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Opportunities, Challenges and the Road Ahead

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Collaborative Logistics in Aalborg: Opportunities, Challenges and the Road Ahead

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Executive summary

Cities across Europe face significant challenges in relation to urban freight transport. The economic development in recent years have boosted activities in the city centres demanding increased freight transport. At the same time, urbanization has increased congestion issues and initiatives to minimize traffic in city centres have made city centres less accessible for freight transport vehicles.

A number of studies have explored how to optimize freight transport and minimize the negative externalities through collaborative logistics, a concept which has received a lot of attention in recent years. Collaborative logistics can be either a vertical collaboration between actors of the same supply chain, or a horizontal collaboration between direct competitors, for example competing logistics companies, aiming to decrease the costs of transportation and increase fleet utilization by sharing assets, information, knowledge etc.

The idea is built around an example if two competing logistics companies each have half a truckload of goods on the same route, then it makes sense for the companies to share the transport, place the goods on one full vehicle and share the saved costs. In turn, this will also generate environmental benefits, i.e. minimize driving and thus emissions of greenhouse gas, particles and noise.

This study provides an overview of the concept of collaborative logistics, and employs mathematical modelling to quantify the benefits which can be gained from collaborative logistics in urban freight delivery and interview-based methods to identify the challenges of implementing collaborative logistics in this setting in practice.

The study shows that horizontal collaborative logistics, i.e. collaboration between competing logistics companies, is found the most suitable approach to optimize logistics within given case of Aalborg. Within horizontal logistics two approaches are found, capacity sharing and order sharing. The study shows, that order sharing is the most beneficial approach. Using real-life data from two competing logistics companies, the analysis reveals that collaborative delivery and order sharing can reduce the total travelled distance of each company by an average of 24.75% compared to the non-collaborative distribution. Importantly, the analysis also reveals that even if the participating competitors only choose to share a subset of their orders, a significant reduction in travelled distance and emission is still achievable.

The analysis of the barriers shows that accessibility limitations in the city, partner selection issues, loss of a competitive advantage, issues in profit and cost sharing, different delivery structures and uncertainty regarding the branding of the delivery were the main barriers. The analysis also revealed that there is a support for collaboration among relevant stakeholders, however, the stakeholders have a low awareness of potential benefits of collaboration.

By simulating and proving the potential benefits of collaborative logistics based on real data, and simultaneously identifying the barriers, one of which being limited knowledge about potential benefits of collaboration, this report constitutes an important step towards implementation of collaborative in cities such as Aalborg.

1. Introduction

In 2017, road freight transport in Europe showed an average growth rate of 4.5% compared to 2016 (Eurostat, 2019). From 2010 to 2017, the total distance travelled by freight transport in Denmark increased from 1.2 to 1.4 billion km with an average growth rate of 2.4% (Eurostat, 2019). Particularly, freight activities in urban areas have increased dramatically, resulting in several issues such as traffic congestion, high levels of air and noise pollution, increased frequency of traffic accidents and greenhouse gas emissions (Demir et al, 2015). Urban freight activities are typically referred to as urban logistics which represents the last stage of supply chain of freight delivery. In the literature, urban logistics is defined as "the movement of goods by freight transport into, out, through and within urban areas" (Ogden, 1992; MDS Transmodal Limited, 2012; Horvath and Wu, 2017). Thus, effective planning of urban logistics will have a great impact on alleviating the issues arisen due to increasing freight activities in urban areas (Rao et al., 2015).

The growth of urban population together with growing volumes of last-mile e-commerce deliveries are among the most important factors for increasing freight activities in cities (Savelsbergh et al, 2016). According to the Population Reference Bureau (PRB) report on global urbanization, in 2018 around 74% of the total EU population lived in urban areas (Statista, 2019b; Allen et al, 2017). By 2050, this share is expected to reach 82%, with roughly 599 million people living in the urban areas (Statista, 2019c; ALICE, 2014). In Denmark, the population is expected to grow and reach 6,04 million people by 2024, which is 4.3% growth to 2018 (Statista, 2019d).

In addition to population growth and urbanization, the continual growth of e-commerce and parcel deliveries contribute significantly to the increased freight movements in urban areas (Browne et al, 2001; Guldbrand, Johansson and Westbloom, 2015). The Ecommerce Foundation (2015) reported that the global sales of business-to-consumer (B2C) e-commerce reached $1.9 trillion in 2014, representing double of the sales in 2011. The growth rate of e-commerce in Europe was around 12-14% in 2014 (Ecommerce Foundation, 2015). It is worth pointing out that e-commerce requires delivering goods to customers' homes instead of the retail stores. A regular size of e-commerce delivery typically is a small parcel, and due to the frequency of orders, it results in a larger increase in the number of freight movements. Because it is difficult to predict the volume of transported goods, this negatively affects the utilization rate of total freight vehicle capacity, e.g. 38% on average in London as reported in (ALICE, 2014). In addition, the increased number of freight movements in residential areas causes traffic difficulties since urban areas are sensitive to any extra vehicular movements (Egger et al., 2008).

The negative impacts of urban logistics become more apparent in the centers of the cities where commercial and business activities are usually more frequent, especially in historical centers that cannot accommodate the continual increase in freight movements. Such historical centers are typically more sensitive to the increased traffic (Hassan and Lee, 2015). According to ALICE (2014), freight in-city transportations are responsible for 25% of overall CO_2 emissions and for 30% to 50% of other pollutants (Particulates, NO_x). Air pollution is closely connected to health problems, and the rate of health issues is higher in cities than in the countryside (BESTFACT, 2013). Experts relate such rapid increase in harmful emissions mainly to the growth of road freight volumes (Allen et al, 2017; Tsiulin et al, 2017; Eurostat, 2019). The problem has become global, as the EU committee established the goal of reaching a level zero emission in cities by 2030 (ALICE, 2014).

The majority of European city municipalities implemented some initiatives in urban areas, aiming to improve the environment (air and noise quality), secure pedestrian spaces, and reduce congestion and accidents while reducing the number of vehicles (Dalkmann and Brannigan, 2007). These initiatives most frequently include restricting the time window of goods deliveries to shops, allowing certain classes of vehicles to access cities, and introducing environmental zones. According to Grosso et al. (2018), these initiatives usually mitigate the negative impact of urban logistics on the environment and society. However, this imposes additional costs on the logistics companies to deliver the freight to their customers in the city center under the regulations of these initiatives. For example, access time window usually forces logistics companies to use more delivery vehicles and longer routes, resulting in increased emissions and higher transportation costs.

In the recent years, collaborative logistics has been widely investigated as one of the most effective approaches to improve freight transport efficiency for sustainability (Goldsby et al., 2014). Collaborative logistics means that logistics service providers, customers, and the public sector collaborate together to increase their efficiency by sharing their resources, such as vehicles, cargo consolidation centers, or last-mile delivery services (Cleophas et al., 2019). Collaboration is seen as a joint partnership at the various stages of supply chain e.g. manufacturing, warehousing or transportation, following a goal to optimize internal business processes of participating organizations (Verdonck et al, 2013). As for transportation, collaborative freight delivery can result in fewer vehicular movements in urban areas, less level of noise and air pollution as well as increased utilization of resources. Collaborative logistics can also help logistics companies to reduce their delivering costs (Tsiulin et al, 2017; Roche-Cerasi, 2012). This motivates this research to investigate the collaboration practice in freight delivery as a solution to the issues of urban logistics in Aalborg, to explore the benefits of collaborative logistics in a European city of this size. Therefore, the aim of this report is to explore opportunities of and challenges to collaborative freight transportation in Aalborg. The study therefore has the following objectives:

(i) Provide an overview of strategies, opportunities and challenges related to collaborative logistics in the context of urban logistics.
(ii) Estimate the potential benefits of collaborative logistics in urban freight delivery through mathematical modelling and simulation based on real-life data.
(iii) Explore the challenges to implement collaborative logistics solutions in practice through interviews with key stakeholders.

The reminder of this report is organized as follows. Section 2 presents an overview of collaborative logistics and its strategies, potential benefits and most important challenges. Section 3 presents the collaborative modelling approach and the results of the case study. Section 4 presents the results from the interviews and followed-up discussions, revealing the main characteristics of the logistics market in Aalborg as well as challenges towards collaborative logistics between logistics operators. Section 5, the conclusion, summarizes the main results of the work and identifies opportunities for the further research.

2. Overview of collaboration in freight transportation

2.1 Strategies of collaborative freight transportation

Collaborative logistics can be classified into two main categories: vertical and horizontal (Simatupang and Sridharan, 2002). Vertical collaboration arranges collaboration among actors at different stages of the same supply chain (e.g. manufacturer and logistics operator), who accordingly share their assets, logistics and material resources, information or responsibilities to better serve the same end-customers (Cleophas et al., 2018). For example, Wal-Mart and its suppliers collaborate with each other by sharing latest information regarding sales and inventory information. Such collaboration enables Wal-Mart to reduce order-cycle time, stocking costs, and suppliers can replenish stocks according to up-to-date sales information, hence stock-out can be minimized (Kshetri, 2018).

Horizontal collaboration occurs between direct competitors (e.g. sharing information with other logistics companies) with a goal to increase the internal productivity and to reduce transportation costs for participating companies that commonly have a compatible performance on the market (Barratt, 2004). For example, suppliers operating with similar type of goods establish an agreement on joint distribution to certain customers. Figure 1 illustrates concepts of vertical and horizontal collaboration.

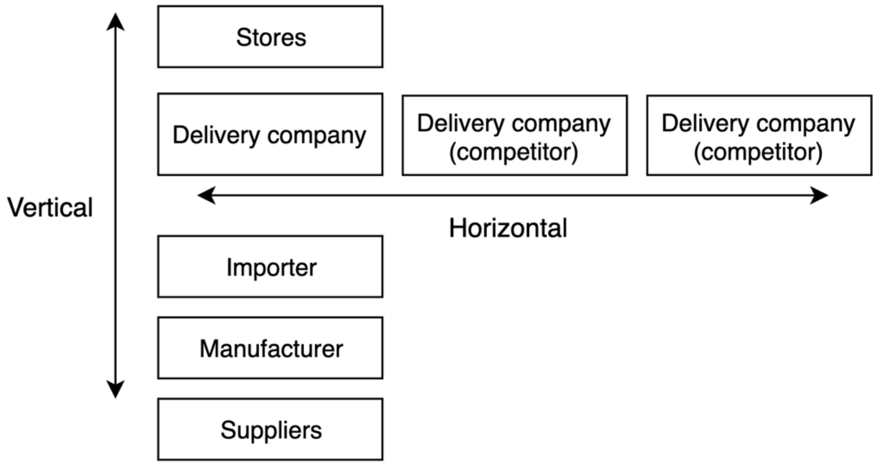

Figure 1. Horizontal Collaboration and Vertical Collaboration (Modified from Barratt, 2004)

In this report, we focus on horizontal collaboration, specifically collaboration by sharing vehicle capacity and customer orders. For more details on other types of horizontal collaboration and vertical collaboration in logistics, the reader is advised to examine the work of Verdonck et al (2013). In the literature, several studies, i.e. (Montoya-Torress 2016; Basso et al 2019; Allen et al 2017), have explored horizontal collaboration specifically within networks of delivery companies operating inside urban areas.

There are two main strategies within horizontal collaborative logistics: order sharing and capacity sharing (Verdonck et al, 2013; Allen et al, 2017; Montoya-Torress et al, 2016). Order sharing re-allocates customer orders between collaborating companies to create more efficient routing and increase the utilization of vehicles. Capacity sharing or “backhauling” focuses on the supply side, where logistics companies share assets and vehicle capacity, particularly, if it matches the destination of involved logistics operators. For example, when a few companies apply capacity sharing, instead of driving two half-full trucks, only one is used, close to truck’s full loading capacity. It saves empty kilometers and increases utilization rate of trucks. From the operational point of view, a great role is given to a third-party actor who is responsible for automation of the process, providing an IT platform for decision-making and route planning (Verdonck et al, 2013).

For capacity sharing, it is essential to identify a situation when trucks belonging to the different companies follow similar routes but in opposite directions for repeated trips. For instance, carriers operating on international routes pick up loads of their competitor for the return trip, and hence reduce empty running and fully utilizing available resources. Figure 2 shows an example of collaboration in which capacity sharing approach is applied. The upper part of the figure illustrates a non-collaborative scenario, each service provider or carrier (square node) arranges routing and serves its own customers. On the contrary, the lower part of the figure shows a collaborative scenario where certain routes are merged.

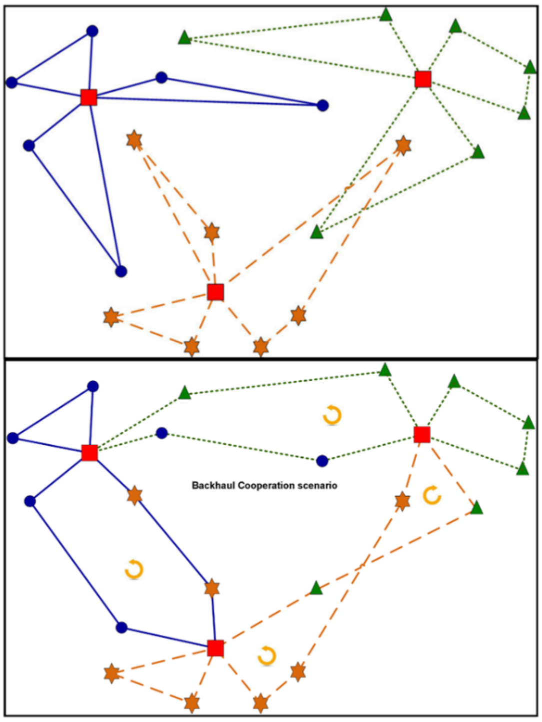

Figure 2. Illustration of a non-collaborative scenario compared to the capacity sharing collaboration (Juan et al., 2014)

The second strategy, order sharing, implies that collaborating partners are willing to share or exchange information on their delivery orders. Order sharing works within a pool of delivery companies where a number of particular delivery orders are exchanged to achieve better routing between delivery stops and delivery companies' depots. The goal is to increase the efficiency by optimal relocation of orders amongst collaborative partners. It is also important to ensure that collaborative partners share transported volumes on a fair basis, leading to a situation when vehicles are properly scheduled and loaded up to the full transporting capacity (Allen et al, 2017).

Order sharing strategy primarily focuses on the last-mile delivery in urban logistics (Juan et al., 2014). Order sharing is characterized by less-than-truckload requests and short-travel distance with an emphasis on transportation flexibility: routing and truck optimization. Unlike capacity sharing, which is focused on saving service costs through full loading capacities of large trucks and significant travel distances, order sharing method is found more suitable within the urban freight transportation (Montoya-Torress et al, 2016; Simatupang and Sridharan, 2002).

Figure 3 illustrates comparison of non-collaborative scenario compared to collaboration by order sharing. Less travelling distance and delivery time can be achieved when collaborating companies share orders to optimize their routes.

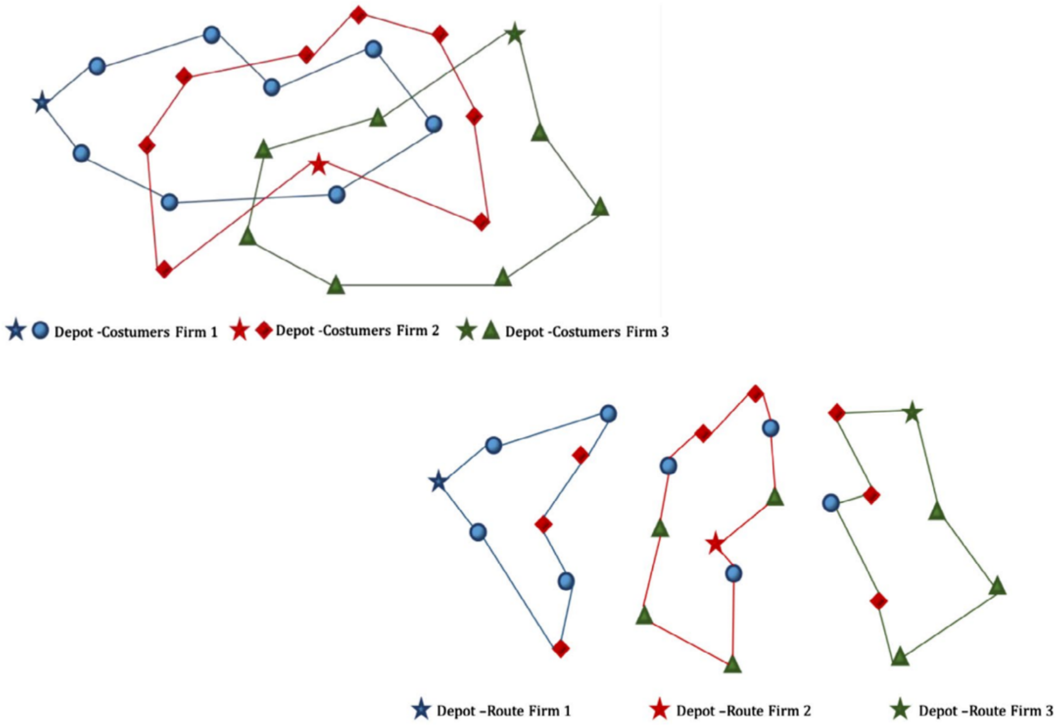

Figure 3. Illustration of a non-collaborative scenario compared to an order sharing collaboration (Montoya-Torres et al., 2016)

2.2 Opportunities of collaborative logistics

As it has previously been stated, horizontal collaboration is mostly suitable for joint cooperation between companies that provide the same service (Cruijssen et al, 2007). According to a variety of literature (Basso et al., 2019; Rodrigues et al., 2015; Cruijssen et al, 2007), collaborative logistics, as a field of studies, has a widely presented research background though potentials and drawbacks are yet to be fully explored. As it will be discussed later, the main opportunities of collaboration are related primarily to service cost reduction. Further, collaboration significantly contributes to knowledge sharing between participating companies thereby synchronizing joint activities, and expanding possibilities for new services and market acquisition.

2.2.1 Cost reduction

The main driver for involved partners towards collaboration is a reduction of their business costs through sharing of their internal assets. That is, to increase productivity when partners work on the same level of supply chain and compatible performance on the market i.e. suppliers operating with similar type of goods establish an agreement on joint distribution to certain customers, or competitive logistics operators establish joint deliveries because they have a match in delivery routes.

In other words, collaboration allows efficiently rearrange routing and transported volumes to better fit companies' internal powers. This could result in using fewer vehicles for last-mile delivery and hence less manpower, minimizing detour, saving fuel costs or significantly reorganizing routing. Additionally, collaboration allows participants to reduce costs in joint purchases, e.g. trucks, office equipment, or jointly apply for external funding (Cruijssen et al, 2007). Within such collaboration, companies also can form alliances consisting of several participants, expanding the network which could serve as a driver for new services.

2.2.2 Knowledge sharing

Collaborative logistics does not exclusively imply mutual exchange of infrastructure and available resources, but also an information and knowledge exchange i.e. skills, usage of partners' know-how, features of managing company's Research & Development, and internal organizational experience and other knowledge-based capabilities. Shared information and management techniques help to level participants' internal information systems. Consequently, it leads to better synchronization of activities and hence speeds-up or automates logistics operational processes. Thus, it upgrades companies' competitive advantages at lower costs across involved SMEs (Basso et al., 2019; Allen et al, 2017; Montoya-Torress, 2016).

2.2.3 Competitive advantage on the market

According to Cruijssen et al (2007), market itself could be a powerful driver for logistics companies to create alliances in order to get access to the new markets, geographical areas or customer acquisition in the form of individual big clients. Moreover, such partnerships might be considered as a protective mechanism from uncertain market conditions, or to enhance competitive powers to protect the market share.

2.3 Challenges to collaborative logistics

Despite wide range of possible benefits that horizontal collaboration brings to the industry of logistics, many barriers exist that resist practical implementation of collaborative logistics. In the following sub-sections, we present an overview of challenges that could prevent collaborative logistics from implementation and achieving its benefits. Most of currently existing challenges are built around lack of trust between partners, syncing assets, and concerns regarding data security and mechanism of how to equally and fairly allocate benefits among partners.

2.3.1 Partner selection

Finding trustworthy partners is one of the main barriers of collaboration (Palmer et al, 2013). Partners' selection could consist of a variety of parameters: data on physical assets, routing, volumes of transported goods, organizational capability, flow balance and tracking data, shipment complementarity or compatibility, or coordination methods. For instance, collaboration may be established if operation areas of potential partners are matching or superimpose on each other. Flow balance means that the amounts of goods moving from one region to another are equal to the amounts that move in the opposite direction. The shipment complementarity or compatibility indicates the possibility of sharing vehicle spaces to transport goods of different logistics companies. It is worth noting that different types of goods may not be combined within the same vehicle, for instance, when one company operates with pallets whereas the other operates with parcels (Muir, 2010; Montoya-Torress et al, 2017; Palmer et al, 2013).

2.3.2 Profit-sharing mechanism

The question regarding financial aspect of collaborative logistics remains unsolved i.e. how to equally and fairly share benefits between partners in accordance with pre-defined agreement, also accounting transportation costs (Guajardo and Rönnqvist, 2016). All partners should be able to gain benefits or profits from collaborative distribution. This would keep partners motivated for collaborating. In addition, profit or cost allocation among partners should be fair and reasonable enough to ensure the continuity of the collaboration. Current mechanism of profit sharing mainly depends on a proportional allocation of savings, or setting rates of a logistics service provider (Palmer et al, 2013).

For example, one of the profit-sharing rules is the following: "profit allocation is proportional to a number of pallets delivered". Hence, profit is divided roughly according to a number of pallets delivered by each partner. However, this rule cannot capture fairly the real contribution of partners, and may induce discontinuity of the collaboration (Lozano et al, 2013).

2.3.3 Information sharing and security

A special concern needs to be given to the security systems i.e. how to eliminate any potential harmful interference. Information security is noted to minimize any inequality in decision making process and to eliminate a possibility of certain actors taking the lead despite agreement regulation, and using competitive advantage against involved competitors (Cruijssen et al, 2007; Basso et al., 2019). Generally, it applies to Decision Support System which ensures to search all matching opportunities for carriers and also allows to quickly re-plan activities in case of execution disturbance (Cruijssen et al, 2007; Dahl and Derigs, 2011; Gunasekaran and Ngai, 2004).

2.3.4 Human factor

Collaborative logistics is faced by the barriers resulting from human factors due to their past experiences of collaboration and relationships with each other. Low trust and fear of changing daily routines are critical factors (Pomponi et al., 2015). It also includes a necessity to teach personnel how to operate with an upgraded software system and respond to freight exchange requests (Rodrigues et al., 2015). A better trust can be achieved between the parties. Lack of trust between actors in sharing confidential data or assets is considered a critical factor (Pomponi et al., 2015). It is extremely essential to achieve system's efficiency since managers among collaborative partners occasionally tend not to provide full data or either information is not unified or hidden (Cruijssen et al, 2007).

2.3.5 Market regulation rules

In many countries, competition laws limit the sharing data processes, thus making collaboration hard to be implemented (Basso et al., 2019). A role of trusted third-party or a mediator is one of the reasons how collaborative logistics establishes trust between partners without violating confidentiality of data and complies with competition law. (Jenks et al., 2013). Market barriers such as vertical integration among shippers and carriers, meaning that shippers refuse other carriers than their contracted carrier to serve its goods (Jenks et al., 2013). Also, collaboration is limited by imbalanced goods movements when large amounts of goods move from one region to another and less in the opposite direction (Xu, 2013).

3. Modelling of collaborative freight delivery: case study-based analysis of collaboration benefits

The promotion of horizontal collaboration practices among logistics companies requires estimating the magnitude of the costs savings attained throughout collaboration. However, it is not easy task to estimate numerically such cost savings. This is due to the existence of many barriers that negatively affect the benefits of the collaboration as illustrated before. The delivery contracts between logistics companies and their customers represent one of the most important barriers to implement the collaboration and attain its benefits. This also exists in case of Aalborg as some logistics companies worry about their branding, meaning that they prefer to serve specific customers by their vehicles rather than share these customers with other logistics companies. This is because contracted customers may refuse that other logistics companies can serve their goods. The aim of this section is to provide numerical estimates on how benefits of collaboration, e.g. travelled distances, vary in different scenarios through a case study from Aalborg city. Because the environmental and financial costs in the freight delivery services are mainly related to the planning of delivery routes, we estimate to what extent the collaboration affects the logistics companies in their route planning process and costs. To achieve this aim, we developed mathematical models for the collaborative planning of delivery routes. In particular, we address this planning process as a Multi-Depot Vehicle Routing Problem (MDVRP) as will be described latter.

The reminder of this section is organized as follows: the first part presents the collaborative freight delivery problem and its solution techniques. The second part describes the proposed modelling approach, while the third part illustrates our solution methodology. The case study and the different scenarios are introduced in the fourth part. The results of solving the case study under different scenarios are shown in the final part.

3.1 The collaborative freight delivery problem and its solution techniques

To perform the collaboration among companies, all logistics companies are required to send information of their customer requests to a central authority who plans the collaborative deliveries. An online platform can be an example of such central authority (Dai and Chen 2012). Therefore, the collaborative freight delivery can be modeled as a centralized decision-making problem. In the literature, this problem is known as Multi-Depot Vehicle Routing Problem (MDVRP) that is a variant of the classical Vehicle Routing Problem (VRP). The VRP includes a set of geographically dispersed customers with known demands to be served by a set of vehicles. Each vehicle has a limited capacity and should start from and return to the same depot. Typically, the VRP is solved for single logistics company to determine the sequence of visiting the customers by each vehicle with objective of minimizing the total distance travelled by all vehicles. In case of collaboration, there are many depots, each of which belongs to at least one logistics company. This requires solving the MDVRP in which each logistics company has at least one depot which serves a number of customers with a set of vehicles that may not be identical.

In the literature, several techniques were employed to solve the MDVRP. Mixed Integer Programming (MIP) models were used as in (N. Aras et al.,2011). Meta-heuristic approaches such as genetic algorithm and a Variable Neighborhood Search (VNS) algorithm were utilized in (Ho et al., 2008, Salhi et al., 2014). Due to the NP-hardness of the MDVRP, some studies solved the MDVRP through decomposing the overall problem into two sub-problems, i.e. assignment problem and routing problem (Tansini et al., 2001, Montoya-Torres et al., 2016). First, the assignment problem is solved to assign each customer to its closest depot with respecting some constraints such as the transport capacity of the depot; then routing of vehicles can be planned to serve customers assigned to the same depot (herein, VRP is solved as many as the number of depots). Of course, it is more efficient to solve the two sub-problems holistically as a one problem. However, this holistic approach is not tractable computationally, especially in the collaborative environment where the size of problem increases dramatically. It should be noted that due to the interrelation of these two sub-problems, poor assignment solution leads to routing solutions of higher total distance (Tansini et al., 2001). However, most of existing decomposition-based approaches have been developed in a way that the interrelation of the sub-problems isn't adequately considered (Montoya-Torres et al., 2016, Muñoz-Villamizar et al., 2015). In this report, we developed a two-level mathematical modelling approach for modelling the MDVRP in collaborative environment. The proposed approach contributes to existing literature by considering the interrelation between the decomposed problems and thus, the solution quality of the overall problem can be improved. We refer the reader to examine our published work (Karam et al., 2019) for more details about the validation and significance of the proposed modelling approach.

3.2 The proposed modelling approach

As stated before, we model the MDVRP by a two-level mathematical modelling approach in which MIP model is used in each level. Figure 4 shows the solution procedures and describes the proposed approach. As a first step, data related to depots, customers, vehicles and other constraints are input to the proposed approach. In the second step, a new MIP model is used for assigning customers to the closest depots. Then, the obtained assignment solution is used as an input to solve a vehicle routing model which is proposed in (Montoya-Torres et al., 2016). Finally, the collaborative solutions for each company can be obtained. In the following, we illustrate the two levels of the proposed approach and our solution methodology for solving the proposed approach.

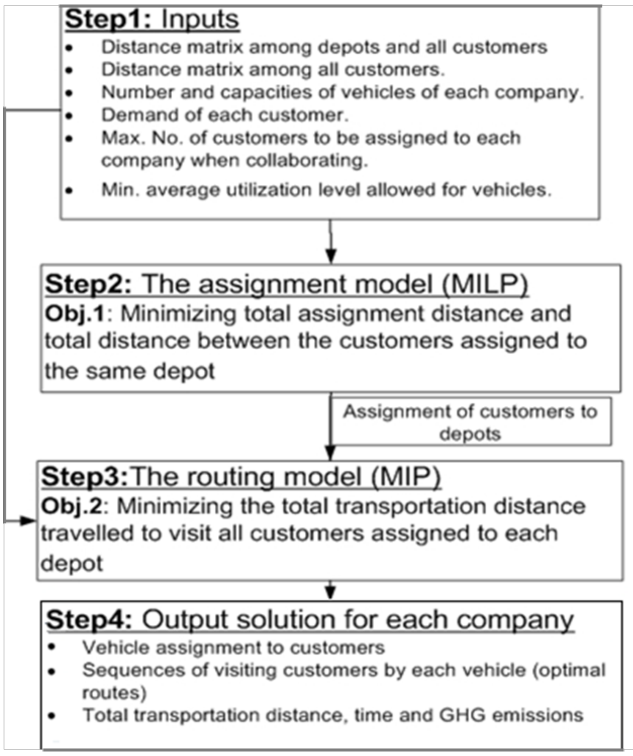

Figure 4. Solution procedures of the proposed approach

3.2.1 Assigning customers to depots

A new MIP model is formulated to assign customers to depots while considering two objectives: minimizing the total distance between customers and their assigned depots; and the total distance between customers assigned to the same depots. Mathematical notations are as follows:

- Sets :
  - A: set of all depots, A= $\{1,2,\ldots,a\}$(indexed by i)
  - B: set of all customers or delivery orders, B = $\{1,2,\ldots,b\}$(indexed by j & h)
- Parameters :
  - c_{ij} : Average distance between depot i and customer j.

$c1_{jh}$: Distance between customer *j* and customer *h: h ≠ j.*

m_i : Maximum number of customers that can be assigned to depot i, $\sum_{i=1}^{a} m_i = b$.

TQ_i : Total capacity of all vehicles at depot *i*, available to serve assigned customers.

q_i : Demand of customer i.

Ut : Minimum limit of average vehicle utilization, %.

- Decision variables

z_{ij} :1, if depot *i* serves customer *j*, 0 otherwise.

y_{ijh} :1, if depot *i* serves customers *j* and *h*: *h ≠ j*, 0 otherwise.

The customer assignement model:

$$f_1: min \sum_{i=1}^{a}\sum_{j=1}^{b} c_{ij}.z_{ij}$$

$$f_2: min \sum_{i=1}^{a}\sum_{j=1}^{b}\sum_{h=1,h\neq j}^{b} c1_{ij}.y_{ijh}$$

Subject to

$$\sum_{i=1}^{a} z_{ij} = 1 \qquad \forall j \in B \qquad (1)$$

$$\sum_{j=1}^{b} z_{ij} \leq m_i \qquad \forall i \in A \qquad (2)$$

$$z_{ij} + z_{ih} - 1 \leq y_{ijh} \qquad \forall i \in A, \forall j,h \in B, j \neq h \qquad (3)$$

$$\sum_{j=1}^{b} q_i.z_{ij} \leq TQ_i \qquad \forall i \in A \qquad (4)$$

$$\sum_{j=1}^{b} q_i.z_{ij} \geq ut.TQ_i \qquad \forall i \in A \qquad (5)$$

$$z_{ij}, y_{ijh} \in \{0,1\} \qquad \forall i \in A, j,h \in B \qquad (6)$$

The first objective f_1 aims at minimizing the total distance between depots and their assigned customer while the second objective f_2 minimizes the total distance between customers assigned to the same depot. Constraint (1) ensures that each customer is assigned to no more than one depot. Constraint (2) guarantees that the number of customers assigned to each depot does not exceed its maximum allowed number. Constraint (3) states that when customer *j* and *h* are assigned to the same depot *i*, y_{ijh} equals to one. Constraint (4) ensures that the total demand of customers assigned to each depot does not exceed the total capacity of vehicles available at that depot. Constraint (5) forces the average vehicle utilization of each depot to be not lower than a minimum specified limit. Constraint (6) defines domains for the decision variables.

3.2.2 Routing of vehicles for each depot

In this level, the optimal routes to visit all customers assigned to each depot, are determined by using the MIP model proposed by (Montoya-Torres et al., 2016). In their model, they considered developing a balanced routing plan in which the number of delivery requests assigned to each vehicle cannot exceed a specified limit, calculated by dividing the total number of delivery orders by available number of all vehicles. In addition, the length of each route travelled by a vehicle cannot exceed a maximum length.
Mathematical notations are as follows:

- Sets :

  M: set of all Vehicles, M= $\{1,2,\ldots,m\}$(indexed by k)

  N: set of all customers or delivery orders assigned to the depot, N = $\{1,2,\ldots,n\}$(indexed by j & h)

- Parameters :

  $d1_j$: Distance between the depot and customer j.

  $d2_j$: Distance between customer j and the depot.

  $d3_{hj}$: Distance between customer h and customer j.

  v : Average travel speed of the vehicle (unit: *km/h*).

  t : Maximum route time (unit: *h*).

- Decision variables

  x_{jk} :1, if vehicle k moves from the depot directly to serve customer j, 0 otherwise.

  y_{jk} :1, if vehicle k returns to the depot directly after serving customer j, 0 otherwise.

  B_{hjk} :1, if vehicle k serves customers j after customer h: $h \neq j$, 0 otherwise.

  U_j :The auxiliary variable for sub-tour elimination.

The vehicle routing model:

$$f_3: min \sum_{j=1}^{n}\sum_{k=1}^{m} d1_j . x_{jk} + \sum_{j=1}^{n}\sum_{k=1}^{m} d2_j . y_{jk} + \sum_{h=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} d3_{hj} . B_{hjk}$$

Subject to

$$n.\sum_{j=1}^{n} x_{jk} \geq \sum_{h=1}^{m}\sum_{j=1,h\neq j}^{m} B_{hjk} \qquad \forall k \in M \qquad (7)$$

$$n.\sum_{j=1}^{n} y_{jk} \geq \sum_{h=1}^{n}\sum_{j=1,h\neq j}^{n} B_{hjk} \qquad \forall k \in M \qquad (8)$$

$$x_{jk} + \sum_{h=1}^{n} B_{hjk} = y_{jk} + \sum_{h=1,j\neq h}^{n} B_{hjk} \qquad \forall k \in M, \forall j \in N, j \neq h \qquad (9)$$

$$\sum_{k=1}^{m} x_{jk} + \sum_{h=1,j\neq h}^{n}\sum_{k=1}^{m} B_{hjk} = 1 \qquad \forall j \in N \qquad (10)$$

$$\sum_{h=1}^{n}\sum_{j=1,h\neq j}^{n} B_{hjk} \leq \frac{n}{m}+1 \qquad \forall k \in M \qquad (11)$$

$$\sum_{j=1}^{n} d1_j.x_{jk} + \sum_{j=1}^{n}\sum_{k=1}^{m} d2_j.y_{jk} + \sum_{h=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{m} d3_{hj}.B_{hjk} \leq \text{t.v} \qquad \forall k \in M \qquad (12)$$

$$U_h - U_j + n.B_{hjk} \leq n-1 \qquad \forall h,j \in N, \forall k \in M, j \neq h \qquad (13)$$

$$x_{jk}, y_{jk}, B_{hjk} \in \{0,1\} \qquad \forall h,j \in N, k \in M \qquad (14)$$

The objective function, f_3 aims at minimizing the sum of the total travelled distance for all vehicles. Constraint (7) and (8) guarantee that the route of each vehicle must originate and terminate at the depot. Constraint (9) ensures the route continuity for each vehicle, meaning that the vehicle entering and leaving a node (customer or depot) must be the same vehicle. Constraint (10) ensures that each customer is visited exactly once and only once. Constraint (11) is used to restrict the total number of delivery requests assigned to each vehicle. Constraint (12) ensures that each vehicle doesn't travel more than a maximum specified limit. Constraint (13) is the sub-tour elimination constraint. Constraint (14) defines the domain for each decision variable.

3.3 Solution methodology

Herein, we present our methodology for solving the two MIP models illustrated above. In particular, we illustrate the normalization of the objective function of the assignment model as well as the method used to solve the MIP models.

As stated before, two objective functions are considered when solving the assignemnt model. From preliminary experiments, it is noted that summing the two objectives into one objective function may be unsuitable as the value of f_2 is often higher than that of f_1, and therefore it is expected that f_2 will dominate f_1. This situation might lead to solutions focus only on minimizing f_2 at the expense of f_1. So, the two objectives are combined into one non-dimensional fitness function (f_4) with equal weights by using a function transformation method as follows:

$$f_4 = w\ x\left(\frac{f_1}{f_1^*}\right) + (1-w)\ x\ \left(\frac{f_2}{f_2^*}\right) \qquad (15)$$

Where f_1^* and f_2^* are minimum or approximate minimum values of f_1 and f_2 respectively while w is the relative weight which we set to 0.5. After assigning costumers to each depot, the routing model will be used to solve the VRP for each depot separately, meaning that we solve the routing model as many as the number of depots.

The computational environment consists of a PC with 2.3 GHz processor and 4 GB RAM working under windows 7 operating system. The MIP models were solved using the branch-and-cut algorithm in CPLEX™ optimization software version 12.2. This algorithm is used because the problem size in this study is small- to medium-sized MDVRP. Therefore, the branch-and-cut algorithm can be used to produce near optimal solution in practical time.

3.4 The case study and collaboration scenarios

In this section, we describe the case study and the different scenarios which will be simulated in this report.

3.4.1 The case study

The proposed collaborative approach was tested using real data from logistics companies operating in Aalborg city. Figure 5 shows the delivery area under study that covers approximately 5 km^2. This area is specifically selected because Aalborg municipality pays a great attention to improving the environment (air and noise quality), securing pedestrian spaces, and preventing congestion and accidents in this particular area that is also considered as city centre.

Figure 5. The delivery area illustrated by the white overlay (map.krak.dk 2019)

Our intent was to test the collaboartive approach using real data from the four logistics companies participating in this project. However, only two logistics companies provided their delivery data of Septemberer 2018 for the experimental tests. For confidentiality reasons, we cannot mention the names of the two companies and therefore, we refere to them as company A and company B. Each company has one depot from which the delivery vehicle starts its route to serve the delivery orders and return back to the depot. The two companies deliver different types of shipments which are palletized goods and parcels. To enable the collaboration between these two companies, we assume that their shipments can be combined in the same vehicle. In general, the data of the two companies shows date and time of each order, name as well as address of each recipient and post number. However, the data has several limitations. For example, only one company reported the weight of each order while the other company stated only the average weight of each order. Also, the deadline for each order was not reported by both companies. Therefore, the weight as well as deadline of each delivery order were not considered in the proposed collaborative approach. The locations of all delivery orders in the data were analyized and the most frequently visted locations are determined and considered into the case study. This way of selecting the delivery loctaions allow us to have a more representative example of the delivery practice of both companies in the delivery area. To avoid high computing time, the number of the delivery requests was restricted to 35 for each company. The average driving speed in the delivery area is 25 km/h while the maximum route length is set to 8 hours. To overcome the missing information about order weights, the case study is solved, assuming that each logistics company can serve the customers with a single vehicle having a sufficient capacity to accommodate its assigned demands. It is worth noting that the proposed approach can consider multiple vehicles as well, we only consider a single vehicle in this case study as any savings coming from one vehicle translate into similar savings for several vehicles. The depot–customer and customer-customer distance matrices are determined using real driving distances using Google Maps™ mapping service. To facilitate obtaining the distance matrices, we created a custom function in Google Apps Script and used it in Google spreadsheet to automatically get the shortest driving distances between different addresses.

3.4.2 Collaboration scenarios

As stated before, we consider the collaboration through order sharing in which logistics companies share the information of their delivery orders, vehicles and plan the routes together. In this context, we will investigate an ideal scenario, in which full collaboration between logistics companies occurs, meaning that companies share all the information of their customers and plan the routing of the vehicles in the most cost-effective way.

To identify the benefits of collaboration, this ideal scenario of collaboration will be compared against the non-collaborative scenario in which each logistics company plans the deliveries to its customers individually. In practice, logistics companies may prefer serving specific customers exclusively by their own vehicles and refrain from sharing their information with other companies. There are many reasons for such situation to occur. For example, logistics companies may have contracts with some customers who refuse that other companies serve their goods. In another case, a logistics company may worry about sharing key customers with its competitors, especially when all collaborating companies operate in the same region. In this report, this situation is referred as contracted customers. It should be also noted that we consider that a logistics company can serve orders of other companies by the same vehicles carrying its contracted orders. The existence of such contracted customers may have a negative effect on the benefits of collaboration, e.g. travelled distance especially if the delivery locations of the contracted customers are relatively far from the depot of company. Therefore, the effect of contracted customers on the benefits of the collaboration will be also analyzed by comparison against other scenarios. In this report, we will evaluate quantitatively the following scenarios:

1. Full collaboration scenario
   This is an ideal scenario in which all companies are willing to collaborate and allow the services of their customers to be made by other companies, assuming that there are no contracted customers.
2. Non-collaborative scenario
   This is the practice without collaboration. In this scenario, each company plans the routing of its vehicles separately to serve the customers with objective of minimizing the total travelled distance.
3. Collaborative scenario with contracted customers
   It is a more practical scenario in which each company must serve its contracted customers itself. In this scenario, we consider the worst case in which locations of the contracted customers are the most distant from the depots of their corresponding company.

3.5 Results and analysis

This section presents the main simulation results of the scenarios for the case study.

3.5.1 Non-collaborative scenario vs. full collaboration scenario

In order to obtain the non-collaborative solutions, the MIP model of level 2 is solved for each logistics company. To obtain the collaborative solutions, we applied the proposed approach, which firstly assigns the customers to one of the two logistics companies, and then the routing problem for each new assignment is solved. m_i is set to 35 for all carriers, meaning that each carrier should keep the same number of customers before and after collaboration. This setting may increase the motivation of carriers to participate in the collaboration process. The solution of the assignment model could be obtained in 20 minutes with an optimality gap of 5% while the optimal solutions of the routing model are obtained in few seconds. Table II shows the numerical results for both scenarios. Note that in table II, the travel time and CO_2 emissions are calculated based on the total travelled distance as follows: travel time (*h*) is calculated as a result of dividing average total distance (*Km*) by travel speed (*Km*/*h*) while the amount of CO_2 emissions (g) can be calculated as a result of multiplying the average factor for the level of carbon emissions, 160 g/km by total distance (Km). The collaborative delivery could result in reducing the total travelled distance, and as a result, the travel times as well as amount of CO_2 emissions are also reduced. The improvements in travelled distances for Company A and B are 21.98% and 27.50% respectively. It is worth noting that company B has slightly larger improvement in the total distance as the location of its depot is closer than that of company A to the delivery area. This is an interesting result because some logistics companies refused to provide their delivery data for the numerical tests, arguing that the closeness of their depots to the delivery areas might result in less cost savings over the non-collaboration practice. The results in Table 2 reflected the environmental and economic impacts of the collaboration. However, there are other positive impacts of the collaboration on the business aspects of logistics companies. For example, the collaborating companies can have a competitive advantage over non-collaborating companies by lowering their prices due to the reduced transportation costs. Also, the service level of each company can be improved due to the reduced driving time which in turn may lead to delivering the goods to customers on time.

Table 2. Comparison of non-collaboration and full collaboration scenarios

	Non-collaborative scenario			Full Collaboration scenario			Difference (%)
	Travelled distance (m)	Travel time (hours)	CO_2 emissions (g)	Travelled distance (m)	Travel time (hours)	CO_2 emissions (g)	
Company A	40967	1.64	6554.72	31961	1.3	5113.76	21.98%
Company B	32738	1.31	5238.08	23735	0.95	3797.6	27.50%

3.5.2 Collaborative scenario with contracted customers

In the full collaboration scenario, we assumed that the two logistics companies are motivated to share all their delivery requests with each other. However, this assumption does not necessarily hold in practice. In the following, we aim to investigate how the existence of contracted customers would affect the benefits of collaboration process. To do so, we extend the assignment model by adding an additional constraint to ensure that the services of contracted customers are assigned to their corresponding companies. We define a *0-1*parameter, $Assign_{ij}$ which is one if customer *j* must be served by logistics company *i* and zero otherwise. In addition to constraints (1)-(6), the following constraint is added to the assignment model:

$$z_{ij} \geq assign_{ij} \qquad \forall i \in A, \forall j \in B \qquad (16)$$

In this scenario, the total travelled distance is investigated under six levels of contracted customers, i.e. 0%, 10%, 30%, 50%, 80%, and 100%. Each level is referred to as a case, therefore we will study six cases (case#1 to case#6) in this scenario. For example, given that the total number of customers for each company is 35, case#2 implies that there are approximately four customers having delivery contracts with the logistics company. Note that case#1and case#6 represent the full collaboration scenario and non-collaborative scenario respectively. As stated before, we consider the worst-case scenario in which contracted customers are the farthest from the depot. Therefore, we select the contracted customers in each case as follows: the customers of each depot are sorted in descending order according to the distance from the depot. Then, a number of customers equals to the percentage in each case is extracted from the farthest customers from the depot. To obtain the collaborative solutions under this scenario, the proposed collaborative approach is solved for each case. Table 3 shows the results of this scenario. As expected, increasing the level of contracted customers leads to reducing the improvements in the total travelled distance compared to the non-collaboration scenario. However, the rate at which the % improvements decreases with increasing the % of contracted customers is not fixed and also is not the same for both companies. For example, from 10% to 30% the total travelled distance is reduced by 2.16% and 7.53% for company A and B respectively while from 50% to 80%, the total travelled distance of each company is negligibly reduced. This trend can be explained as follows: the contracted customers in each case are formed by adding more contracted customers to those of its precedent case. The fact that the newly added customers have distances to depots less than that of contracted customers in previous cases, leads to such trend. Based on the results of this scenario, it can be concluded that even if there is small number of contracted customers whose locations are far away from the depot, they represent one of the most important challenges to implement collaborative freight delivery and attain its benefits. However, it is still viable to achieve benefits of collaboration even if the contracted customers represent high percentage of the total customers in each company. For example, at 80% contracted customers both companies can gain benefits due to the collaboration. It worth noting that this improvement would be much larger in case of solving large-scale problems where many depots and multiple vehicles are included. It is very important to propose solutions to overcome obstacle caused by contracted customers. One of this solution can be involving the contracted customers in the collaboration process by offering them financial benefits so that they can allow other logistics companies to serve their delivery orders.

Table 3. Percentage improvement in total travelled distance in each case compared to the non-collaborative scenario

	Cases					
	Case#1* (0%)	Case#2 (10%)	Case#3 (30%)	Case#4 (50%)	Case#5 (80%)	Case#6** (100%)
Company A	21.98	7.98	5.81	4.80	4.60	0.00
Company B	27.50	19.60	12.07	9.51	9.49	0.00

* Full collaboration scenario
** Non-collaboration scenario

4. Interview-based analysis of challenges in collaborative logistics

Previously, we have shown how collaborative freight delivery, based on real data, can give logistics companies an opportunity to decrease the total travelled distance and thus, it can also contribute to decreasing the level of CO_2 emissions. However, the previous section represents a mathematical simulation and did not consider the practical barriers to collaboration with logistics companies. Therefore, it was necessary to look at the current operations of logistic companies operating in Aalborg to analyze the basis for collaboration, especially current challenges faced in relation to implementing collaborative freight transportation as a means of improving urban logistics in the city. To generate data on this a interview based study was conducted. In the following sub-section, we firstly describe the interview methodology. Then, the findings of the interviews are presented and discussed.

4.1 Interview methodology

The current study used a semi-structured interview study approach (Kvale and Brinkmann, 2015). For this research, we selected a group of six mid to large-sized logistics companies that operate in Aalborg.

Interviews were conducted individually with employees of each company. Roles of the respondents included the following positions: regional manager, operational manager, chief of distribution, chief of the terminal, team-leader, and team coordinator. The interviews with each of the respondent were structured around two themes: 1) current situation of the companies and their operations in Aalborg and 2) challenges and opportunities in urban logistics including collaborative logistics.

The understanding of opportunities and challenges generated in the interviews was used as a basis for a following round of discussions with respondents, as well as other experts from the logistics industry in and around Aalborg, in order to validate the results. The data was also presented in a workshop, where members from some of the logistics companies, public and private organizations participated.

The interviews were analyzed using the method of Meaning Condensation (Kvale and Brinkmann, 2015). Each interview contains multiple statements, and by analyzing these statements individually, the meaning of each was condensed and subsequently assigned to a theme. By comparing these themes across multiple interviews, it was possible to find common opportunities and challenges for logistics collaboration among the participant organizations.

4.2 Findings and discussion

To present the key findings of the interviews, we organize this section as follows: the first part presents the most important characteristics of the logistics industry in Aalborg, which affect the promotion of the collaboration practice among logistics companies. The second part presents the challenges to implement the collaboration practice in Aalborg.

4.2.1 Characteristics of logistics industry in Aalborg

4.2.1.1 High level of competition

There is a high level of competition between logistics companies in Denmark, as in most European countries. The situation in the industry can be described as a red-ocean competition, where the focus is on cost minimization. This also holds in the case of Aalborg. Nevertheless, logistics companies are competing with each other, but in relation to a number of issues they consider each other as colleagues.

The competition situation in the industry affects the willingness of the companies to adapt new technologies of information systems and the promotion of the collaborative practice solutions among the companies. The fierce competition creates an industry with low margin. According to respondents, margins do not exceed 4-5%. The low margin does not allow companies to invest in expansion of their activities or business development. The willingness toward adapting new unproven innovations, e.g. collaborative logistics, therefore appears relatively low. This is because with the low profit margin failed investments pose a high risk for the companies. On the other hand, if the potential of a new technology is proven, then the companies are fast to adapt new technologies, because of the hard competition. Therefore, the current lack of knowledge about precise quantifiable benefits of collaborative logistics in an urban setting is a key barrier to the implementation of collaborative logistics among logistics companies.

4.2.1.2 Accessibility limitations

Accessibility policies in the city influence the delivery structure and the potential of collaboration. An example of accessibility policies is the access time window of freight delivery vehicles to the pedestrian areas in Aalborg. The municipality allows freight delivery vehicles to access the city centre only during a time window from 7 AM to 11 AM. However, in most of the shops in the city centre the staff starts working at 10 AM, meaning that logistics companies have only one hour from 10 AM to 11 AM to unload the goods and drive their delivery vehicles out of the pedestrian area. Deliveries to some shops in these areas include parcel delivery by 3.5-ton vans, and pallets delivery by 12-ton or 18-ton trucks. Thus, logistics companies face a challenge to deliver the whole payload of a 3.5-ton van or 12-ton or 18-ton truck in one hour in this area. The current practice of logistics companies is to plan their delivery trips to these areas so that the trip starts with a full 3.5-ton vehicle payload in the morning, and then by 10.00 AM the majority of this payload is delivered to customers in suburban areas or on the outskirts of the city centre. At 10AM, the truck may thus have around 50% of its load or less remaining destined for the pedestrian area, which the truck then enters and delivers the goods within the remaining hour of the access time window. According to the respondents, although the total freight of the shops in the pedestrian area can be carried by only one van, typically two or three vans from a single company are used to deliver the freight to these shops to be able to deliver within the narrow time window. Therefore, limited time access to the city centre usually results in higher operational costs for the logistics companies. Besides the access time windows, there are few parking spaces for delivery vehicles in the city centre. This became apparent due to the increased number of delivery vehicles operating during the access time window. Respondents explained that the recent development of the city centre has reduced the available spaces for parking vans and trucks legally under drop-offs and pick-ups. They also stated that illegal parking occurs in companies and among drivers because there are no options for legal parking in certain parts of the city centre.

It is therefore possible that the vehicle capacity often is fully utilized when vehicles start their delivery and pickup trips, but there are still room for improving the usage of vehicle capacity on the trip, i.e. load factor. That is, driving as short distance in the city as possible with as high load utilization as possible along the trip of goods to be delivered, in the beginning of the trip, and goods collected in the end of the trip. According to the majority of the respondents, demand is not equal to logistics companies' capacity possibilities. A significant number of freight vehicles following urban deliveries and especially intercity directions have a low load factor, reaching 50% and below of the total vehicle unit capacity. In this case, collaboration potentially brings a positive effect as it can be seen as a decentralized planning system that could combine participating companies' volumes within consolidation terminal and then use fully-utilized vehicles for a last-mile delivery. Also, as we illustrated in Section 3 (modelling section) that the main idea of the collaboration is to assign the delivery requests to the closest depot so that travelled distance as well as driving time can be reduced. This in turn would lead to less driving time by an average of 25% which can help collaborating companies to deliver the goods more efficiently in the central areas of the city.

4.2.1.3 Business growth and dynamics due to e-commerce

A majority of respondents noted that currently there is a rapid growth of e-commerce industry and subsequent issue of how to serve its resulting demands within strict time-schedule. In case of potential collaboration, respondents showed a concern of how to redistribute e-commerce volumes among potential collaborative partners.

According to interviewees, increased average number of trips is partially caused by the growth of e-commerce and parcel deliveries. On the broadened picture, parcel delivery and growing rate of e-commerce potentially present two of the reasons for a low load factor. This is supported by several respondents, they emphasized the importance of heterogeneous and rapid growth of e-commerce rate in daily-deliveries, one respondent estimating a 20% increase within the last years. In addition, due to scattered nature of deliveries, customer addresses do not tend to repeat daily and therefore, this complicates the daily routing and planning activities. As such, e-commerce generates extra vehicle movements consequently influencing total number of trips and environmental impact.

Respondents also referred that this situation becomes more complicated due to the nature of e-commerce related deliveries. This is because it is difficult to predict the volumes of transported goods, and this uncertainty influences the vehicle load capacity usage negatively. Moreover, there is an extreme level of pressure on the delivery companies at major sale dates e.g. Black Friday or Christmas Sale, when the amount of order exceeds average daily amount significantly. Customers want their parcels as fast as possible, paying extra for a fast delivery. This represents a challenge for companies since their fleet capacity is not sufficient for such dramatic increase in the demands. In addition to the highly increasing demand, the majority of e-commerce deliveries are made “door-to-door”, this can also result in extra freight movements within residential areas that are sensitive to distribution during off-work hours. Some delivery companies use package boxes at shops (e.g. “pakkeshop”) or specific dedicated outdoor boxes in central areas where customers can pick up deliveries to avoid door distribution and minimize cost.

The business growth due to the e-commerce creates a high rate of return, the transportation of which also should be rearranged, and, in case of collaboration, properly scheduled with other participants. Respondents emphasize that return rate is fluctuating around 40% average from all e-commerce volumes, and such returnable shipments should also be taken into consideration in case of joint planning procedures while collaborating.

4.2.2 Challenges to collaborative freight delivery in Aalborg

4.2.2.1 Partner Selection

The interviews revealed, that there has been a long discussion in Aalborg about how to improve urban logistics. Interviews and meetings with officials from Aalborg Municipality were also conducted to understand the history of these initiatives. Our findings across all interviews emphasized diverse opinions on collaborative logistics. Partner selection was stated as the main problem in order to reach a sufficient level of trust. Namely, a compatibility of the shipments that delivery companies serve. Since some of the companies operate exclusively with palletized goods, other companies with packages and third ones with combination of two, filling the truck mainly with pallets and packages on top, it creates an extra difficulty in synchronizing delivery operations not only by the destinations, routing or vehicle capacity, but also by the type of shipments.

4.2.2.2 Loss of competitive advantage

Among the interviewees, competitive advantage might be another big challenge for collaboration, i.e. loss of autonomy. For example, when a third-party company delivers the package for the last-mile or door-to-door. In this case, according to several respondents, the final customer will not see the branding: company logo or uniform colours. The respondents emphasized that in conditions of relatively equal delivery service provided, local companies are seeking to find distinctive competitive advantages in order to retain the customer. Importance of that is explained through overall equality in companies' services to the final customer. According to respondents, local logistics market has levelled when the majority of companies started to offer similar quality of service. Under these conditions, operating limits were reached in terms of delivery schedule and tracking functionality. Therefore, companies aim for exclusive competitive advantage that could be branding, access through mobile applications or tracking features. Some of the companies see competitive advantage by branding their services, meaning not only the company's identity, but also a model of driving green and frequent use of environmentally friendly trucks for transportation. In this case, some see branding as a solid competitive advantage over other competitors, which they would like to keep even in case of potential collaboration.

Apart from that, those companies who had already implemented electrical vehicles to their fleet, indeed consider it as part of marketing campaign and branding. This argument is riddled by another part of respondents who state that branding is overrated and only an insignificant number of customers pay attention to a "green labelling" or any type of branding simply because delivery service has other customer values. As long as a delivery made on time, not damaged, and has a receipt, to respondents believe the customers will not pay attention who stands behind such delivery.

4.2.2.3 Profit and cost sharing

One respondent noted another challenge towards collaborative operations, reminding that previous experience in Denmark showed weak engagement in joint efforts between stakeholders and authorities, including lack of desire to work on the partnership in conjunction. A great importance was given to how to precisely share the benefits and transportation costs between partners considering that each company has a different financial model and price policy. The companies do not use the same pricing system thus it becomes unclear how potential benefits can be distributed among participants throughout the whole delivery including service costs.

4.2.2.4 Involvement of contracted carriers

Another challenge of companies towards potential collaboration is that logistics companies prefer to transport their loads by their trusted contract carriers rather than other carriers. As this is the case with the logistics industry in general, a number of subcontracting services is usually utilized. In some cases, the large logistics companies own the local terminal and subcontracts the delivery of the goods to a local delivery company. According to the respondents, logistics companies typically subcontract the deliveries of goods to a local delivery company.

The analysis revealed also that logistics companies will not give their profit from the last mile delivery to another company. If a solution is to work, it needs to make the delivery structure on the supply side cheaper than the current setup. If it does not do this, logistics companies will not utilize it, as there is no willingness on the demand side to pay more for a green transport in a long-term perspective. Thus, demand side leaves suppliers as the only active part of the discussion due not willing to pay for extra initiative i.e. collaborative logistics in the long run. This imposes additional difficulties.

4.2.2.4 Practice compatibility

The level of automatization in route planning was also varying. In some cases, the route choice was left to the local driver, who loaded the vehicle and planned the route him/herself. In other cases, the route was planned using IT systems in the large logistics company. Further, the method used for route planning varied depending upon the type of goods, parcel, pallet, refrigerator, heavy cargo etc. What was clear from the interviews were that all companies tried to increase the use of IT technologies for optimization. This relates both to the demands created from the hard competition, and from the logistics side, where full tracking is highly demanded.

However, one aspect of creating a better tracking flexibility to a client and internal company's routing may consequently affect extra mile running. That is, an expansion of functionality available to the customer e.g. an ability to change pick-up location while goods are on the way. However, in this case, the flexibility in deliveries could result in detour and extra freight movements within central areas as well as in residential areas, sensitive to any vehicular traffic. This can also bring difficulties to collaboration since routing systems should support better flexibility in terms of orders and routing changes. The respondent concludes, offering such flexibility can only work through fully automated routing software, which would account not only other possible pick-up points for the client, but also considering traffic, local construction sites, and other factors.

5. Conclusion

This report has analyzed the opportunities and challenges of collaborative logistics in an urban logistics context. The study investigated the potential benefits of collaboration among competing logistics providers in reduction of travelled distance by freight vehicles within the city center, as well as challenges of implementing such an approach within Aalborg.

The first line of conclusion from this study relates to the benefits of collaboration. It was found that horizontal collaboration is one of the most suitable approach for green urban logistics. The analysis also revealed that such horizontal collaboration should rely on order sharing. The report used a mathematical model to quantify the benefits of order sharing between actors in terms of total travelled distance and CO2 emission, using real-life data.

The results showed that the collaborative distribution could reduce the total travelled distance of each carrier by an average of 24.75% compared to the non-collaborative distribution. Some logistics companies argued that they didn't expect collaboration to be beneficial for them, as their depots were close to the considered delivery area. However, the analysis showed, that the company closest to the delivery area was also the company that gained the largest benefits from collaboration. This is thus a highly relevant finding. Additionally, the analysis showed that collaboration can generate benefits in terms of CO2 emission reduction and decrease the total travelled distance by freight vehicles in the city.

Another key finding was, that the simulation showed, that even if the companies did not share all orders, a significant reduction of driven distance and thus CO2 emissions was still possible. This means, that just by collaborating on a part of the full order set, delivery companies are able to achieve significant benefits from collaborative logistics in a city as Aalborg.

The second line of conclusions relates to the barriers for implementing collaborative logistics in daily operations. This issue was analyzed through semi-structure interviews conducted with representatives of six logistics companies delivering freight within Aalborg. It was found, that part of the barriers towards such collaboration is centered around technical and operating challenges: diversified cargo types, different accounting and dispatching systems used by carriers. Partners need to be assured of a fair distribution of benefits, i.e. a cost sharing algorithm has to be in place to secure transparency and trackability. Another concern is loss of branding in situations when goods are delivered by a collaborative partner. Some respondents consider branding as a competitive advantage over other competitors, and therefore they are reluctant towards collaboration, which will result in delivery of their cargo by other companies.

In regard to overcoming the technical issues, the analysis showed that knowledge was a key factor. Knowledge about the potential benefits that can be gained for the individual company, as an example, even in the case of central depot location. Also, knowledge about how to collaborate, and fairly share benefits, for example by implementing a profit-sharing algorithm in the system. To reap the full potential benefits of collaboration, a certain amount of knowledge sharing and synchronization on a general level is necessary. The companies do not need to reveal confidential business knowledge, but a general understanding of mutual delivery systems and delivery structures are needed.

The interview analysis revealed that there is a support for collaboration among stakeholders, however, these stakeholders had a low awareness of potential benefits of collaboration. The analysis also revealed an important finding, that despite a hard competition between the logistics companies, the respondents from the different logistics companies still regarded themselves as colleagues facing a difficult task, i.e. delivery in an urban area. This means, that there is a mutual knowledge base to build collaboration on. The numerical analysis in the report has proven that there are benefits to be gained from collaboration, and the existence of a mutual understanding, and a regard between the companies as colleagues facing a challenge, means that this analysis has paved the first important step towards increasing the awareness of benefits of collaborative logistics, by suppling the needed knowledge about actual benefits.

The analysis also revealed a need for the engagement of public authorities to overcome the obstacles faced by companies trying to implement collaborative logistics. One of key challenges is to involve stakeholder's into in-city logistics planning procedures to achieve the common level of coherence between freight logistics companies and local authorities. More specifically, the analysis showed that issues relating to urban freight policies measures, e.g. environmental zone, time access restriction, infrastructure changes, parking opportunities etc., has to be reconsidered in a light of collaboration, i.e. how can the municipality create a good environment for collaboration, by aligning urban freight policies towards collaboration.

Future research should focus on how to overcome the barriers identified in this report. The next step will thus be to address the barriers in more detail. As an example, the next step could be to establish a formalized network of major stakeholder representatives and city authorities, where the specific barriers and possible solutions could be discussed.

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