($edges_2$) that occur on the same day as the shipment's destination and belong to the same trailer as $edges_1$, occur after each $edges_1$, and satisfy the spatial constraint. This step yields a set of edge pairs [($edges_1$, $edges_2$)] for each shipment.

In step 3, the set of edge pairs for each shipment is initially filtered based on capacity and additional constraints and then filtered further based on temporal constraints.
This step yields the final edge pairs for each shipment. Each pair contains an edge for picking up the shipment and an edge for dropping it off. Each pair of edges then combines with a shipment to form an opportunity.

The figure on the previous page demonstrates how this algorithm works. Each parenthesis gives the attributes of a TCG vertex. From left to right, the first value is the trailer identifier, the second value is the order of the vertex, and the third value is the available capacity. The edge connecting two vertices m and n of trailer t is identified as $edge_{n,m}^{t}$, and it is represented by its route shape.

$origin^x$ and $dest^x$ are the origin and destination of a shipment x, respectively, where the number in the parentheses is the load of x.
Dashed lines represent edges to be matched or edges that cannot be matched with x while solid lines are edges can be matched with shipment x. Here we also assume that the

temporal constraints have all been satisfied and that additional constraints have not been considered.

The top left-hand window (a) shows the result of step 1. In the top-right hand window (b), step 2 first attempts to spatially match $origin^x$ with edges, and thereby identifies three qualifying edges: $edge_{1,2}{}^{t1}$, $edge_{1,2}{}^{t2}$ and $edge_{1,2}{}^{t3}$.

Then, for each of the three trailers (t1, t2, t3), step 2 attempts to identify edges that occur temporally after its qualifying edge and can be spatially matched with $dest^x$.

This results in two qualifying edges: $edge_{3,4}{}^{t1}$ and $edge_{2,3}{}^{t2}$. Thus, the result of step 2 is a set of two pairs of edges: $[(edge_{1,2}{}^{t1},edge_{3,4}{}^{t1}),(edge_{1,2}{}^{t2},edge_{2,3}{}^{t2})]$.

The lower right-hand window (c) shows that in step 3, the edge pair ($edge_{1,2}{}^{t2}$, $edge_{2,3}{}^{t2}$) is filtered out since the available capacity at vertex (t2,2,1) is less than the load of *x*.

However, the available capacity at each vertex between $edge_{1,2}{}^{t1}$ and $edge_{3,4}{}^{t1}$ is greater than the load of *x*.

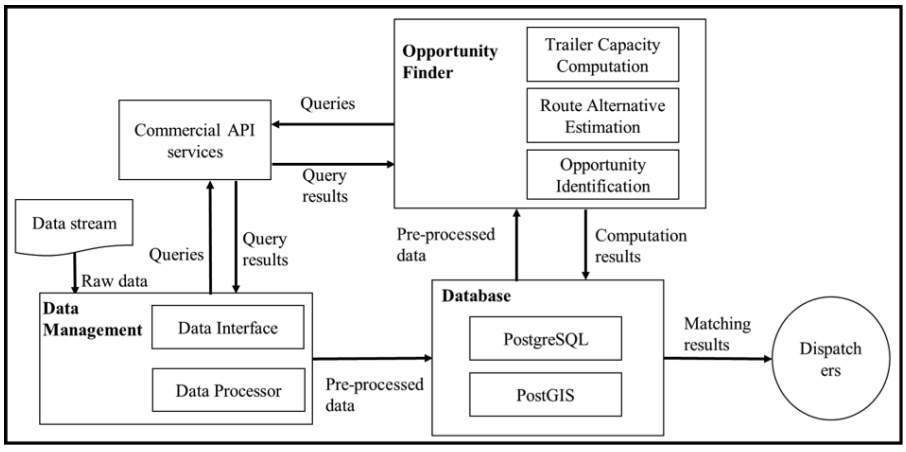
In the bottom left hand-window (d), where the result of the algorithm is shown, only the edge pair ($edge_{1,2}{}^{t1}$, $edge_{3,4}{}^{t1}$) and *x* form an opportunity.

IMPLEMENTATION OF THE OPPORTUNITY IDENTIFICATION ENGINE

In order to identify collaboration opportunities, for each particular time interval (for example every five minutes), the engine creates a real-time TCG based on each company's live trailer trip data and matches the live shipments with of other companies' edges in the TCG.

The matched shipment and trips are then presented to the relevant companies as collaboration opportunities.

A collaboration agreement is achieved when an opportunity is accepted by dispatchers from both companies.



Engine architecture.

INTRODUCTION TO THE OPPORTUNITY IDENTIFICATION ENGINE

The figure above describes the system architecture of this engine. Broadly speaking, the engine has two main modules besides the database: a data management module and an opportunity finder module.

The data management module contains two sub-modules. The ***data interface*** receives live shipment and trailer trip data from different companies, and the ***data processor*** processes the raw data and prepares it for use by the opportunity finder module.

The opportunity finder module comprises three sub-modules.

The *trailer capacity computation* sub-module extracts trailers' en-route capacity from trip plan data; the *route alternative estimation* sub-module obtains geographical information on route alternatives for each edge in the capacity graph; and the *opportunity identification* sub-module matches shipments and trailer trips from different companies using the capacity graph.

In addition, the *database module* stores all of the data, including shipment data, trailer trip plan data and geographical data needed for identifying opportunities.

With the aim of being able to handle collaboration between multiple companies, this engine places an emphasis on algorithm and operation efficiency.

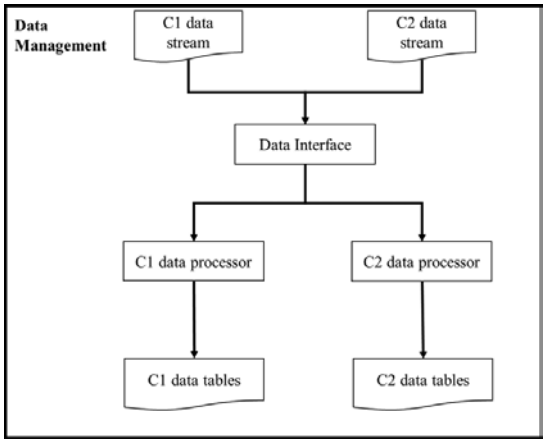
> In terms of development technology, engine modules are developed using Python 3.6.7. PostgreSQL 10 is used as the main database that stores shipment and trailer trip plan data.
>
> PostGIS 2.4.4, an extension of PostgreSQL 10 that is dedicated to geographical data, is used for managing geographical data and conducting geographical computation. In addition, commercial geocoding and routing API services provided by Google Maps (Google, 2018) and HERE (HERE, 2018) are used for imputing missing coordinates of addresses and estimating routes of trailer trips, respectively.

DATA MANAGEMENT MODULE

The data management module processes live shipment and trailer trip data from different companies. It then outputs shipment and trailer trip data in a unified data format that can be efficiently processed by the opportunity finder module.

The data interface sub-module is responsible for obtaining live raw data from different data sources, and the data processor module carries out raw data pre-processing. While

obtaining live raw data is relatively straightforward, diversity of data formats and representation of location data are two major challenges in raw data pre-processing.



Workflow of the data management module.

Data interface

The purpose of the data interface sub-module is to download real-time shipment and trailer trip planning data files uploaded by companies from FTP servers established by Gatehouse and save the data in the engine's database. The first time the engine is run, the data interface will check for the existence of necessary tables in the database and create any missing data tables.

At present, DF and Freja upload their data to two separate FTP servers; nevertheless, the data interface has been developed as a universal sub-module. Accordingly, different instances of this module can process the different companies' data simply by changing the parameters. The figure on the following page shows the pseudo-code of the data interface sub-module.

From one company to the next, the main difference in the data interface is the method used to determine the data file timestamp, which records the last upload of file modification. Based on a field study, Freja's data file timestamp is determined using the timestamp information in the file name, whereas DF's data timestamp is determined using the last file modified time on the FTP server.

The data files are stored physically on the engine's server mainly for testing purposes. Since the data files uploaded by both companies include redundant data fields that are not relevant to the matching algorithm, data in useful fields are extracted first and then stored

in the database to reduce data storage costs and improve database performance. Moreover, the extracted data is only temporarily stored in the memory and is removed once it has been saved in the database.

```
If first run:
    For table in necessary tables:
        If table not exists:
            Create table in database
    Initiate local directory for storing downloaded data files
last update timestamp = None
For each iteration i:
    If last update timestamp == None:
        Read the latest timestamp of the data files stored in the local directory: last update
        timestamp = latest timestamp
    Connect to the FTP server
    If last update timestamp == None:
        Download all the files from the server directory
    Else:
        Download files from the server directory with file timestamp > last update timestamp
    Close the FTP server connection
    For each data file download:
        Extract data in relevant fields into memory
        Copy data into the corresponding table in the database
```

Data interface pseudo-code.

Data Processor

The data processor has two main purposes. Firstly, it *transforms data from different companies into a unified data format*, which can later be efficiently processed by the opportunity finder module. Secondly, to increase the probability of trips and shipments being matched, the data processor *utilizes external commercial map API services to impute the missing coordinates of trailer trips' waypoints and the origin and destination of shipments*.

Since different companies use different information management systems and planning tools, raw data will inevitably come in different data formats. At present, this engine is developed in the context of two collaborating logistics companies in Denmark: Danske Fragtmænd and FREJA.

Danske Fragtmænd's data is broken down into separate tables; trailer trip and shipment

Column name	Data type	Definition
Shipment ID	Character-varying	Unique trailer ID
Goods ID	Character-varying	ID of goods
Package type	Character-varying	Unique waypoint ID
Loading metre	Numeric	Shipment goods load measured by loading metre
Cubic metre	Numeric	Shipment goods load measured by loading metre
Gross weight	Numeric	Shipment goods load measured by kilogram
Length	Numeric	Length of shipment goods
Width	Numeric	Geographical position of the waypoint
Height	Numeric	Trailer company
Action	Integer	Either pick-up or drop-off
Action timestamp	Timestamp without time zone	Expected timestamp of when action happens
Action location geometry	Geometry	Geographical position of the waypoint
Action address	Character-varying	Literal address of the action
Company	Character-varying	Trailer company
Harmful	Character-varying	Harmfulness of the goods

Relation schema for a shipment table.

data are stored as points (a waypoint of a trailer trip and either an origin or a destination of a shipment).

FREJA's data on the other hand is organized in a single table. Each entry describes a shipment and the trailer trip fulfilling the shipment. As such, the trips and shipments are stored as 'lines'.

This significant difference in data format - particularly when it comes to the representation of shipment and trailer trip data - makes it difficult and inefficient to use the raw data directly for identifying opportunities using a TCG.

Column name	Data type	Definition
Trailer ID	Character-varying	Unique trailer ID
Waypoint ID	Character-varying	Unique waypoint ID of the trailer
Position timestamp	Timestamp without time zone	Expected timestamp when trailer is at waypoint
Current capacity loading metre	Numeric	Current remaining capacity measured by loading metre
Current capacity cubic metre	Numeric	Current remaining capacity measured by loading metre
Current capacity weight	Numeric	Current remaining capacity measured by kilogram
Waypoint geometry	Geometry	Geographical position of the waypoint
Company	Character-varying	Trailer company

Relation schema for a trip table.

Since a different variant of the opportunity identification algorithm is required to accommodate each different combination of data formats, assuming there are N (number of) collaborating companies and each of them has a different data format, the number of algorithm variants required will be $N \times (N\text{-}1)$.
This means that as the number of collaborating companies increases, the required number of algorithm variants increases dramatically, making it difficult to develop and implement the algorithm.

Moreover, the large number of different data formats can make it difficult to present identified opportunities to different companies. Accordingly, a unified format for different companies' shipment and trip data is necessary.
With a unified data format, the opportunity identification algorithm only needs to be implemented once. In addition, the unified data format can also be used to present indentified opportunities.

The table on the right shows the unified data formats designed for shipment data and trailer trip data. For shipments, the data covers the shipment information on pick-up and drop-off locations and expected time of a shipment action (pick-up or drop-off) and information on its goods, including goods load information and whether it is harmful.

Shipments				Trailer trips	
Column name	Definition	Column name	Definition	Column name	Definition
Shipment ID	Unique ID of a trailer	Action address	Literal address of the action	Trailer ID	Unique ID of a trailer
Goods ID	ID of the goods	Harmful	Harmfulness of the goods	Waypoint ID	Unique ID of a waypoint of the trailer
Package type	Unique ID of the waypoint of the trailer	Company	Trailer company	Position timestamp	Expected timestamp when trailer is at the waypoint
Loading metre	Shipment goods load measured by loading metre	--	--	Capacity changed loading metre	Capacity change measured by loading metre
Weight	Shipment goods load measured by kilogram	--	--	Capacity changed weight	Capacity change measured by kilograms
Action	Either pick-up or drop-off	--	--	Waypoint geometry	Geographical position of the waypoint
Action timestamp	Expected timestamp when the action happens	--	--	Waypoint address	Literal address of the waypoint
Action location geometry	Geographical position of the waypoint	--	--	Company	Trailer company

Unified shipment data and trailer data format.

For trailer trips, the data covers information on the identity of the trailer, information about waypoints on the trailer's trip, the capacity of the trailer at each waypoint and the company running the trip.

Given that, in practice, different units of measurement are used to measure the goods load and capacity of a trailer, goods load and trailer capacity are recorded separately as two

different measurements, loading metres and weight in kilograms.

The design of this data format incorporates the merits of DF and FREJA'S data schemas. It retains the simplicity of FREJA's data schema, making it straightforward for the opportunity identification algorithm to use.
More importantly, this data format is the same as DF's data schema in that both shipment and trip data are stored as points, which has two main advantages: firstly, storing a shipment as a pick-up point and a drop-off point facilitates the use of TCG for identifying opportunities. Secondly, as shown in the section on trailer capacity computation, storing trip data as points makes it convenient to compute a trailer's en-route capacity.
Based on this unified data format, a separate instance of a data processor has been implemented to transform the raw data from each different company.

Location data representation

For both shipment and trailer trip data, the geometry type column is generated using the provided GPS coordinates of a location. This column is used by the opportunity finder module to compute the spatial distance between a shipment and a trailer trip.

To achieve efficient spatial distance measurement, GPS coordinates that are spherical coordinates - and computationally expensive in PostGIS - are projected on a flat surface using a coordinate reference system, which is much more computationally efficient.

For various reasons, the data provided by both companies contains locations without coordinates. Shipments and trailer trips with missing coordinates cannot be matched, which decreases the engine's effectiveness in identifying opportunities.

> Here, the EPSG:3035 system (MapTiler, 2018) was selected for two main reasons. Firstly, the projection system is applicable for onshore and offshore areas of Europe and has a acceptable projection accuracy (one metre). More importantly, the unit of distance used in this system is metres, while the unit of distance used in most other projection systems has no practical meaning; thus, the EPSG:3035 projection system enables the setting of distance criteria for the engine a more intuitive and straightforward process (for example, the distance threshold can be set at 100 metres rather than one degree). Additionally, a GIST index was created for the geometry column of the shipment table to enable faster computation.

Therefore, after transforming the data format, the missing coordinates are imputed using external geocoding API services that convert literal addresses (for example, a street address) into geographic coordinates (like GPS coordinates).

The geocoding API provided by HERE is selected for geocoding if the number of locations to be geocoded is larger than a pre-specified threshold, for example 100, since HERE provides a batch geocoding function that has the best response speed for large volumes of geocoding requests; for smaller numbers of locations, the geocoding API provided by Google Maps is used for geocoding, since it tends to provide more accurate results.

Furthermore, the engine creates and maintains a coordinate imputation table, which stores all of the previous geocoding results. A unique address ID is created for each imputed location based on its literal address. Missing coordinates for the same address in the later data can be found directly in this table eliminating the need to request geocoding services more than once. This reduces the running costss of this engine since most of the well-known and reliable geocoding API services charge based on the number of API requests. Moreover, this reduces the running time of the engine since reducing the number of external API request means less time spent waiting for a response from API services.

OPPORTUNITY FINDER MODULE

The opportunity finder module implements the TCG definition to identify collaboration opportunities. It consumes the shipment and trailer trip data processed by the data management module and outputs opportunities to collaborating companies.

The *trailer capacity computation* sub-module first computes trailer capacity at each vertex in the TCG based on the trailer trip data. The *route alternative estimation* sub-module then generates estimates of route alternatives and their geographical shapes for each edge in the TCG.

Finally, the *opportunity identification* sub-module matches shipments and trailer trips based on fundamental constraints.

In a similar way to the data management module, trailer capacity computation and route alternative estimation sub-modules also process data for shipment and trip matching using the TCG. However, instead of simply transforming data into the same data format and imputing missing data, these two sub-modules conduct more sophisticated computation, and for this reason areincluded in the opportunity finder module.

Trailer capacity computation

Since DF and FREJA only record which shipments are loaded and unloaded at a waypoint of a trip, the unified trailer trip data only records the change of trailer capacity at each waypoint.

It is worth noting that since the coordinates of addresses cannot always be found due to the poorly-recorded addresses in the data, locations with missing coordinates will eventually occur. These locations of shipments or trailer trips will not be matched; however, the actions happening at the locations are still used for the calculation of trailer capacity. Based on the order of waypoints, the available capacity of a trailer at a waypoint can be computed based on its load change accumulated up to the current waypoint.

Route alternative estimation – Improving engine running efficiency

To estimate route alternatives for each edge in a TCG, external routing API services are used to search for feasible and significantly different route alternatives between the start and end vertices of each edge - based on the geographical location (coordinates) of each vertex.

There is no guarantee that a specific number of route alternatives can be found; sometimes feasible route alternatives significantly overlap each other too much for them to be significantly different route alternatives.

Moreover, since estimating route alternatives and measuring distances between a shipment location and route alternatives are the two most time-consuming processes in this engine, two approaches have been taken in order to reduce the engine running time.

Trailer route approximation

In a similar way to the coordinate imputation table for storing coordinate imputation results, this engine maintains a route shape table for storing route alternative search results received from external APIs.

The route alternatives of each edge are uniquely identified by the coordinates of its start and end vertices and a serial number. This helps reduce the number of external API requests since the route alternatives of an edge with previously searched start and end locations can be directly extracted from the table instead of requesting external APIs.

Moreover, it is reasonable to assume that if the start and end locations of two edges are close to each other, it is likely that the routes of the two edges are largely overlapping.

When measuring the spatial distance between a shipment location and an edge with a route (r), another route that largely overlaps with r is likely to produce a distance with a small error. Accordingly, if the small error is negligible in proportion to the spatial dis-

tance threshold and the length of route r, the largely overlapping route can be directly used to measure the distance between a shipment location and the edge.

Therefore, if a pair of locations whose route alternatives have not previously been searched, are close to existing locations in the route shape table, the route alternatives of these locations can be directly used for the distance measurement for the unsearched pair.

Based on the analysis above, to further reduce the number of routing API requests, this engine approximates route alternatives based on the proximity between the start and end locations of two edges. Before searching for route alternatives for an edge using external APIs, the engine will first search for the closest pair of start and end vertices in the route shape table using the following rule:

1. The distance between the start location and the start vertex of a route is shorter than a threshold (η);
2. The distance between the end location and the end vertex of a route is shorter than a threshold (η);
3. If at least one pair of vertices is found in the route shape table, the pair with the shortest total distance from the start and end vertices to the search is selected.

The routes of the selected pair of vertices in the route shape table are used as the routes for a new edge.

Route shape simplification

A major issue with the obtained route shapes of an edge is that their shapes usually consist of a large number of map coordinate points to describe the curvature of the road in detail. Due to the nature of road curvature, many of the coordinate points are tightly clustered within a small area.

For the purpose of measuring the distance between a shipment location and a route, a large number of coordinate points is not ideal as they can significantly slow down the distance computation time.

More importantly, in proportion to the scale of distance threshold considered, the tightly clustered coordinate points will not significantly improve the accuracy of distance computation.

To improve efficiency when measuring the distance between a shipment location and a route, a clustering algorithm, DBSCAN (Ester et al., 1996), is applied to simplify the shape of a route alternative in the route shape table.
DBSCAN is a density-based clustering algorithm that can group points and their close neighbours. One of the main advantages of DBSCAN is that it is highly scalable and has a relatively low computational cost.
Also, unlike most other clustering algorithms, it does not require the user to pre-specify the number of groups (clusters), something which is difficult to determine because of the diversity of route shapes.
Instead, DBSCAN requires a pre-specified epsilon (ε) that defines the maximum distance between two samples necessary in order for them to be considered as situated in the same locality.

When the value of ε increases, more coordinate points will be clustered into the same group and as a consequence, the route shape will become simpler, but also less accurate.
In addition, DBSCAN requires a parameter (*ms*) that defines the minimum number of points necessary to form a group, which is set at one in this study so that all of the points on a route can be classified into a group.

The general idea here is to first group closely-packed coordinate points and select one point from each group to represent the group. The shape consisting of these representative points is the simplified shape of a route alternative, which will then be used to compute the distance between shipments and routes. For each group, the point that is closest to the centroid of the group is selected as the representative point. This simplification may be understood as zooming out from a route shape.

Since this route shape simplification runs only once for each route alternative, the computational cost of the DBSCAN algorithm can be further offset when a route alternative is used for distance computation multiple times.

Because the simplification of a route shape is carried out independently, parallel computing technology is applied to simplify several route shapes simultaneously, which can dramatically reduce the running time of the simplification of routes.

In addition, less complex route shapes can also speed up the process of storing the route shapes in the route shape table.

Opportunity identification algorithm implementation

The opportunity identification sub-module implements fundamental constraints to match shipments and a TCG: the *temporal constraint*, the *spatial constraint* and the *capacity constraint*.

In terms of the ***temporal constraint***, different variants of constraints can be applied based on the characteristics of the data provided. In this project, since the data provided by both companies do not include trip waypoint and shipment action timestamps with precision better than date, a shipment action and an edge are matched if they occur on the same day. Occasionally, there are trailer edges whose timestamp at the start and end vertices are different. To avoid an infeasible match where the shipment action is conducted on the first day while the edge (trip section) is conducted mainly on the second day, edges with different start and end dates are excluded from matches.

Although the most accurate spatial distance measurement between a shipment action and a trailer route is the diversion distance - the travel distance that a trailer diverts from the route to get to the shipment action and back to the route - the measurement of this diversion distance is costly since it requires using external routing APIs.
Therefore, in this study, the straight-line distance between a shipment location and a route, which can be directly computed within the system, is applied as an approximation of the traveling distance.

The straight-line distance is the minimum travel distance between the shipment location and the route. If the straight-line distance is greater than threshold ε_d, the actual travel distance must be greater than ε_d. Accordingly, satisfying the straight-line distance constraint is a necessary condition if the distance constraint is satisfied.

Using this constraint, a large number of pairs of shipments and trips can be filtered out. Even if the actual diversion distance is required, the diversion distance can be estimated for a relatively small number of shipments and trips that satisfy the straight-line distance constraints, significantly reducing the computational time. Moreover, since different routes have different travel distances, ε_d is defined as a percentage of the travel distance of a route, rather than a fixed distance value.

Finally, since both shipment load and trailer capacity are often measured using two units: loading metre and weight, for computing the trailer capacity constraint, loading metre is further converted into weight:

$$w = \theta \times ld \tag{1}$$

w is the weight in kilograms; ld is the loading metre; and θ is the maximum weight of a loading metre.

VALIDATION OF THE ENGINE'S EFFECTIVENESS

The engine was validated in an experiment using real-world data provided by DF and FREJA from 12 June 2019 to 26 June 2019.

The distance threshold is set at 10 percent of the travel distance of a route. To reduce the complexity of the analysis and running time of the experiment, the iteration interval is set at one day.

It is worth noting that the iteration interval is much shorter (e.g. 10 minutes) when applying this engine in practice.

However, with a small iteration interval, the TCG is still created using all of the data received and the all of the shipments are matched with the entire TCG to identify new and expired opportunities in each iteration.

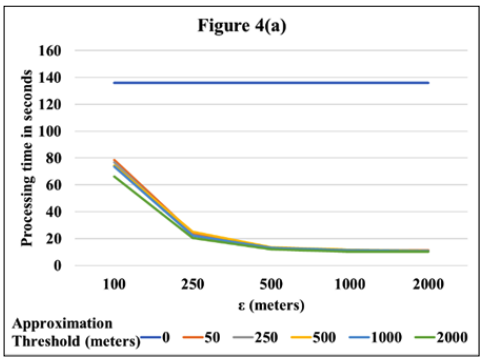
The new data received in each iteration is relatively small; as a result, the running time of each iteration with different intervals is similar.

ANALYSIS OF ENGINE PERFORMANCE

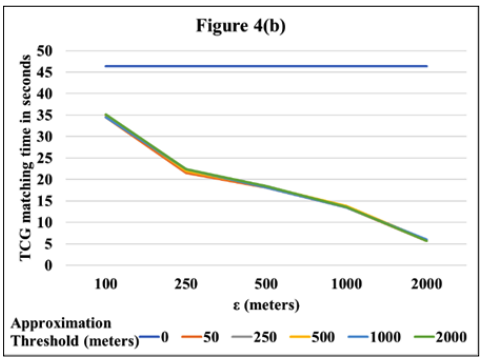
For the purposes of analysis, the performance of the engine under different configurations in terms of route approximation and route shape simplification, the route shape processing and TCG matching time of each iteration, are evaluated under different configurations, together with the opportunity identification sensitivity (True Positive Rate), which measures the proportion of the actual opportunities that have been successfully identified:

$$TPR = \frac{TP}{AP} \tag{2}$$

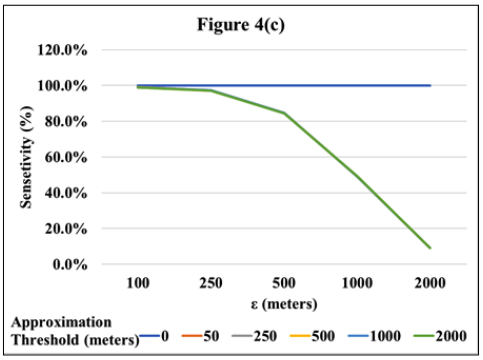
TPR is the sensitivity; TP is the number of identified opportunities that are true opportunities and AP is the number of all true opportunities identified by the engine when neither route approximation nor route shape simplification is applied.



Route processing time.



TCG matching time.



Sensitivity.

The figures above show the route shape processing time, TCG matching time and opportunity sensitivity when the engine consumes the data for 26 June 2019, since all of the data from the previous days can be included and this TCG is the most complete.

Figure 4(a) shows that the route shape processing time decreases dramatically when both route approximation and simplification are applied. More specifically, ε plays a more important role in reducing the processing time than ε_d', as the reduction in processing time is much less significant with the increase of ε_d' than with the increase of ε.
Increasing ε_d' can reduce the processing time, given that when ε remains constant at 100 metres, the processing time when ε_d' is 2000 meters (66 seconds) is 16 percent less than when ε_d' is 50 metres (79 seconds).
Moreover, results from Figure 4(a) indicate that ε_d' must have a higher value than ε to have a significant effect on reducing route processing time.

Figure 4(b) shows the time required for matching shipments and the TCG. An increase

in the value of ε can significantly reduce the matching time. Compared with when DB-SCAN is not applied (ε=0), when ε=2000 meters, the matching time is reduced by 87.0%, from 46 seconds to 6 seconds.

Moreover, ε still has a more significant impact on the matching time than ε_d', as when ε remains constant, a change in the value of ε_d' has almost no effect on the matching time. This is because the matching time depends on the number of points on each route shape and the total number of route shapes to be matched, which ε_d' has no impact on.

Figure 4(c) demonstrates the opportunity sensitivity when we change the values of ε_d' and ε. As with the TCG matching time, ε_d' has a negligible impact on the sensitivity, as the lines in Figure 6(c) almost overlap each other.
However, with the increase of ε, the sensitivity dramatically decreases.
When ε=100 meters, 99 percent of the actual opportunities can be identified by the engine, while when ε=2000 meters, the engine can only identify 9.2 percent of actual opportunities.

The results in Figure 6 indicate that the setting of ε_d' and ε is actually a trade-off between running time and the quality of identified opportunities. ε in particular has a bigger impact on the running time and opportunity quality than ε_d'.

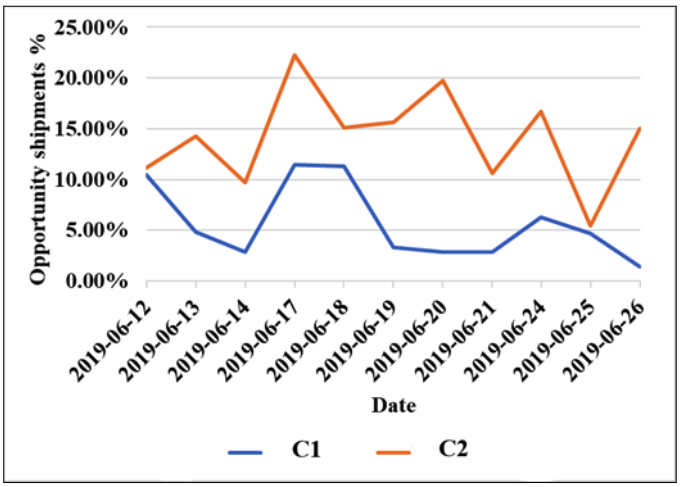
With an increase in the value of ε, the engine running time in terms of processing the route shapes and TCG matching can be dramatically reduced, while the opportunity quality is significantly sacrificed.

At the same time, ε_d' mainly influences the route shape processing time. Moreover, the running time and quality are more sensitive to changes to the value of ε than ε_d'. For this reason, it is recommended that ε_d' be set at a relatively high value, while ε should be set at a relatively low value in order to effectively identify enough actual opportunities.

ANALYSIS OF IDENTIFIED OPPORTUNITIES

This section provides a brief analysis to help understand what proportion of shipments and trailers can be identified as opportunities.

The opportunities identified when neither route approximation nor route simplification is applied are used.



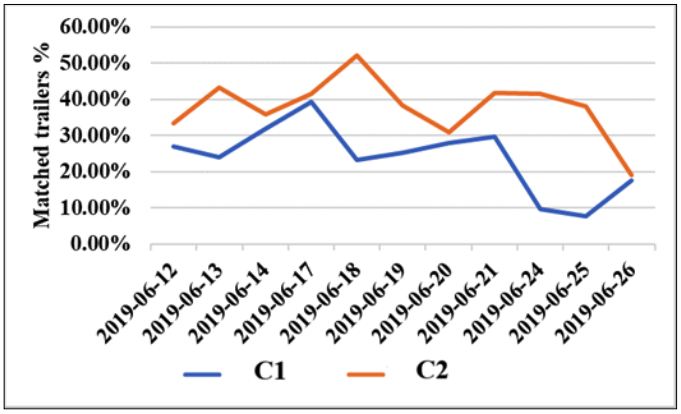
Percentage of opportunity shipments against all shipments each day.

The above figure shows the percentage of shipments that are identified as opportunities as a proportion of all shipments that are picked up each day, excluding weekends.

During the eleven days of the experiment, shipments belonging to C2 had a better chance of being identified as opportunities than those belonging to C1.

This is mainly due to two factors. Firstly, the load of C1's shipments is on average a bit larger than that of C2 during the period. Hence, C1's shipments may be more difficult to fulfil by C2's available capacity.

Secondly, on average, C1 has a lower load factor of trailers on a day than C2. Therefore, C1's trailers may form a TCG with a much larger coverage, which can provide C2's shipments with more capacity.



Percentage of matched trailers against all trailers each day.

Secondly, on average, C1 has around 2.3 times more trailers that have never been fully loaded on a day than C2. Therefore, C1's trailers may form a TCG with a much larger coverage, which can provide C2's shipments with more capacity.

On the other hand, the figure below demonstrates the percentage of trailers identified as opportunities against all trailers. As was likewise the case with the shipments, C2's trailers are easier than C1's to match with the other company's shipments, given that on most days, C2 has a significantly higher percentage of matched trailers than C1.

Despite the fact that C1's shipments have a larger average load than C2's, the average number of shipments carried out by C1 is around 5 times larger than that of C2. This indicates that edges in the TCG formed by C2's trailers may have a higher chance of matching.

In addition, C2 had on average around 10 percent more trailers not fully loaded over the eleven days than C1. With a larger proportion of trailers with available capacity, the chances of C2's trailers being matched increased.
To summarize, there is a higher chance of C2's shipments and trailers being matched compared with C1's. Moreover, the larger number of C1's shipments and trailers has a positive impact on their chances of being matched.
Please note that these exact numbers should be interpreted with caution, as they vary over time and may to some extent reflect the quality of the data.

During the 11-day experiment, C1 had a much larger business volume than C2. C1 also had a larger number of trailers not operating at full capacity. In other words, over this period C1 was a larger operator than C2.

Viewed from this perspective, our results suggest that this two-partner-collaboration entails an imbalance favouring the smaller operator, which enjoys a greater increase in its business volume than the larger operator.
An appropriate cost and benefit sharing framework that accounts for this imbalance would need to be put in place. However, this unfavourable imbalance for the larger operator is likely to reduce as the number of operators joining the collaboration increases.

PILOT TESTING THE DiRECTLY-DSS

Pilot testing promotes early detection of flaws in the DSS before the usability test that follows. In the case of the DiRECTLY DSS, the email system is the front end of the DSS

and is the only component with which the dispatchers interact.

The research team conducted the pilot test to ensure that the email system provides an effective and appropriate user interface while satisfying end user requirements for sufficiency and privacy of information, and ease of use.

The pilot test was scheduled to last one month from 13 November 2019 to 13 December 2019.
During this period, dispatchers received matches from the DSS via email and were asked to review and respond to these emails, typically while one of the research team observed them to identify where they encountered problems or became confused.

The test wfocused on the following aspects in particular:

1. How easy it was for dispatchers to review matching emails without confusion.
2. Whether the emails provide enough information for dispatchers to take a decision on the matches.
3. The ability of dispatchers to review all of the matching emails they receive continually over the course of the day.

Chapter 4 Findings: finding gaps and building bridges

The DiRECTLY project faced many challenges trying to develop a system to reduce empty running. It came as no surprise that there were several challenges related to the innovation project, which was why we chose to involve many partners with different competencies. However, the complexity of developing the DiRECTLY DSS also revealed new problems that needed to be solved.

We quickly learned that there were no easy technological, managerial or organizational solutions to the problem. The problem of empty running is intertwined with many other logistics planning problems. Therefore, it could not be solved merely by gaining access to the right data, developing the most suitable algorithm, applying the most innovative business model, or organizing in a specific way. We needed a wide range of skills and competencies, which could only be obtained through collaboration. Despite the fierce competition in the logistics industry, the only path towards more sustainable freight transport is through collaborative logistics.

The various partners proved to have the right competencies to address specific aspects of the problems, but they still needed us to create a collaborative solution that catered for the full spectrum of challenges. However, there are still a few systemic challenges that remain to be adressed, such as data quality and legal issues.

Empty running is in many ways also a symptom of technological progress in the logistics industry. This has reduced the costs and increased the flexibility of logistics planning, which have led to shortened planning horizons, making it more difficult to avoid empty running. In this chapter, we are going to discuss the results of the project as well as important challenges and proposals for solving them.

We identified three major challenges to developing a functioning collaborative system. Firstly, the existing knowledge on collaborative logistics focuses on methods of fair sharing of profits and costs or on the most optimal use of capacity by the collaborating companies. While the literature did provide us with some pointers, it fundamentally ignores the competitive reality of the industry and - more importantly - European competition law.

Competition law presents obstacles to collaborative logistics, but we managed to devise a set-up that steers clear of anti-collusion laws. However, collaborative innovation projects require interaction and an exchange of knowledge, something which was rendered quite difficult and cumbersome by this set-up.

Secondly, we faced the problem of implementing the system in the haulage companies themselves. There is no point in developing a technical solution to the empty running problem that clashes with how the management wants to develop and manage their company or a system that clashes with the dispatchers' work routines.
Accordingly, it is necessary to get the management and dispatchers involved in the development of the DiRECTLY DSS system and to get the different levels of management to support its development and implementation. The dispatchers were also able to provide us with valuable information on the routines and complexities of their work tasks and the planning process. It was important to us for DiRECTLY to be an intuitive tool that would assist dispatchers in their work and not just a system that would be used' *time permitting*'.

Thirdly, the functionality of DiRECTLY DSS proved to be a major challenge. Which is to say: what types of data will be shared between the two companies? Which data can be used? How do we identify options and present them to the dispatchers while ensuring competition, avoiding unintended knowledge spill-overs and complying with legal barriers?

As illustrated in Chapter 3, we actually developed a functioning DiRECTLY DSS that is able to handle the existing insufficient data as well as routing problems. The system identifies and presents options in real time and the algorithm is scalable, making it possible to add additional logistics companies. This offers good prospects for the future of the DiRECTLY system. Additional companies present further opportunities for reducing empty running.
However, the challenge of the insufficient quality of the data supplied by the logistics companies participating in the project has been a problem that makes it difficult to estimate precisely how much empty running can be reduced.

As shown in Chapter 3, we were able to address many of the problems presented by missing data, but if the hauliers do not provide information on size/weight, data and time of pick-up or drop-off, the system may potentially provide 'bad' or expired opportunities. This increases the transaction costs and reduces speed and usability. Furthermore, as we

shall return to later in this chapter, it is difficult to estimate the economic benefits of the system.

The issue of data quality is well known in the industry and both our participating logistics companies are working on improving their data. Based on those elements of the goods and tour data that had sufficient data quality the algorithms worked and provided opportunities that the dispatchers found interesting.

However, despite data quality problems, the DiRECTLY DSS identified a surprisingly large number of opportunities for sharing goods and capacity. The project also revealed new applications for the system. The DiRECTLY DSS is able to identify options for reducing empty running between different companies, which was the goal of the DiRECTLY innovation project. In addition, the system can also identify options for reducing empty running within the same company.

Dispatchers typically work in groups based on specific types of cargo, customers or geographical areas. This reduces the complexity of the planning process, but it also presents a risk of empty running since the dispatchers only have a partial overview of potential orders, capacity and routes.

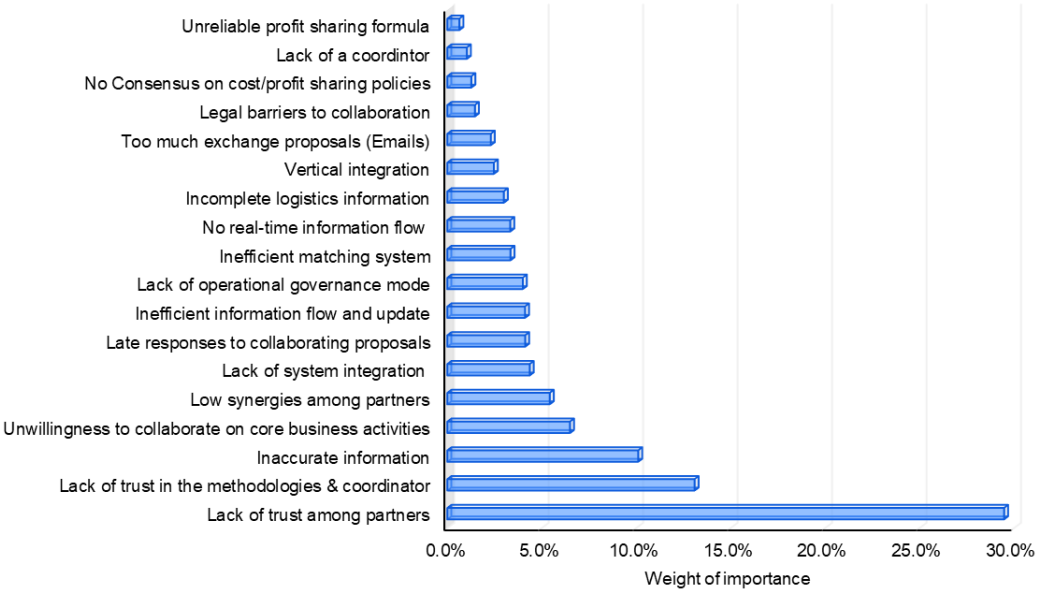
This is often mitigated through time-consuming interaction and knowledge-sharing between groups. An internal use of the DiRECTLY system could potentially facilitate this process and provide dispatchers with options automatically. Any internal application of the DiRECTLY DSS would require further investigation.

RANKING THE COLLABORATION BARRIERS

Having demonstrated the feasibility of the concept, the idea is to scale up the DiRECTLY project by inviting more logistics companies to join. To do this efficiently, it is necessary to formulate possible mitigation strategies to overcome barriers to the implementation of collaborative freight transport.

Before setting out, we had already identified and explained the different barriers affecting the collaborative process. However, since it is impossible to overcome all identified barriers due to limited resources, ranking them is extremely important: we have to pinpoint the most important barriers to prioritize when suggesting possible mitigation solutions. For this evaluation, we conducted empirical research to prioritize the individual barriers from an industrial point of view.

A survey questionnaire was developed which took the form of comparison matrices between different barriers. The results were analysed using the analytical hierarchy process method. This process helps us determine the priority of the identified barriers based on inputs from experts in this project. The results are summarized in the figure below.



The importance weight of identified barriers

The results indicate that the most important barrier to collaboration is 'lack of trust between partners'. Although the two companies currently participating in the project may only have limited trust issues, trust issues will become more common when the system is expanded and includes companies that have never worked together before.

The second most important barrier is a 'lack of trust in the methodologies and coordinators'. There are several reasons for this. Companies might be concerned about information privacy if it is shared in external systems. Additionally, they may not have faith in the fairness of the profit-sharing policies.

The 'inaccurate information' barrier was ranked in third place. When shared information has a low level of accuracy, this can potentially lead to completely invalid decisions and misleading estimations of profits and costs.

Some of the lower-ranking barriers have a relatively high impact on the collaboration, such as the 'unwillingness to collaborate on core business functions' barrier and the 'low synergies among partners' barrier.

As a general conclusion, it is essential to be aware of barriers related to human factors and information sharing. The starting point when it comes to overcoming these barriers is to identify their root cause. Trust issues are mainly rooted in opportunistic behavior, lack of commitment and the risk of information disclosure.

While the literature on organizational and human relations proposes a range of trust-building and trust-developing models, very little attention has been paid to how these models can be facilitated through ICT-based solutions. In other words, further work is required to develop a CDSS whose design characteristics and functionalities provide greater information transparency, resolve conflicting objectives, and facilitate communication and negotiations between partners.

There is a clear need for strategies for how to persuade companies to use the CDSS so that they can explore the benefits it will bring to their day-to-day business operations.

BUSINESS MODELS, COSTS AND MEASURING THE EFFECT

In Chapter 2, we highlighted some of the challenges arising from the business model and in particular how to facilitate the exchange of goods. As shown in Chapter 3, the DiRECTLY system generates a relatively high number of matches within a relatively short window of opportunity for exchange. Trading goods create the problem of frequent pricing and cost calculations in order for the dispatcher to make the decision to buy or sell. Additionally, there is the related problem of how to measure the economic impact of the DiRECTLY system.

The purpose of this section is to illustrate the findings of the project in terms of what possibilities they provide to help dispatchers select from among a set of matches by calculating costs as well as addressing how to measure the effect of the DiRECTLY system. Here we will discuss the difficulties and complexity involved in doing this and the need for better data and - ultimately - better algorithms. We will also propose possible solutions.

COSTS AND SELECTING BETWEEN OPPORTUNITIES

The planning horizon for domestic logistics in Denmark is very short. Typically, the logistics companies receive orders that have to be executed within 24 hours. The automated

DiRECTLYsystem aims to reduce empty running by identifying opportunities for transport of unassigned goods from one logistics service company by assigning them to already-planned trips with excess capacity at another. When the system identifies a match it emails the dispatchers who then have to approve it and settle on a price. The short planning horizon only leaves a relatively short span of time in which to agree on the terms. Thus, we worked on developing a solution that could assist the dispatchers in calculating the prices and costs. However, these calculations proved to be anything but trivial.

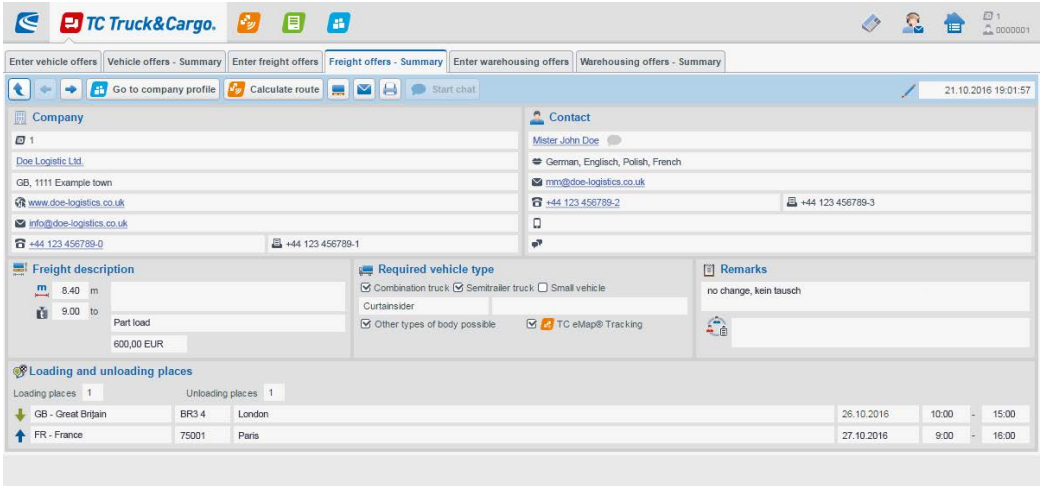
In order to improve the functionality of the DIRECTLY system it was necessary to make better use of the information about the opportunities available to the dispatchers. In order to do this, some additional steps were required.
Firstly, it was necessary to provide an overview of how estimated costs could be calculated and handled by the system.
Secondly, since opportunities for estimating costs depend on the data input provided by the participating companies, it was necessary to analyze the existing system and how it integrates with the dispatchers' way of working. It was also necessary to keep in mind that the system needs to be able to work with more than two companies.

The main role of a dispatcher is to provide services to the customer in terms of picking up and delivering goods in accordance with the requirements of the order (e.g. in terms of time and place). According to the participating companies, more than 90 percent of the daily orders they receive are from existing customers on a fixed contract. The customers input data into the logistics company's IT system more or less automatically and the dispatcher is often not involved in this process.
The contract is typically negotiated between the customer and the logistics company's sales department and runs for a couple of years. The dispatchers do not necessarily know the terms of the contract nor the prices for individual transports in the day-to-day operations. The orders arrive in a steady flow over the course of the day and often have to be executed within 24 hours. Consequently, the dispatchers' main task is to fill trailers, calculate routes, and deliver services to their customers. There is a high level of time pressure and only limited time to search for additional goods to fill the trailers.

The dispatchers are typically involved in purchasing and selling off goods, but this is not their main activity. The dispatchers are contacted by potential customers by email or telephone with opportunities for "buying" transport goods (deliveries) or capacity continuously through the course of the day. The same applies to the sale of goods.
The decision to buy or sell depends on many factors, such as price, available capacity,

capacity constraints, technical factors (e.g. equipment requirements) and geographical matches with existing orders. The commonly-used web solution for selling and buying goods among logistics companies, timocom.com, is also used to buy and sell goods from and to customers.

TIMOCOM is not something dispatchers use particularly often, as the revenues are often unattractive and because it increases the risk of lower delivery quality. Trading is an ongoing process which evolves over the course of the day, and prices and opportunities vary from hour to hour. Prices are negotiated by the dispatchers on an ad hoc basis and vary depending on e.g. the expected cost of transport, estimated profit margins, and price perception on the market.



Screendump from timocom.com

The timocom.com webpage typically provides information on amount and weight of goods to be sold or offered, capacity, type of cargo (e.g. pallets), pick-up and delivery locations (postal codes and city names), distance, number of pick-up and delivery locations, pick-up and delivery time windows, contact information for the company (name, email, telephone number, company web page), contact information for the dispatcher (name, email, telephone number, company web page), equipment requirements, price (sometimes), together with other information. In an email-based system, emails offering capacity or goods typically provide similar information with some variation.

The main difference between the automated DiRECTLY system and ad hoc email-based or online systems, is that the DiRECTLY system contacts dispatchers with potential

matches that – ideally - should be relevant. The automated system is also faster and offers dispatchers who have excess capacity the possibility tof carrying additional goods on an already-planned trip without spending excessive amounts of time searching for relevant offers.
The dispatcher with available goods is thereby offered an opportunity to sell off the said goods at an early and/or convenient stage of the planning process. Due to variation in routes and deliveries from one day to the next, as well as the limited number of matches, it would be very hard for dispatchers to infer any new information about competitors' capacity utilization or prices.

The logistics industry is characterized by a high degree of competition that pushes prices down whenever companies are able to lower their costs. As such, cost-based pricing dominates the industry. Accordingly, pricing decisions and cost calculations are closely connected. Pricing and costs typically depend on a range of factors, such as from/to postal codes, distance, fuel surcharge, quantity and size, equipment requirements (trailer costs), delivery requirements (driver and truck costs), frequency, competition, fit with existing transports (return load and load percentages), capacity, and flexibility. Cost calculation is a rather complex task that involves a lot of information.

The DiRECTLY system, by virtue of its ability to identify matches between planned trips and orders, renders cost calculation less complicated. Since the trip has already been planned, the costs of adding extra pallets (insertion costs) depends on surplus variable costs, such as fuel, driver and truck costs stemming from additional distance and pick-up/delivery. Most other costs are sunk costs that do not affect the cost calculation, as they have already been incurred. Thus it becomes more attractive for the trip owner to add additional pallets, since doing so will reduce the average cost and increase the profit.

For the seller of the matched order, the cost calculation is not quite as simple. The dispatcher needs to assess the opportunity in terms of the costs of executing the order, its fit with existing orders as well as the aforementioned variable operating costs.
This is reflected in the pricing decision, which also depends on a range of other factors, such as perceived price on the market, type of customer, likelihood of return goods, from/to postal codes, time of day, flexibility, quantity and equipment requirements. Furthermore, the costs and prices will also depend on the frequency of exchanges.

In order to estimate costs and opportunity costs, the respective companies will need to supply a large amount of information - as well as accurate data on orders and routes. The

quality of the data proved to be a challenge throughout the project, but it was nonetheless possible to identify matches. However, the DiRECTLY system does not collect any economic information from the two companies, and the quality of the order and trip data used was not good enough to make viable cost estimates.

We therefore took the decision to use an ad hoc negotiated price during the test phase. This was a viable solution, but it also has the knock-on effect of increasing transaction costs – especially for the dispatchers. However, a future DiRECTLY system would involve the participation of a large number of logistics companies which in turn would increase the transaction costs. Accordingly, it is *necessary for participating companies to set up an interface between the information provided by the DiRECTLY system and their own financial systems in terms of cost calculations*.

MEASURING THE POTENTIAL ECONOMIC IMPACTS OF THE SYSTEM

The future of the system depends on its ability to generate positive effects for the participants. Accordingly, it was necessary to analyse how the economic effects can be measured.

This is a highly complex task given that we could only document the opportunities presented by the system and the actual accepted opportunities. We were unable to document the decisions leading up to this. As such, it was difficult to measure a 'true' economic effect. Another challenge is that the economic impact will vary depending on the input of data from the participating companies. In Eriksen and Østergaard (2021), we note that there are three different ways to measure economic effects:

1. comparing average earnings or average costs based on all dispatchers at different points in time depending on their use of the system;

2. applying nonrandom assignment of the use of the DiRECTLY system and comparing different groups of dispatchers;

3. designing a random treatment assignment to be used by the DiRECTLYsystem. However, since the DiRECTLY system does not include any concrete financial information it was impossible to estimate causal effects of the implementation of the DiRECTLY on relevant and well-defined economic variables.

Chapter 5 Into the future: changing the industry

In February 2021 Aalborg University had been in Corona lockdown since autumn the previous year. On the morning of the 2nd of February Professor Christian Richter Østergaard and Associate Professor Kristian Hegner Reinau met for yet another online meeting. Having spent a few months working from home during lockdown, both were missing the coffee machine chats at the university. After coming to terms with this, their focus turned to the objective of the meeting – preparing the final series of interviews for the DiRECTLY project.

On the horizon two milestones were fast approaching. On April 20th a concluding conference would be held to disseminate the results of the project. By the end of June, the project had to be finalized.

It was time to look back at the previous four years of work and pose the question: How do we present the results in a user-friendly format? Over the years, a considerable number of scientific publications had sprung from the project, but there was a need for a broader, more accessible story.

How were they going to condense the work of several people over four years into a story of what had been achieved in the project? The idea emerged to conduct a series of interviews with the overall objective of shedding light on the actual implications of the research. The DiRECTLY system had been tested in practice the previous year. It worked, and yes - there were issues with data quality in both companies. A few other improvements to the software engine were underway, but work was moving slowly as COVID19 restrictions limited the project's access to the companies. Much of the planned work that involved interaction had been postponed indefinitely.

In other words: the system is a success, but several barriers still remain. Being in lockdown, the obvious question was: did COVID19 have an impact on the usability of the system? In many organizations, the lockdown and restrictions had promoted the use of IT in their daily work. Maybe a positive side effect of COVID19 was an increased digitalization of the work methods of the dispatchers and in the industry in general, which would

facilitate the use of the DiRECTLY system?

The idea was to interview the top management and dispatcher managers at both companies to understand the broader development of the companies. During the four years of the project, both companies have changed, not only in relation to company structure and size (with several acquisitions and a merger in FREJA's case), but also culturally. Collaborating closely with the companies had given the researchers a clear understanding of the cultural change the two companies were going through. The application of new technology appeared to have become central to the employees' self-understanding. The companies understood the innovation challenge the logistics industry is facing as well as the need to collaborate to solve the complex challenge of empty running.

The researchers started to compile a list of themes to discuss with the companies in order to understand the journey of the companies had undertaken over the previous four years, and how a collaborative system like DiRECTLY can be used as they continue moving forward.

The first theme was the wider development in the industry and at the companies: How had the companies changed over time and where were they going in light of COVID19? How had the dispatchers and their work developed, and how does the future look to them?
How do they feel – in broader terms - about a collaborative logistics systems? And last but not least, did they expect to use the DiRECTLY system?

During the early spring, the researchers conducted a series of interviews with managers at the two companies. The interviews revealed that the companies felt a pressure to increase their use of technology and digitalization. Several technology-based companies are trying to enter the logistics industry, which could lead to a disruption of the whole industry, but so far, the main challenges by entrants are not in the business-to-business (B2B) market, but in the business-to-consumer parcel market. The barriers to entering the direct-transport B2B market are seen as being quite high due to its less-fragmented market, short delivery deadlines and challenges in handling pallets compared to parcels.

It is necessary for the logistics companies to be able to integrate new technology, such as new systems, robots, artificial intelligence, machine learning and automation. However, this places huge demands on the logistics companies themselves, suppliers, dispatchers, and customers. As we have seen in the project, the increased use of IT systems for op-

timization, such as the DiRECTLY system, requires good data quality. Improving the data quality is a systemic challenge that involves a longer journey of development for the logistics companies and their customers alike. Both parties need to be more aware of data quality and adapt their work processes. Good data quality starts at the source: Customers have to provide proper information to enable proper logistics, but the value of good quality data is often invisible to the customer. Thus, the systems need to be able to handle different types of customers with different levels of transport-related IT readiness.

Improving the data quality requires interaction, learning and feedback. As demonstrated in the project, missing data on pick-up times or incomplete address information might seem unimportant for the specific order and customer, but creates problems later on for the logistics companies' advanced systems. Extra cargo handling is expensive and time consuming.
For transports within Denmark, time is a critical factor. The short time span from receiving the transport order to its execution leaves little room for delay. Furthermore, avoiding delays or finding alternative solutions to deliver goods under narrow time constraints often results in disproportionately high costs.

The advanced logistics systems can assist dispatchers by providing suggestions for automatic dispatching and route planning, but the use of such systems places demands on the dispatchers' skills and competencies. The IT-based systems can assist the dispatchers in doing routine work and free up time for solving more complex tasks and helping customers. However, adaption of IT-based tools often requires a different planning approach from the dispatchers - as well as IT-related skills. At this point there seems to be a notable difference between younger dispatchers and dispatchers that are more experienced. Younger dispatchers have a different skill set and typically compensate for their lack of experience and overview of complex tasks by using the IT-based solutions more actively.

Our many days spent with dispatchers at the logistics companies revealed that the dispatchers do their planning and dispatching in several different ways. Previous experiences and tacit knowledge about customers and transportation leads to different ways of solving problems, but sometimes also to less-than-optimal use of IT-based systems and solutions.

This is particularly visible in times of narrow deadlines when the pace is high. In such situations, the reliance on old methods and work practices seems to dominate. While this seems to solve the short-term challenges, ad-hoc planning often creates a need for support and management in other parts of the logistics company. These practices also

hinder the implementation and use of new technology and create a hidden potential for improvement. There is definitely a need for improved knowledge sharing and better communication between the dispatchers internally at the companies as well as between the inexperienced and experienced dispatchers.

The DiRECTLY DSS could assist the dispatchers not only in identifying opportunities between companies, but also within each company. Ideally, there should not be any possibilities for reducing empty running within the companies themselves, but the complexity of transport planning nonetheless creates missed opportunities. The group-based organization of dispatchers makes it difficult to get an overview of the possibilities for reducing LTL internally at the companies. DiRECTLY DSS could facilitate internal sharing of information, cargo and capacity. An internal system also helps solve two of the challenges in the DiRECTLY system: the legal problem and cross-company data differences.
As mentioned in previous chapters, collaboration between firms is difficult due to anti-collusion laws. We found a manageable way to solve this in the project, but it is difficult - particularly if the system is going to be used frequently and widely among logistics companies. A full implementation of a DiRECTLY system in Denmark would therefore require a broader discussion of the legal framework for collaborative logistics with the competition authorities.

A major challenge for logistics companies is reducing their environmental footprint. Customers seem unwilling to pay extra fees for using biodiesel, and electric trucks are not yet a viable option. Customers also prefer fast delivery and short planning horizons, which adds to empty running. One of the great potentials of the DiRECTLY system is its environmental benefits. It promises an effective way of reducing empty running by identifying opportunities between companies. If the transport were made greener, this would add value for the customers. However, there are still some challenges in relation to data quality that need to be solved.

The COVID19 situation has disrupted the market. Suddenly, the ability to deliver has become more important than keeping to deadlines and low operating costs. It has highlighted the importance of IT-based systems, but also led to delays in implementing new technologies. The COVID19-crisis has demonstrated that easy and informal communication between dispatchers is still important. The long-term effects remain to be seen, but it is likely that customers will return to traditional demands and requirements, while the logistics companies will push for increased digitalization.

THE INNOVATION CHALLENGE

The logistics companies face several challenges: reducing their environmental impact, adapting to new technologies, and addressing customer demands for lower costs and higher flexibility. In order to meet these demands, they need to innovate.
However, innovation is not a straightforward process of simply coming up with a good idea and turning it into an innovation. Innovation is a complicated non-linear process that requires interaction between different actors within and between organizations. The challenge for companies trying to introduce green innovations (i.e. with environmental benefits for themselves, their users or both) is often considered harder than traditional innovation, as it requires the companies to also focus on the environmental impact (Hall and Vredenburg, 2003).

Uncertainty and complexity are important characteristics of innovation processes. Uncertainty depends on the rate of change in technology and in the market. It can be reduced by internal investments in innovation.

Complexity depends on interdependencies between technologies and organizations, which can only be reduced by collaboration in networks. The DiRECTLY innovation project is characterized by both high uncertainty and high complexity. In order to overcome the uncertainty and complexity and succeed in the innovation challenge, the DiRECTLY project brought together a range of partners: two competing logistics service providers, suppliers, consultants, and universities.
This novel combination of actors is very unusual for innovation projects in the logistics industry, but, as the project demonstrates, it was necessary to collaborate on innovation in a network of actors.

The project only involved two logistics companies, which made it difficult to verify whether the findings solely applied to the participating companies or were a general feature of the logistics industry. Therefore, the project applied survey data from Statistics Denmark to analyze the general innovation patterns in the Danish logistics industry.
The Danish Research and Innovation Survey is an annual questionnaire on companies' innovation activities. Innovation is defined as the implementation of a new or significantly-improved product (goods or services) or process (methods of production, logistics, distribution or support activities), a new marketing method (product design, packaging, placement or pricing) or a new organizational method (business practices, workplace organization or external relations).

A company is considered innovative if it has introduced any of the above during the last three years. In the analysis, we combined information from the surveys from 2010, 2013, and 2016, resulting in 13,349 observations (see Østergaard and Rakas, 2021, for more information).

There are many myths regarding 'how to innovate' in the freight logistics industry. It is important to address these myths, as they can act as real barriers to innovation by deterring companies from trying to innovate or clouding the actions and strategies followed by successful innovators. The typical myths encountered during the course of the DiRECTLY project were: logistics firms are not innovative; our customers are very conservative and do not want any change except lower prices; the low profit margins and fast-paced work environmentmake innovation impossible; the high level of competition makes collaboration on innovation impossible. Therefore, we decided to investigate these myths further.

The innovation data show that logistics service providers are less innovative compared to most other industries. This especially applies to larger companies with over 250 employees and smaller ones with fewer than 50 employees. Both groups are considerably less innovative than other industries.

Looking at what might explain such a low level of innovativeness, we find a low level of collaboration on innovation in the logistics service industry. Only 23 percent of the innovative firms collaborate on innovation, which is lower than most other sectors. In addition, only 7 percent collaborate with their customers, 6 percent with their competitors, and less than 1 percent with universities or other higher educational institutions.
By comparison, 21 percent of the innovative firms collaborate with suppliers. This pattern is also reflected in the firms' innovation expenditures, where 40 percent of the innovative firms have spending on new machinery, equipment and software, while only 7 percent have research and development (R&D) expenditures. To a large extent, the logistics firms rely on acquiring technology and equipment from suppliers for innovation.

Applying more sophisticated econometric models, Østergaard and Rakas (2021) show that characteristics of innovative firms in the logistics service industry are quite similar to those of companies in other industries in general and other service industries in particular. Logistics firms that invest in R&D, have innovation expenditures, and collaborate with external partners are more likely to introduce innovations.

There is no evidence in the Danish innovation data to support the myth that customers do not want change nor that innovation is more difficult in the logistics industry, or that competition hinders collaboration. However, there is evidence of a lack of systematic collaboration with customers on innovation as well as a lack of investment in innovation. There is an awareness of the need for innovation in the logistics industry, but companies seem more focused on buying new equipment from suppliers than working systematically on innovation, for example by collecting ideas from employees and customers.

There are plenty of opportunities for collaboration with customers, since logistics firms are close to their customers and frequently interact with them. However, it seems that interaction in relation to innovation is downplayed when there are trailers that need to be loaded, trips need to be planned and goods need to be delivered.

This suggests that there is a need for a more strategic approach to innovation in the logistics industry. Companies need to invest in R&D and innovation as well as collaborate more openly on innovation. These actions cannot be done in isolation, since a strategic approach to innovation would necessitate that dedicated human resources be allocated to innovation. Employees with a specific role as innovation managers could work systematically on collecting internal ideas and helping turn the best ideas into innovations. In addition, this could lead to a better use of customers as a source of innovation. Customers do not always know what they want to change. Therefore, it might be necessary to work with different tools known from service innovation, such as customer journey mapping or service blueprinting to tease out ideas for new services.

Investments in human capital also increases companies' absorptive capacity, which is defined as the ability to identify, access and apply external knowledge. An increased absorptive capacity would also make collaboration with external partners easier since collaboration on innovation requires available resources for innovation.

Collaboration on innovation is not easy, especially if it involves many different partners, but the DiRECTLY project has demonstrated that it is at least possible. However, it should be noted that there may be a selective effect at play. The two logistics companies in the project were probably better equipped to participate in collaborative innovation projects to begin with, compared to an average company in the logistics industry. They have clearly demonstrated a strategic intention to innovate by their willingness to participate in the project.

There are several barriers to overcome when collaborating on innovation with universities and competitors. Universities work under different institutional logics (e.g. incentives and the orientation toward openness and intellectual property) and competitors do not have aligned economic interests.
However, the DiRECTLY project proved to be different from traditional innovation projects in the industry. It was characterised by a high degree of complexity that necessitated a network of partners in order to overcome this complexity and find solutions to avoid empty running.

In addition, the two competing companies had aligned economic interests in the project. Furthermore, the university partners and consultants acted as neutral intermediaries, who facilitated interaction and helped build trust and social bonds. The many interactions during the project have not only created a mutual trust, but also facilitated a smoother coordination and exchange of knowledge and ideas.
Thus, the partners in the project learned how to collaborate. This skill is important for projects that involve universities and competitors, because it increases the chances of success and paves the way for additional innovation projects. Thus, an important outcome and lesson from the project is related to learning to collaborate, which is likely to support future innovation processes.

The present form of the DiRECTLY system focuses on finding matches between empty capacity on planned trips at one company and orders at another company. This is a rather static use of the system. However, the project also illustrated that new opportunities arise if the dispatchers use the system as a dynamic tool when planning routes - rather than a last resort after the old-fashioned planning process has run out of options.
The system also provides opportunities for offering new services to customers. However, a successful implementation of the DiRECTLY system at the companies would require a stronger involvement of customers. This could lead to new ideas for improvement in delivering value to their customers and thus lead to innovation.

THE POTENTIAL ROLE OF THE DANISH RESEARCH CENTER FOR FREIGHT TRANSPORT

In June 2020 the DRCFT (Danish Research Center for Freight Transport) was formed by several relevant actors in the Danish freight transport and logistics industry (Aalborg University, 2020a). While the main aim of the DRCFT is to increase both the industry's and the public's - knowledge and awareness of important issues in freight transportation (Aalborg University, 2020a), the Research Center may additionally play a role in facilitat-

ing a horizontal collaboration between the actors in the industry.

As for the "H-factor", there are certain dynamics between people, such as a lack of trust (Jeng, 2015; Lydeka & Adomavičius, 2007; Reuer & Ariño, 2007), that may hinder the implementation process of a collaborative logistics system (CLS). Thus, these dynamics need to be recognized and addressed, in order to enable the necessary horizontal collaboration for an initiative like DiRECTLY, to succeed (Aalborg University, 2020b; Edmondson & Roloff, 2009).

In order for an automated collaborative logistics system (CLS) to become a reality in the future, it has to be implemented and adapted into the daily practices of employees from different departments and organizations (Orlikowski, 1992). But, as we have learned throughout this project, enabling collaborations between people previously unrelated by their organizations and practices, may present several challenges. These include sensemaking barriers such as a lack of trust (Jeng, 2015; Lydeka & Adomavičius, 2007; Reuer & Ariño, 2007), difference in knowledge (Chatenier, Verstegen, Biemans, Mulder, & Omta, 2009; Hansen, 2002), miscommunication (Kuznetsov & Kuznetsova, 2014; Traum & Dillenbourg, 1996), and a lack of alignment of goals (Edmondson & Roloff, 2009).
Efficient and precise communication between different work practices is not only dependent on common knowledge and trust, but also on a common language and practice, in that different groups of people may associate themselves with different local practices and discourses (Potter & Wetherell, 1987), leading to misunderstandings and sensemaking issues (Kuznetsov & Kuznetsova, 2014).

Finally, the alignment of goals between the actors using the CLS is important. This ensures that everybody is working in the same direction, and that emergent strategies (Mintzberg & Waters, 1985; Mirabeau & Maguire, 2014) can be developed continuously, enabling different groups of people to individually adapt to challenges that may arise, without risking a dealignment of collaborative practices (Edmondson & Roloff, 2009; Sammut-Bonnici, 2015).

In order to explain DRCFT's role in enabling horizontal collaboration in the industry, there are two main takeaways from the sensemaking barriers listed above:
1) Criteria such as trust, shared knowledge, a common discourse and the alignment of goals, should not only be met by the decision makers in each organization, but also at a local level between the specific employees that need to work together on a daily basis - even though they may work in different organizations, and have not directly been part of

the project or strategy development themselves (Edmondson & Roloff, 2009).
2) None of the criteria: trust, shared knowledge, a common discourse or the alignment of goals, can be met without dialogue and interaction (Holmesland, Seikkula, Nilsen, Hopfenbeck, & Erik Arnkil, 2010; Maitlis, 2005).

As the DRCFT works closely with different actors in the industry, they have in-depth knowledge about freight transportation practices and development, along with a general overview of the comprehensive logistics infrastructure in Denmark. This means that they will be able to pinpoint the key practices that are crucial in order for a CLS to work.
Once these practices have been identified, the DRCFT may be able to facilitate interaction between relevant employees across the industry, enabling them to take part in a dialogue about the potential and the challenges of a CLS.

The reoccurring facilitation of dialogues between key employees may offer the potential for the development of relations, such as trust, shared knowledge, language and goals, and thus may help enable horizontal collaboration in the future.

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Empty running and half-empty trailers have been a headache for logistics service providers for years. It is costly and time consuming as well as a cause of unnecessary emissions, congestion and air pollution.

Despite numerous attempts involving new technology, company mergers and ad-hoc collaboration between competitors, empty running still presents a major challenge for the business as well as for the environment.

In 2016, a group of researchers and industry professionals gathered to develop a system that automates the ad-hoc collaboration by matching available goods and excess capacity - we call it the DiRECTLY system.
However, doing this in practice was far from straightforward.

This book is about the DiRECTLY project - a project that ended up not only being about collaborative logistics, but also about how to advance the road freight industry through new technology.

BUILD, Aalborg University

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