Smoovit - System of systems for sustainable urban goods transports

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1 Sammanfattning på svenska

Smoovits syfte var att undersöka, med en system-av-systems-ansats, hur olika transportaktörer, fysiska resurser och transportaktiviteter kan kombineras för att uppnå hållbar citylogistik. Projektet var organiserat i följande arbetspaket med olika teman.

Arbetspaket 2b utvecklade en affärsmodellshypotes för Smoovit som syftade till att skapa mer effektiva och hållbara stadsleveranser. Kort sagt definierar affärsmodellen en tvåfaldig värdeproposition: transportörer kan utföra Smoovit-transporter, eller de kan delegera leverans av försändelser till Smoovit. Resultatet är en hybrid-affärsmodell som kombinerar flera intäktsströmmar.

Arbetspaket 2c utvecklade en metod för system-av-systems (SoS) ingenjörskap som hanterar hög flexibilitet och beslutar om krav och driftskoncept sent i utvecklingsprocessen. Metoden innehöll tre steg:

1. SoS-initiering: Definiera den intressanta SoS-enheten, SoS-mål, SoS CS-typer, SoS CS-roller.
2. SoS-koncept: Utveckla SoS driftskoncept, SoS-krav och SoS arkitekturdesignalternativ baserat på arketyper.
3. CS-förmågor: Identifiering och design av arketyper för generiska förmågor.

Arbetspaket 3 fokuserade på att leverera en mjukvarusystem prototyp som underlättade ett system-av-systems för stadslogistik (Smoovit Management System). Målet var att ge transportköpare och leverantörer ett konkret exempel på hur ett medlande mjukvarusystem kunde påverka nuvarande verksamhet och möjliggöra validering av resultat och hypoteser från arbetspaket 2.

Arbetspaket 4 utforskade möjligheterna till hur policy och reglering kan samverka med IT-systemutveckling för att öka möjligheten till ett hållbart poolnings-system.

Den miljöanalys som utfördes inom arbetspaket 5 hade som mål att: Samla standardhållbarhetsvärden för transportsystem relaterade till eller påverkade av Smoovit, med användning av modellerade data från källor som NTM och HBEFA. Dessutom samlades driftsdata in från nuvarande trafik för att förbättra beräkningsnoggrannheten för specifika parametrar.

Arbetspaket 6 etablerade, med hjälp av en Living Lab-ansats, ett samarbete för sista kilometerns leveranser mellan Smoovits partner. Hypotesen var att genom att samordna leveranser i en distributionsnod i staden kunde en hållbar leveransvolym uppnås med färre fordon på vägarna. Trots att samarbetet först var en pilot för att testa hypotesen har det utvecklats till en välfungerande och robust Smoovit-märkt verksamhet som kommer att fortsätta efter att det av Vinnova finansierade projektet avslutas.

2 Executive summary in English

Smoovit's purpose was to investigate, with a system-of-systems approach, how different transport actors, physical resources and transport activities can be combined to achieve sustainable urban logistics. The project was organized into the following thematic work packages.

Within work package 2a, different variants and concepts for pooling, or co-loading, have been developed and explained.

Work package 2b developed a business model hypothesis for Smoovit that aimed to create more efficient and sustainable urban transports. In short, the business model defines a two-fold value proposition: transporters can carry out Smoovit transport, or they can delegate delivery of shipments to Smoovit. The result is a hybrid business model that combines several revenue streams.

Work package 2c developed an approach for system-of-systems (SoS) engineering coping with high flexibility and deciding on requirements and concept of operation late in the development process. The approach contained three steps:

1. SoS Initiation: Define the SoS of interest, SoS objectives, SoS CS types, SoS CS roles.
2. SoS Concepts: Develop SoS concept of operations, SoS requirements and SoS architecture design alternatives based on archetypes.
3. CS Capabilities: Identification and design of archetype generic capabilities.

Work package 3 focused on delivering, a prototype software system facilitating a SoS for urban logistics (The Smoovit Management System). The aim was to provide transport buyers and providers with a concrete example of how a mediating software system could affect current operations, and to enable validation of the findings and hypotheses from work package 2.

Work package 4 explored the possibilities to how policy and regulation can work together with IT systems development to increase the possibility of a sustainable pooling system

The environmental analysis in the work package 5 aimed to: Gather standard sustainability values for transport systems related to or impacted by Smoovit, using modeled data from sources like NTM and HBEFA. Also operational data was collected from current traffic to improve calculation accuracy for specific parameters.

Work package 6 established, using a Living Lab approach, a last-mile delivery collaboration between the Smoovit partners. The hypothesis was that by consolidating deliveries in a city distribution hub, a sustained delivery volume could be achieved with fewer vehicles on the road. Although initially piloted to test the hypothesis, the collaboration has been developed into a well-functioning and robust Smoovit-branded operation that will continue after the Vinnova funded project ends.

3 Background

It is evident that urban deliveries are important, but also a source of problems. On the one hand, efficient deliveries ensure the supply of goods at stores and at home. On the other hand, delivery traffic contributes to congestion, emissions of greenhouse gases, local air pollution, accidents and noise that impact adversely on the quality of life (Crainic et al, 2004). Urban logistics account for around 20-50% of the emissions of air pollutants (depending on the pollutant considered) by transport activities in a city, although they represent only 20%-30% of urban road traffic (Dablanc 2007). Reversing the perspective, freight vehicles are delayed by congestion and are constrained to carry out deliveries because of insufficient parking spaces and long dwell times when accessing receivers, reducing the efficiency of urban logistics operations (Hesse and Rodrigue, 2004). Urban logistics therefore presents one of the major challenges **for both urban sustainability and freight transport efficiency.**

A study in the EU project NOVELOG (civitas.eu, 2023) showed that that there are inefficiencies when it comes to deliveries in the central parts of the city of Gothenburg, Sweden. As one example, it was found that just a third of the goods delivered was causing 90% of the city traffic—indicating opportunities to improve efficiency. This is, however, not the case for all transport providers in the city of Gothenburg. As demonstrated in the SMOOTh pre-study (Vinnova/FFI:2018-02016) **some trucks do operate very efficiently, and some others do not.** Additionally, there is an unwillingness due to organizational and contractual constraints to participate in consolidation schemes leading to a scattered market of actors for urban logistics (Browne et al 2005).

Urban areas increasingly suffer from congested traffic, pollution, noise and low effectiveness from transports (Browne, Allen, Nemoto, Patier, & Visser, 2012). While such transports are critical to the functions of a city, an often used way of alleviating some of these problems is **urban freight consolidation** (Anderson, Allen, & Browne, 2005). The intention of such initiatives is to identify freight transports with low fill rates and group them with other less-than-truckload consignments to manage more freight with fever vehicles. An additional response of alleviating urban logistics negative impact is **Urban Consolidation Centre's (UCC)** within or in proximity to urban areas to enable using fewer, larger and more efficient trucks in urban areas. However, such initiatives are **frequently troubled by a lack of long-term business viability** and shifting degrees of support from stakeholders (Dablanc, 2007; Sternberg, Linan, Prockl, & Norrman, 2022). Cities frequently do not have an authority responsible for freight transport issues (Zunder & Nicolás, 2004) and it is frequently viewed as a private industry with little regulation (Crainic, Ricciardi, & Storchi, 2004). Local authorities are also subject to political 'short-termism' and contradictions within policy objectives (Hull, 2005).

To optimize the use of UCC and to manage the above stated challenges requires a dynamic decision-making system to know when to channel goods through the UCC, as well as an increased collaboration among transporters, receivers, and local city regulations. To create collaborations to reduce negative sustainability impact of urban logistics, the Smoovit project applied a system-of-systems (SoS) approach, combining sharing of information, physical infrastructure of trucks, cargo bikes and consolidation hubs, as well as polity and regulation mechanisms and incentives through business models. Furthermore, the full approach was co-created, tested and evaluated in the real living lab in the city centre of Gothenburg (the Nordstan mall area). Additionally, the aim was to develop a prototype software facilitating actor collaboration in the SoS, as well as to develop an evaluation methodology to understand the sustainability effects of consolidation.

As collaboration has been essential, a broad consortium consisting of 11 parties was established for the project. With involvement from Gothenburg city (Traffic Authority and Swedish Traffic administration), transport providers to solve logistic issues (GLC, DHL, BEST, PLING, Velove), demands from real estate owners (Nordstan Samfällighet, a vehicle manufacturer (Volvo) to find new innovative and sustainable transport solutions, and RISE and IVL to support with research insights.

4 Purpose, Methodology and Research Questions

4.1 Purpose

The purpose of the Smoovit project was to improve sustainability of urban transports with the underpinning hypothesis that, by establishing a goods flow with sub-urban consolidation hubs and city distribution hubs, a sustained goods flow would be accomplished with fewer vehicles on the road (as depicted in the figure below).

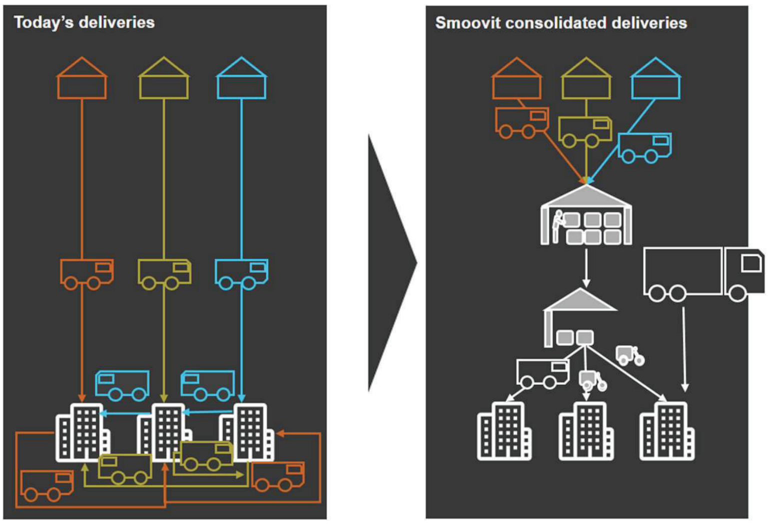

Figure 1 The consolidated goods flow as envisioned in the Smoovit project

Establishing such a consolidated goods flow presents a range of challenges that must be addressed. Therefore, the Smoovit project addressed incentives to establish mutually beneficial **collaboration between transport providers and buyers**, how existing **physical infrastructure**—such as trucks, cargo-bikes, consolidation hubs—can be utilized more efficiently, requirements on supporting **IT-systems** for information sharing, dynamic decision making and coordination. These investigations combined with exploring **sustainable business models,** and **policy and regulations mechanisms** were done to build knowledge of how a **system-of-systems (SoS) approach** can create more **sustainable urban logistics.**

4.2 Methodology

The Smoovit project was divided into 6 work packages (WP), each focusing on a specific aspect of the common challenge, with their own research questions and methodology, and with the Project management (WP1) continuously ensuring alignment between the WPs.

The WPs, each separately presented with background, purpose, research question and result in chapter 6, were:

- WP1 Project management
- WP2a Transport Plan
- WP2b Business Model
- WP2c SoS concept
- WP3 SoS Development & Integration

- WP4 Policy and Regulations
- WP5 Sustainability Model
- WP6 Living Lab

4.3 Research Questions

Each WP addressed specific research questions as summarized below, and with more details provided in chapter 6.

- WP2b How can a sustainable business model be designed to incentivize participation in the Smoovit system?
- WP2c How can 'late binding' of design decisions be achieved in SoS projects?
- WP2c How can current SoS engineering methods support practitioners faced with wicked SoS problems?
- WP3 How can the Smoovit IT system be designed in order to maintain data integrity and trust?
- WP4 How policy and regulation can work together with IT development to increase the possibility of a sustainable pooling system?
- WP5 Which of several available transport options leads to the smallest environmental impact (ex ante) and Which environmental impact should be linked to a completed transport (ex post).
- WP6 How can the urban logistics stakeholders be involved in implementing a Smoovit demonstrator?

5 Objective

The objective of the Smoovit project was to develop and demonstrate concepts to make urban goods distribution profitable and more sustainable by taking a SoS approach as point of departure.

In a SoS, the "system" as a whole (urban goods distribution) comprises loosely coupled constituent systems (e.g., transport providers, hub operators), where the constituent systems (CS) are managerially and operationally independent. This independence means that the CSs function well on their own without a strict need to be part of the SoS—illustrated in the left part of figure 1, where each transporter performs their missions independently of other transporters.

However, the hypothesis motivating the Smoovit project was that, by operating separately, the transporters risk sub-optimizing the goods flow. By instead collaborating—as illustrated in the right part of figure 1—a consolidated goods flow can be established which should increase vehicle fill-rates and thereby support a sustained goods flow with fewer or more appropriate vehicles, thus resulting in more sustainable transports. The SoS approach was considered to offer a promising model to establish such a collaboration.

There are, however, several well-known challenges in establishing a SoS. Among those are: how to incentivize CSs to collaborate in the SoS instead of acting on their own (e.g., by developing lucrative business models, establishing new policies and regulations, and collaboration arenas); how to coordinate operations among the actors (e.g., by mediating IT-systems); how to measure and control the SoS to ensure an efficient and more environmentally neutral transport chain.

The project addressed these challenges through information sharing (an IT-system), a multi-modal physical cargo flow combining larger (electric) freight vehicles for more efficient transports from suburban areas to the city hubs enabling trans-shipments to light and electric vehicles for the last-mile distribution. Additionally, the project aimed to developed methods to evaluate the sustainability potential of urban logistics solutions from a system perspective in terms of transport efficiency, transport quality, traffic safety and environmental impact, enabling the management of trade-offs between the different transport needs.

The development, implementation and validation of the suggested Smoovit SoS solution was based on the well-pronounced desire among the partners for collaboration. This willingness to collaborate between key organizations along the transport chain allowed the construction of a SoS with access to relevant physical and information resources. The diverse composition of the project group ensured that both internal and external advantages and disadvantages could be identified and evaluated. Furthermore, the design of and interaction between incentives (business models) and disincentives (regulations, policies, and demand management) was identified as central for implementation of a similar SoS for urban logistics in other cities.

The project also established a living lab to enable co-creation and testing of the system-of-systems in a real context. The overall goals, as specified in the project application, were:

1. Development of a SoS for urban logistics (WP2c, WP3)
2. Design of a sustainable business model for fair sharing of the efficiency gains generated within the SoS, hence giving the incentive to participate in the SoS (WP2b)
3. Development of an evaluation methodology for assessing the logistics efficiency and sustainability effects to avoid negative side-effects and sub-optimisation of consolidation (WP5)
4. Development of policies and regulations to support effective consolidation (WP4)
5. Continuous demonstration in a living lab of a SoS for urban logistics in close cooperation with the urban logistics stakeholders (WP6)

6 Results

As each work package addressed a specific aspect of the common project challenge, with WP1 coordinating and aligning results, this chapter reports the details of each work package separately.

The initial deliveries as stated in the application, and with comments in italic:

D1. A validated plan for the transport operations of integrated and consolidated multi-modal urban logistics. *Draft plan that was the base for the real setup in the living lab.*

D2. Incentives and business models for integrated and consolidated multi-modal urban logistics. *A hypothesis of a two fold business model value proposition done.*

D3. A model for designing a SoS for urban logistics enabling integrated and consolidated urban logistics. *Done in WP2.*

D4. A prototype software facilitating the SoS for urban logistics. *Done in WP3, the Smoovit Management System.*

D5. An evaluation tool for analyzing the transport efficiency, logistics quality and environmental impact of urban deliveries. D*iscussed in WP5.*

D6. Guidelines for policies and regulations as well as demand management measures supporting integrated and consolidated multi-modal urban logistics. *Initial job done ending with the survey done spring 2023.*

D7. A living lab in the city of Gothenburg demonstrating integrated and consolidated multi-modal urban logistics. *Done combining Volvo Electric Trucks and cargo-bikes that will continue after the Vinnova-project ends.*

D8. Establishment of (i) one new UCC for consolidation of cargo flows brought into (ii) one new city-hub for the transhipment from trucks to light electric vehicles in Gothenburg city. *No new UCC but use of existing hub via Pling.*

D9. An assessment of the improvement potential of a full-scale implementation of Smoovit in the city of Gothenburg. *Since a full scale potential concept was not defined the improvement potential was hard to define since the main focus was to get the living lab activities going.*

D10. Dissemination activities, *8 seminars done and 2 articles published, see chapter 7.*

6.1 WP2A—Transport Plan

Consolidation of goods to recipients in central parts of cities can be realized in several different ways. Within work package 2a, different variants and concepts for pooling, or co-loading, or consolidation, have been developed and explained. The starting point has been models developed in logistics research based on the needs of various actors and the possibility of finding physically feasible collective loading concepts. The purpose of the work within WP2a has been to conceptualize the thoughts and ideas that emerged in the project and deliver thought support for the development of business models and IT systems for Smoovit Appendix 1 presents a summary and results of the work carried out within the framework of work package 2.

6.2 WP2B—Business Model

From a commercial perspective, the Smoovit goods flow was designed with three main building blocks: the brand, the use of existing physical infrastructure and the IT system.

Work package 2b aimed to explore, create and evaluate business model hypotheses for sharing efficiency gains within the Smoovit's System of Systems (SoS). The central topic in the work package concerned **how to design a sustainable business model that incentivizes participation** in the Smoovit SoS.

A design thinking process was applied, with data collected from multiple sources. The exploratory phase utilized methods such as stakeholder analysis and business model canvas development.

6.2.1 WP2b Purpose and research questions

The primary purpose of work package 2b was to explore, create and evaluate various business model hypotheses for sharing the efficiency gains generated within the Smoovit System of Systems (SoS). These efficiency gains refer to the benefits derived from utilizing the Smoovit SoS, including reduced costs, improved quality of service, increased customer satisfaction and enhanced sustainability. The business model hypotheses outline how the value proposition of the Smoovit SoS can be delivered to and captured by the various actors involved in the system, such as transport providers, potential customers, regulators and intermediaries.

The central research question addressed in work package 2b was:

- How can a sustainable business model be designed to incentivize participation in the Smoovit system?

6.2.2 Method

To answer this question, a design thinking process was applied with support from service design methodologies. Data was collected from multiple sources to gain a comprehensive understanding of the stakeholder landscape and the needs and preferences of potential users. Data collection methods included interviews with key stakeholders, a benchmark study of similar initiatives and several workshops with consortium members and external experts.

The exploratory phase of the project utilized methods such as stakeholder analysis, business model canvas development, lean start-up approach and testing. Feedback from consortium members was incorporated throughout the process to create a business model that would support and contribute to a more sustainable urban delivery system.

6.2.3 Objective

The objectives of this work package were aligned with the overarching goals of the research project and aimed to develop a business model that would support the transition towards a more sustainable urban environment.

Specifically:

1. the business model should be designed to decrease the amount of vehicle movement within city centres
2. reduce the number of kilometres driven by vehicles
3. decrease exhaust emissions
4. increase the service offerings for potential users

The expected outcome of this work package was a proposed business model hypothesis that supports the overall purpose and objectives of the project. By achieving these objectives, the business model would contribute to creating a more sustainable city environment.

6.2.4 Results and deliverables

Work package 2b has developed a business model hypothesis, see figure 2 below, for Smoovit that aims to create more efficient and sustainable urban transports with higher fill-rates. The value proposition of Smoovit is two-fold: first, transporters can carry out Smoovit transports to contribute to more efficient urban transports and generate new revenues, and second, they can hand over shipments to Smoovit to avoid performing inefficient transports, thereby becoming senders. This will lead to less costly last mile deliveries and reduced congestion in cities.

The result is a hybrid business model that combines several revenue streams. The hybrid model includes the outsourcing of last mile/meter deliveries by transporters, a marketplace for local producers to buy a cheaper consolidated transport, extra services such as storage solutions for businesses in cities, nudging and investing by real estate owners to promote and subsidise usable space for Smoovit actors, and adaptable policies that can be tailored to local requirements.

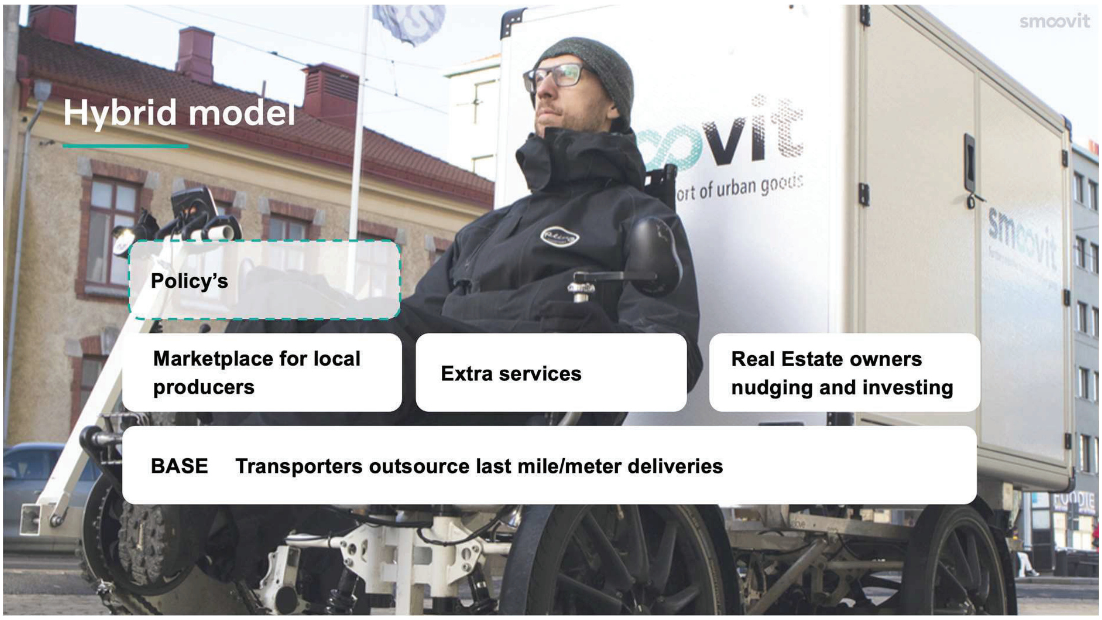

Figure 2 business model hypothesis

Smoovit is proposed to be designed with three main building blocks: The use of existing physical infrastructure for consolidating hubs and vehicles through transporters (1) integrates with an IT system for route matching and sustainability modeling (2) - all these under the new brand 'Smoovit' for business offerings and agreements optimisation (3). By leveraging existing infrastructure, Smoovit aims to meet its objectives of decreasing vehicle movement within city centres, reducing the number of kilometres driven by vehicles and decreasing exhaust emissions. The provision of a strong brand is expected to fulfil parts of the fourth objective of increasing service offerings for potential users, while the Smoovit IT system is anticipated to contribute to all stated objectives.

Complementary findings from interviews conducted within this work package revealed that transporters and last mile carriers often struggle with low margins. While many actors want to contribute to sustainable solutions, few are currently willing to invest or pay extra for them. Sharing data between actors can be challenging, and branding/visibility within the cities is important for larger carriers. There is a trend towards smaller, more frequent orders and a need for cheaper storage solutions in cities. Local political restrictions can also pose challenges.

6.3 WP2C—Smoovit SoS Concept

6.3.1 Background, purpose and research question

The main goal with WP2c has been to find an approach for SoS engineering coping with high flexibility and deciding on requirements and concept of operation late in the process. As part of this work, WP2c aimed to answer the following more generic and refined research questions:

- How can ‘late binding’ of design decisions be achieved in SoS projects?
- How can current SoS engineering methods support practitioners faced with wicked SoS problems?

As described in the background section, the operational environment of urban logistics can be construed as a “wicked problem” (Rittel & Webber, 1973). Among other things, it is characterized by: difficulty in reaching consensus of the nature of the problem; proposed solutions are costly tradeoffs, and; every new urban setting is likely unique, making it difficult to apply standard solutions. Indeed, considering the presence of the following complexities, the SoS context can be characterized as “super wicked”(Levin, Cashore, Bernstein, & Auld, 2012): Problems of this type is seen as increasing over time, also those seeking to end the problem are simultaneously causing it. Furthermore, there is no central authority dictating the terms and conditions, and current policies (or lack thereof) seem to discount the future in favor of short-term gains.

Requirement engineering methods in general tend to assume the existence of a keystone actor that can define and set the overall scope and scaling of the system to be developed. However, key tenets of ‘super wicked’ problems (Levin et al., 2012) are that there is no keystone stakeholder to rely on and that the actors needed to solve the problems are involved in creating it. This type of complexity calls for alternative development strategies and methods. The SoS engineering perspective acknowledges complexity in terms of relationships between constituent parts and is thus a promising way of illustrating these problems.

6.3.2 *The wicked case of city logistics*

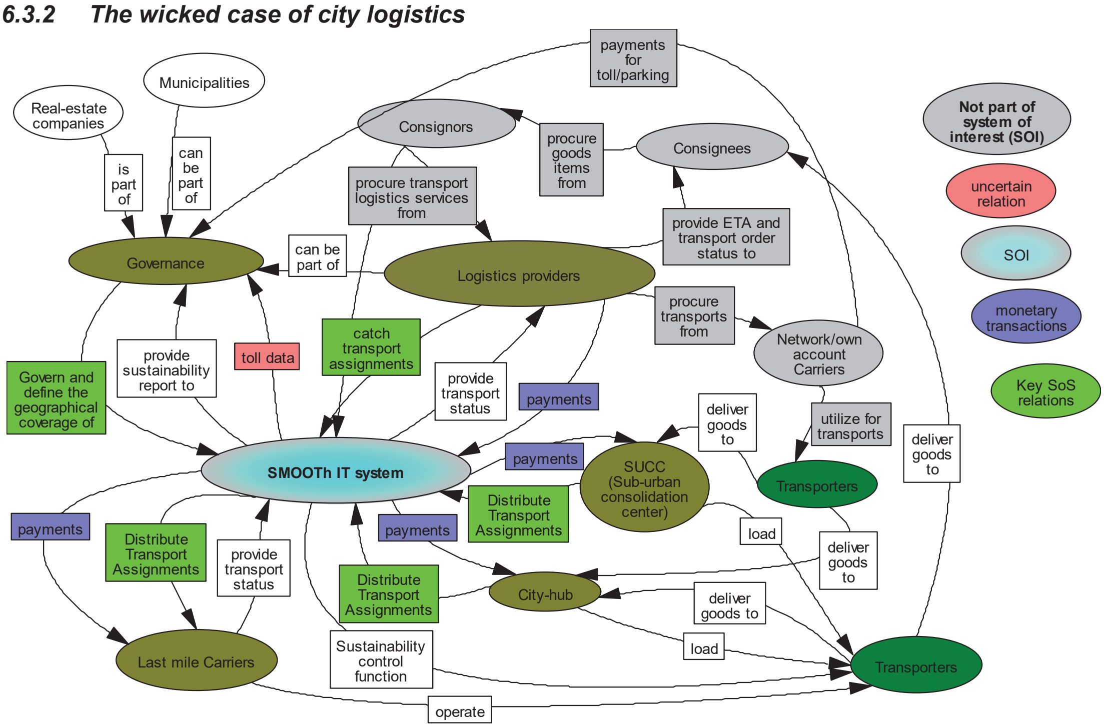

Figure 3 An early systemigram describing the system of interest (SOI), actors, relations and environment of the Smoovit SoS.

The case concept operation was based on the logistical assumption that targeted improvements can be achieved by redirecting current transports to a sub-urban consolidation center for further transports to a city hub located in the mall at the city center. Today all transports are performed on an open and unregulated market where consolidation, if at all present, is performed at the logistics operator enterprise level. To reach the aims of the project, certain strategic mechanisms were thought of as possible incentives for logistics operators to change their operation and participate in the SoS. Such strategies include:

- Political and regulatory frameworks, e.g., banning certain size of vehicles, noise levels, pollution levels in city areas
- Commercial frameworks decreasing or increasing costs e.g., taxes for use of certain transport types and or infrastructure
- Technical and physical infrastructures facilitating certain transport types and processes
- Cultural and behavioural influences, e.g., branding and certification of sustainable transports providing an improved consumer choice

However, as it turned out, all of these proved difficult to achieve. The municipality was hesitant to put in place regulations or taxes for political reasons, yet unwilling to rule them out over time. Consequently, regulatory support could not be implemented or detailed as an element of the SoS, but it could not be discounted either as it was thought to come into effect in the near future. Without actual regulatory support, it proved challenging to find a business model covering additional costs and catering for the needs of consignees and consignors as well as the transport organizations involved. Yet actors were still keen to participate in testing solutions. Ultimately, whereas several stakeholders were willing to participate, they could not agree on setting a strategy from which a SoS design process could be initiated. There was an additional expectation that the IT components developed should be scalable to other similar cases and cities where other strategies and relations among otherwise near identical stakeholders may very well be in place.

Seeing as there were little in terms of a stable common problem or solution definition, but still a high degree of commitment, the SoS design needed to be open for various strategy changes late in development of its IT supporting and facilitating functions.

In most SoS design processes, a set of 'archetypes' are frequently utilized early on as a means of visualizing and choosing the conceptual mechanics of an intended SoS (Rylander & Axelsson, 2021). In our case, a 'directed' SoS would entail a high degree of policy guided control of operations and goals whereas a 'collective' would build solely on voluntary contributions of freight and resources on commercial grounds. An acknowledged archetype was envisioned as somewhere in between these two extremes.

In terms of possible SoS archetypes, not only was none of the four most frequently cited in literature proven decisively optimal. In addition, only one of them could be rejected. This left any attempt at using an SoS archetype as a stable foundation for a conceptual design tenuous. Owing to the challenges involved in finding a specific optimal conceptual SoS solution, to move the process forward, an alternative path was chosen involving revisiting SoS development literature and forming a set of coping strategies to alleviate the inherent contextual uncertainties.

6.3.3 Related work

The study of System of systems (SoS) is a Systems Engineering sub-field that offers methodology and tools to design and manage systems with specific characteristics. In a SoS independently useful constituent systems forms a larger system to deliver unique capabilities (DoD, 2008). A SoS comprise independent constituent systems (CS) (ISO/IEC/IEEE, 2019) and mediators (Svenson & Axelsson, 2021). Mediators are enabling systems needed for the SoS to function. A SoS can, furthermore, include keystone systems which are a type of central management system for the SoS. Not all SoS have a keystone system, but the existence and behaviour of a keystone greatly affects the nature of a SoS.

Maier present five principal characteristics to distinguish monolithic systems from true systems-of-systems, these are (Maier, 1998):

1. Operational independence
2. Managerial independence
3. Evolutionary development
4. Emergent behaviour
5. Geographical distribution

The first two (managerial and operational independence) address the characteristics of the constituent systems and the last three characteristics of the SoS as a whole.

A SoS includes constituent systems (CS) that form the SoS. Based on design pattern the SoS may include a keystone system that manage the SoS. Further, different mediator systems may be included to enable and facilitate the SoS purpose and CS interactions. The orchestration of the SoS can be categorized by its design pattern (J. S. Dahmann & Baldwin, 2008):

- **Directed** - SoS with common objectives, a designated manager, and resources for the SoS. A keystone directs and/or specifies changes in the SoS
- **Acknowledged** - SoS with recognized objectives, a designated manager, and resources for the SoS. Changes in the SoS are based on collaboration and negotiation.
- **Collaborative** - CS's interact voluntarily to fulfill agreed upon central purposes. There is no keystone that control the SoS.
- **Virtual** - SoS that lacks a central management and a centrally agreed upon purpose.

The design patterns can be useful both to recognize, describe, and understand the characteristics of an existing system, and in the design process to realize a new system (Boardman & Sauser, 2006). Kazman, Schmid, Nielsen, and Klein (2013) argue that a SoS must be regarded as integrated systems only in some use cases. When making design choices about a SoS they stress the importance to understand those use cases.

DoD (2008) define seven core elements for systems of systems engineering where the first element is to translate SoS capability objectives into SoS requirements. To be able to translate, the capabilities need to be known. We argue that the capabilities of the SoS is based on the strategies of the SoS. In this project, the overall objectives and desired effects are known, but the exact strategy and means for how to reach them have not been agreed upon or decided by any type of long-term viable stakeholder constellation. As the SoS therefore needs to be flexible to different strategy implementations, there are use case and capability variations for the integrated systems and constituent systems based on the direction of choice. As this SoS is regional, the reuse of artifacts for other regions, where other strategies may apply requires a flexible and generic construct of artifacts.

J. Dahmann, Rebovich, Lane, Lowry, and Baldwin (2011) presented a wave model method which provides the foundational information to start the SoS systems engineering (SE) process. This includes an understanding of objectives, key users, user roles and expectations as well as supporting capabilities. Such information includes the top-level objectives and SoS concept of operation (CONOPS). A CONOPS describes the proposed system in terms of the user needs, its relationship to existing systems or procedures, and the ways it will be used (IEEE, 1998).

In summary, the main goal with the work presented here was to find an approach for SoS engineering coping with high flexibility and deciding on requirements and concept of operation late in the process.

6.3.4 Method

This research has been informed by design science methodology. Design science is a paradigm for conducting and communicating applied research. It describes an iterative method to construct artifacts with the goal of fulfilling utility according to set of guidelines. This includes ensuring rigor by utilizing and addressing previous research, treating design as a search process, and guidelines to the evaluation of results (Hevner, March, Park, & Ram, 2004). The work utilizes the knowledge base described within SoS engineering and the Wave model (J. Dahmann et al., 2011) in particular. We have very much viewed design as a search process. The case setting invited satisficing (Simon, 1969), without explicitly specifying all possible solutions, or the optimal solution. This was achieved by constant interactions with the project stakeholders throughout the duration of the 3-year project coupled with literature studies.

Our main evaluation method was analytical. The sought-after flexibility of the results and its generalizability were validated through regular meetings with key stakeholders who were part of the project group as well as skilled experts involved in the execution and assessment of the results. The main means of involvement of key actors has been through interviews, meetings and workshops both in the construct of artifacts as well as for their assessment.

6.3.5 Results

As described in preceding sections, the setting proved to be difficult to pin down for several reasons among which the lack of obvious strategic ownership and keystone, conjoint problem causers and solvers, and agreeing upon problem definition were the most prominent. The emerging SoS therefore needed to be flexible towards changes in strategies that affects the ‘Concept of operations’ (CONOPS). For this reason, the key elements, defining the interactions of the component systems needed to be generalized so that it could scale towards alternative future strategies whilst remaining interoperable with changes to archetype and CONOPS.

High-level case objectives were identified but simultaneously the CONOPS could not be decided upon due to the need to adapt to changes in strategy over time. In such environments where possible up-front decisions are few and continuous updates and changes to strategic decisions is sought for, the current literature provides little guidance for the SoS SE development process. For this reason, a late binding approach is suggested. We refer to this as the ‘Wicked wave model’ (Rittel & Webber, 1973). The remainder of this part describes the model, on a conceptual level, as a method to find archetype agnostic capabilities for a SoS CONOPS design with late binding. The model is an adaptation of the Wave model presented by J. Dahmann et al. (2011). The method utilizes the SoS archetypes with the purpose to identify and describe CONOPS alternatives. These alternatives are further analyzed to identify lower level SoS core capabilities. Of these capabilities, those that can be made generic and flexible towards strategy changes affecting the SoS CONOPS are prioritized. These archetype- and CONOPS-generic capabilities are suggested as a starting point for development of IT artefacts to facilitate latest possible binding to concept and strategy dependent capabilities. To identify the generic capabilities, multiple options need to be modeled and somewhat iterated to adapt and find generic capabilities.

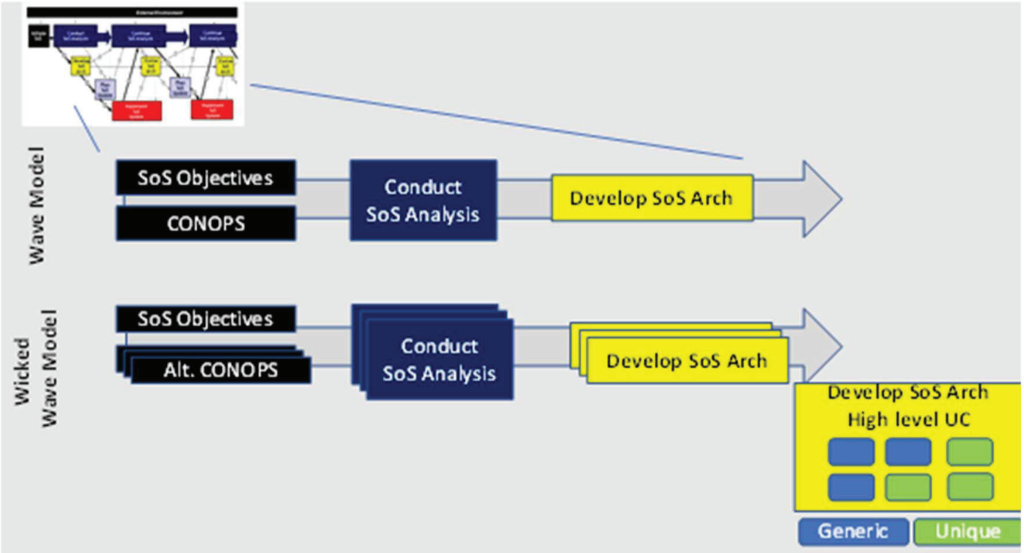

Figure 4 The Wicked Wave Model supporting late binding and requirement change flexibility

The method is based on the following steps:

1. **SoS Initiation:** Define the SoS of interest (SoSoI), SoS objectives, SoS CS types, SoS CS roles.
2. **SoS Concepts**: Develop SoS CONOPS, SoS requirements and SoS architecture design alternatives based on archetypes.
3. **CS Capabilities**: Identification and design of archetype generic capabilities.

The SoS Initiation

The project SoS is an adaptation of a current logistics system where key users and roles are well developed. The main objective of the SoS is to adapt the current SoS to achieve certain effects. To achieve the desired effects several design options and strategies are possible. For this reason, several CONOPS are possible. The logistics system is a complex operation where several stakeholders, interests, and roles exist. The larger logistics system is a global system where the SoSoI in the project is limited to a specific geographical area where desired effects are sought. To define this SoSoI the generic CS types need to be understood. The characteristics of CSs are defined [2] as "*Constituent systems can be part of one or more SoS. Each constituent system is a useful system by itself, having its own development, management, utilization, goals, and resources, but interacts within the SoS to provide the unique capability of the SoS.*"

The following constituent system types with described roles was identified that fulfil the described CS characteristics:

- **Logistics providers** – A logistics provider is a person or a company responsible for organizing transports of goods from one point to another (E2E). Logistics providers, or 'freight forwarders' procure physical transports from one or several carriers to execute transports legs.
- **Carriers** – are legal entities that provide physical transport capacity. Carriers utilize and organize 'transporters', which consist of a resource combination including drivers and physical vehicles, capable of transporting goods.
- **Hubs** – The primary task of the hubs are to perform inbound transport consolidation to hub-outbound but can also functions as a delivery point where consignees collect their deliveries

All CS types fulfil the characteristics of a SoS as they can be separate enterprises, often with competing interests, that have operational and managerial independence, and evolutionary development. Additionally, the SoS itself fulfils the characteristics of emergent behaviour and geographical distribution.

To construct a SoS including the described component systems that meets the objectives and capabilities identified requires facilitating artefacts that includes IT-systems. In this context, the IT-system can be considered a mediator, or indeed a keystone, depending on the strategy and CONOPS, as well as which effect role and archetype design pattern that is chosen for the SoS. To understand the design choices and how they influence CS capabilities and interactions, different CONOPS and architectures can be modelled based on the archetypes.

SoS Concepts

Based on our analysis, the following system design choices were made based on interpretations of the archetype differences in characteristics. The Virtual archetype characteristics lack the existence of a common goal, whereas the goal of the SoS in our setting is clear and forms the basis for collaboration among the component systems; the Virtual archetype is therefore excluded from our analysis.

Directed archetype: In the Directed archetype there exists a central management—a *keystone*—that can control CS to a large degree. It is assumed that the CS type 'logistics providers' would participate with mandatory commitment and that the keystone system would have insight into details of the carrier's operation. The keystone would have direct control or visibility of specific transport resources with this design. The SoS core system would work as a keystone with central intelligence and strong authority in negotiations between component systems.

Acknowledged archetype: In the Acknowledged archetype, again, there is a central management keystone but with limited authority and control. It is assumed that CS type logistics providers would participate with mandatory commitment, but the control of execution would be more abstract, providing carriers with freedom to choose how to execute and perform the transports. In this case the central IT system would work as a keystone system with limited central intelligence, control and authority.

Collaborative archetype: There is no central management in Collaborative archetypes. We assume that the participation of constituent systems type logistics providers would be voluntary. The CS type 'carriers' could either participate on a spot market on packet level or by long term contract. In this case the central IT system would work as a broker of information with reporting functionality, focusing on proof of delivery, cost and sustainability data. As such the SoS core would largely lack control and could rather be described as mediating with the main purpose of facilitation.

The differences between the architectural concepts are summarized in Table below. Based on whether participation in the SoS is e.g., legally forced or completely voluntary or depending on business strategy and intention of the SoS, the relation between different CS types and actor roles are changed, and so are the CONOPS descriptions. For this reason, we propose to model the different CONOPS and architecture alternatives in parallel at this stage.

Table 1 The archetype characteristics of Smoovit

	Collaborative		***Acknowledged***	***Directed***
Voluntary use of SoS by logistics providers	X			
Independent planning of Transporters	X		X	
Mandatory commitment of goods			X	X

CS Capabilities

To understand and identify the archetype agnostic capabilities, high-level information sequence diagrams were developed for each archetype to highlight the main interactions in between the CSs. Besides the archetype differences it was found that there may be two different types of business relations that adds a complexity dimension to the design space. The two different types can be described as the use of common and contract carriers. This significantly affects the sequence of interaction in-between CSs and mediating IT systems.

Common carrier refers to transport provider that offers their services to any person or company on transport basis. The common carrier is able to work with more logistics providers within the same day because they are not bound by any long term contract. Common carriers are available on spot-markets.

Contract carrier refers to the company or person that provides transport services for a specified shipper on a long-term basis. This means the contract carrier reaches a common agreement with the shipper and agrees to work under certain conditions over the length of the contract.

While analysing the six different design variants for needed CS capabilities and information exchange in between CSs. 31 high-level capabilities where identified. Of these high-level capabilities, 4 were found to be generic across all 6 archetype variants and an additional 7 were occurring in more than one variant. The remaining capabilities can be grouped based on types and included actors in the information flows. Grouping them may assist in the construction of software system artifacts to make them partly re-usable towards future change.

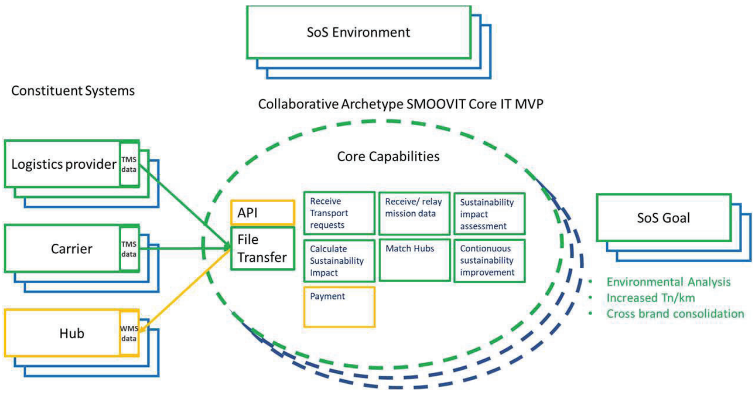

Figure 5. High-level Smoovit Conceptual Model—Collaborative archetype

6.4 WP3—Smoovit SoS Development and Integration

6.4.1 Purpose and Research questions

WP3 focused on deliverable D4, a prototype software system facilitating a SoS for urban logistics ("*The Smoovit Management System*", *SmoomS*). The purpose of the prototype was to address the research question:

- How can the Smoovit IT system be designed in order to maintain data integrity and trust?

6.4.2 Method

The work package was an integral part of the design science methodology applied in WP2, where WP3 focused on the steps '*Design and Develop*' and '*Demonstrate*', as well as contributed to '*Evaluation*'. More specifically, the functionality of the prototype was defined as part of WP2 and a close collaboration with all three WP2 sub-activities guided the development into an implementation that show-cases core features required for providing the mediating role between transport buyers and providers in an urban logistics SoS.

6.4.3 Purpose

The purpose with the prototype was to provide transport buyers and providers with a concrete example of a mediating software system to facilitate analysis of how it could affect their operations, and to enable validation of WP2 findings and hypotheses. The prototype was used to demonstrate an IT solution with both management representatives and IT specialist from the consortium in the living lab (WP6), and feedback from these sessions were included in the lessons learned from the project.

The specific objectives (stated in the project proposal) with the prototype were met as follows:

6.4.4 Objectives and results for WP3

Objective 1 Integrating information on routing, fill rate, and revenue from participating logistics firms' mobile and stationary systems

Result Design of SmoomS was done based on participants' information. While no integration with participants' IT-systems was accomplished within the project, APIs for that purpose were implemented. Furthermore, the availability of data required for the system to function was validated in workshops with the project participants.

Objective 2 Manage ***access*** securely to avoid leakage of information to competitors

Result State-of-the-art security mechanisms were implemented. In addition, the SmoomS design validated that required functionality can be achieved without requiring sharing of sensitive information.

Objective 3 Automate decision to enter consolidation centre or bypass, based on transport characteristics in relation to sustainability- and business-goals set collectively

Result SmoomS implemented rudimentary functionality to calculate routes, assign transport resources, as well as to calculate estimated emissions. While more capable methods will be required in a production-ready system, SmoomS has shown that a mediating system can deliver the basis to define and follow up sustainability and business goals.

Objective 4 Passing routing information onto last mile operator in micro hub when applicable and optimize last mile deliveries

Result The SmoomS prototype calculates a route from origin to destination, as well as performing (limited) consolidation in each step of the transport, including the last mile leg.

Objective 5 Managing incentives and business model that potentially redistributes revenue among transporters when applicable

Result The prototype has been used in discussions with project partners to investigate and evaluate incentives and business models. Revenue distribution was, however, not implemented in the prototype. Although acknowledged to be an important part of a production-ready system, it was not considered a prioritized feature for the prototype.

Objective 6 Collecting data on environmental impact for follow up and adjustments to decision algorithm, from vehicle systems

Result An emission calculation model, using information from the participating partners (see *Objective 1*, above), was developed as part of WP5 and implemented in the prototype. Data needs from vehicles and external IT systems was investigated as part of the evaluation of the prototype. Findings have been included in the lessons learned from the project.

6.4.5 SmoomS in Context

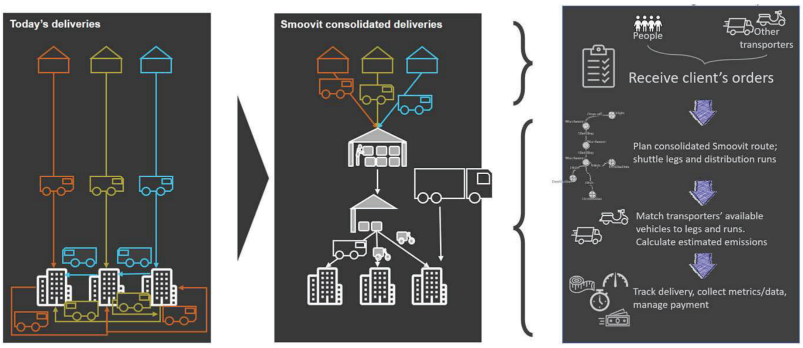

Figure 6 Smoovit aims to consolidate goods transports into the city, the Smoovit System shall facilitate coordination

As illustrated in the two left-most parts of the figure above, the goal of the Smoovit project was to reduce the number of vehicles required to deliver goods to urban areas. The approach taken in Smoovit was to utilize sub-urban hubs (warehouses) to consolidate shipments and thereby increase the fill rate of the vehicles traveling to and within the city centres.

The consolidation of shipments, as shown in the middle of the figure above, would be done in the Suburban hubs (SUCH) and transported to a City or Distribution hub (CH), from where shipments would be delivered to their destination addresses. By consolidating shipments in the SUCHs, higher fill rates were expected when shuttling the goods to the CH. Using smaller distribution vehicles to deliver the shipments to their destination addresses would in turn reduce the number of large vehicles trafficking urban areas.

To facilitate coordination between the transporters, the need for an IT support system was identified, as shown to the right in the figure. The Smoovit Management System (SmoomS) shall:

1. Receive a transport buyer's request
2. Plan a route from the origin (sender's address) to the various shipment destinations addresses, typically consisting of a Dropoff/Pickup leg (from the place of origin to the closest SUCH), a Shuttle leg (from the SUCH to the CH), and several Distribution runs (one for each unique destination address)
3. Assign vehicles to each leg and calculate emissions (as well as price and delivery time)
4. Track progress of the delivery
5. Facilitate payment
6. Collect data/metrics to enable evaluation efficiency

In the figure below, one vision of the SmoomS is illustrated.

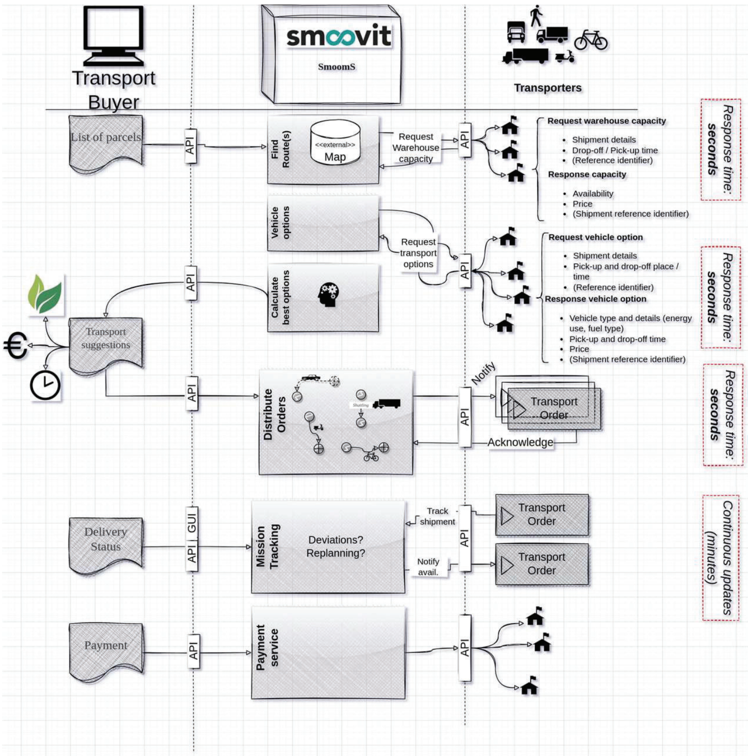

Figure 7 The envisioned Smoovit flow, showing interactions between a transport buyer (to the left)

Shown to the left in the figure is the interaction with the transport buyer, which is typically businesses that have shipments with destination in the city centre but can also be other transporters that do not have enough goods to fill up their available vehicles. While there may be a user interface for human interaction, requests for transport quotes would normally be submitted via machine-to-machine communication using APIs provided by SmoomS.

On the right in the image above, resources such as hubs and transporters are shown. These have announced availability of their resources for Smoovit.

In the middle, SmoomS is shown which is responsible for coordinating the need of the transport buyer with the resources available for satisfying that need.

From **the transport buyer's perspective**, the envisioned interaction flow is as follows:

1. The transport buyer submits a request for quotation, comprising a list of packages with their measures (weight and volume), place of origin and a destination
2. From SmoomS, the transport buyer receives a list of suggestions, with alternative routes and vehicles; each suggestion may differ in the estimated emission, price and/or delivery time
3. The transport buyer selects and option and submits it as an order
4. The transport buyer receives notifications about the progress of the transport
5. The transport buyer pays for the transport

An **envisioned interaction flow** from the perspective of SmoomS is:

1. SmoomS receives a request for quotation from a transport buyer
2. SmoomS calculates one or several alternative routes from place of origin to the destination addresses

3. SmoomS requests capacity for each of the way-point hubs on the routes (interaction is envisioned to be machine-to-machine, thus response time is required to be in the rage of seconds)
4. SmoomS requests capacity from transporters for each of the legs or the alternative routes (response time in the rage of seconds)
5. SmoomS calculates an optimal combination of routes and transporters (based on emissions, price, and delivery time) and returns a list of options to the transport buyer
6. SmoomS receives one of the options from the transport buyer as a transport order
7. SmoomS notifies the hubs of in- and outgoing shipments, as well as each transporter of new assignments
8. SmoomS expects acknowledgement from the involved hubs and transporters
9. SmoomS receives notification from the hubs and transporters as transport is progressing; SmoomS propagates the status to the transport buyer, shipment receiver, as well as transporters that are scheduled for subsequent legs of the transport (to facilitate real-time coordination)
10. SmoomS receives payment from the transport buyer and distributes to the resource providers

6.4.6 The Proof-of-concept Implementation

In the project, a simplified variant of the envisioned SmoomS was implemented as a proof-of-concept (PoC). The functionality of the PoC is illustrated in the figure below.

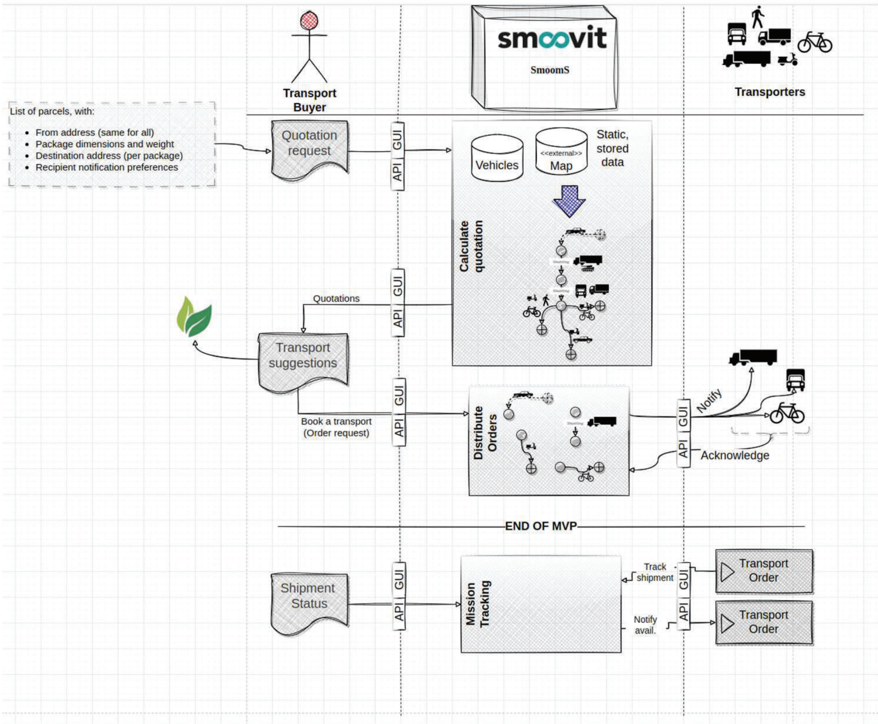

Figure 7 Overview of the SmoomS PoC functionality

From the transport buyer's perspective, the interaction flow is broadly as described in the vision (above), with exceptions:

- Management of payment has been omitted

- Only emissions are calculated for transport suggestions (price and delivery time has been omitted)
- The PoC only contains a rudimentary implementation of assignment progress tracking
- While there are APIs for all interactions no integration with external IT systems was done. Instead, a comprehensive front-end application was implemented to show-case the PoC

Concerning the implementation of the SmoomS PoC, there are fundamental differences from the envisioned implementation. Whereas the vision describes machine-to-machine communication to request resources (from hubs and transporters), the PoC contains repositories with information about these (shown as the *Map* and *Vehicle* databases in the middle of the figure, above).

The SmoomS PoC deployment can be bootstrapped with test data. The test data is illustrated in the figure below.

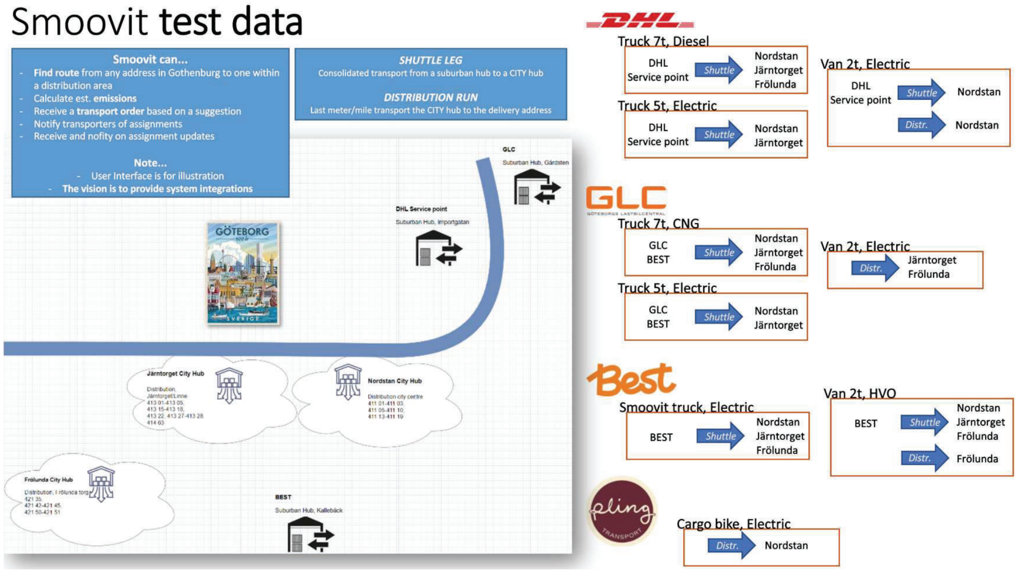

Figure 8 Illustration of PoC test data

Using the test data, a transport buyer can request transport from any address in the city of Göteborg to destination addresses within any of the postal codes associated with one of the three City hubs. SmoomS will suggest

- A Drop-off leg, which is calculated to the closest hub to the origin address
- A Shuttle leg, from the Suburban hub to the City hub that services the destination postal codes (if the closest hub to the origin address is a City hub, this is leg is omitted)
- One or more distribution runs (one for each unique destination address)

6.5 WP4— Policy & Regulation

The experience from the last 30 years of work around co-loaded transport of goods to recipients in city centers can be summarized as that collective loading between existing players is not commercially viable. A number of projects have been started with various new concepts, business models, vehicle types or actor constellations. What the projects have had in common is that there is initially external funding for the establishment and the initial operating phase. Getting a pooling system to continue thereafter on a purely commercial basis has proven difficult. An observation that can be made is that the economic actors involved lack sufficient internal incentives to change from today's transport solutions, at the same time as the actors who are affected by the external effects of transport (congestion, queues and air pollution) do not find these to be sufficiently negative to push forward a change from the outside . The political pressure from citizens and businesses is thus very weak, which also makes it difficult for the authorities to develop and implement effective rules and regulations that drive change.

The main purpose of the Smoovit project is to explore whether the interconnection of different IT systems can create a change in the actors' interest and incentives to develop and use solutions for co-loaded goods delivery. Despite that, the project, based on previous experiences, has chosen to do a smaller recapitulation of previous work on how policy and regulation can work together with IT development to increase the possibility of a sustainable pooling system. Appendix 2 reports the results of a literature study that shows an exposition of various regulations with the aim of realizing pooling. The basis was used as inspiration for the work within WP 6 linked to the plan to test some regulations in Gothenburg with the aim of promoting an increased interest and acceptance for collective loading solutions. Proposals to reduce access to loading zones in street level around Nordstaden were discussed. The idea would be to refer the affected drivers to the underground cargo bay under the Nordstaden facility or to use Smoovit to solve their transportation needs. As the project developed, the possibilities to make any regulation in

6.6 WP5— Sustainability Model

6.6.1 Purpose and goal

Within the Smoovit project in WP5, the issue of environmental sustainability has focused on answering two questions:

- Which of several available transport options leads to the smallest environmental impact? (ex ante)
- Which environmental impact should be linked to a completed transport? (ex post).

The first question arose in the project's initial stage when the possibilities for an overall coordination (and control) of the freight transport into a city area were investigated. Expected environmental performance for the various alternatives then constituted one of the indicators that would guide the choice of transport solution to assign to those who wanted to deliver goods to recipients within the area. The starting point for the work within Smoovit was to investigate whether access to information from all actors involved would enable a dynamic system where collective loading was only chosen for those transports where this was expected to reduce the total environmental load. The idea was that planned transports with sufficiently good environmental performance and transport efficiency (i.e. high load capacity utilisation) would therefore not be included in a collective loading solution, but would be carried out without connection to other actors' flows.

Even in a not fully implemented 'controlling' collective loading system, there is a need to obtain an indication of the environmental performance of the various action alternatives. In such a system (which was what was developed within Smoovit), a transporter is presented with available options for pooling (consolidation), as well as the associated environmental performance, and then has to decide for himself whether the transport should be pooled, and if so with which of the offered transport options[1] . In this system, a database must be compiled of the participating carriers' typical environmental performance for different transport solutions (different vehicles, different destinations, different transport services, different types of goods, etc.). Based on the various operators' specified performance for the transports to the area in question, an average value can also be calculated per transport type, to be used as a default value for a generic transport solution (ie not operator-specific). This type of average values are also suitable for use in different types of modeling of existing or new variants of transport solutions.

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[1] *See wp3 description for details.*

The second question was based on the need to be able to report from an operational Smoovit system for collective loading the environmental performance that the completed freight transports have given rise to. To realize this type of calculation, the system needs access to detailed data about how the actual transport was produced. IT systems at hauliers and freight forwarders then need to make available data on the vehicles (fuel consumption, emission performance) that were used, which fuels they used, driving routes (which addresses were visited and driving routes in between) that were chosen and how much goods were carried in the vehicles on each part of the journey (i.e., how much goods were loaded or unloaded at each stop). This information is normally available in transport planning systems and can be purely (IT-) technically transferred (e.g., via APIs) to various external systems (such as Smoovit). The chosen solution for the Smoovit IT system did not realize this type of solution as automatic data interconnections with the operators' IT systems could not be made available. Therefore, in the Smoovit system, the ex ante calculation that is carried out in the planning stage is also used for the ex post compilations.

The question of the environmental performance of completed transports (question 2) was also addressed in another part of the Smoovit project, namely in the model analyzes developed within the project. Above all, there was the need to calculate the environmental performance of today's ongoing traffic, 'Business As Usual' (BAU), and the alternatives with collective loading solutions that were selected for potential analysis.

Based on this target image and content of the project, the purpose of the environmental analyzes within the Smoovit project came to include the following elements:

Compilation of representative standard values for sustainability analyzes of the transport systems that are part of or affected by Smoovit. This was done by using modelled data available in the literature and from platforms such as NTM – Network for Transport Measures and the Handbook for Emission factors for road transport (HBEFA[2]) tool.

Collection of operational data from existing traffic, to replace selected standard values, was carried out for selected parameters, thereby increasing the validity of calculations, see further information in the section ‘Environmental data for the Smoovit system’ below.

6.6.2 Background - Sustainability analysis for freight transport

The concept of sustainability is broad and intends to describe how an activity or a system affects its surroundings. A complete sustainability analysis includes a large number of evaluation variables within three defined areas, the impact on the natural environment, the impact on economic conditions and conditions and the impact on social conditions. Common evaluation variables in the environmental area are emissions to air, land and water (of mainly gases, liquids and particles), use of natural resources and energy and the spread of noise. Contributions to congestion and queuing as well as traffic accidents can also be included in the environmental analysis, although these dimensions are also relevant for evaluating economic and social sustainability.

When assessing the sustainability of freight transporters, it is common to limit the number of evaluation parameters regarding environmental impact to emissions of climate-affecting gases into the air, emissions of substances that contribute to poorer air quality, generation of noise and contribution to traffic congestion and accidents. Furthermore, the narrowest system boundary is usually defined to only take into account what happens from or at the vehicle itself (so-called Tank to Wheel - TTW) or also to include information connected to the manufacture and distribution of fuel and energy carriers (so-called Well to Tank - WTT). It is in principle only in the more extensive life cycle analysis studies (so-called LCA) that contributions from manufacturing, operation, and maintenance as well as the demolition of the vehicle itself, the road infrastructure and all the subsystems built with the aim of enabling traffic are also included. Also, construction and operation of the terminals and properties used for loading, unloading and intermediate storage of goods are usually left out of the analysis as the contributions from these are usually small compared to the WTW data related to the transport vehicles. Table

[2] *HBEFA – Available from: https://www.hbefa.net/*

below lists the main environment-related evaluation areas that are usually included in a broad sustainability analysis for a freight transport.

Table 2 Environmental aspects usually included in sustainability assessments.

Air pollutants
Climate gases
Energy use
Resource use
Noise
Congestion
Accidents

In our analysis of freight transport to city areas, the impact on human health is the biggest negative direct environmental effect. Thus, emissions of air pollutants, noise, congestion and accidents are the factors that make the biggest contribution.

When comparing different transport solutions for urban deliveries, all these factors should be evaluated. In most evaluations, however, the effects linked to noise and accidents are omitted as these are methodologically difficult to evaluate in detail. When it comes to noise, there are often no measurements of how big the emissions are from different vehicles and powertrains in specific traffic situations, while the negative environmental impact is dependent on how the exposure of the recipients looks like. This in turn is a direct (instantaneous) effect that varies greatly in time and place. The complexity means that the effect is often estimated qualitatively or only roughly categorized. As far as accidents are concerned, well-developed methods for distinguishing between different vehicle concepts and special solutions are also lacking. Parameterizing and finding data for different transport concepts is thus difficult. The number of accidents with transport vehicles in cities is however relatively small, which is why absolute differences in risk values between different vehicle sizes tend to be small in comparison to the external costs caused by noise and congestion. However, a general observation is that larger cargo vehicles have poorer visibility and pose a greater risk to unprotected road users in their direct proximity. This is reflected in a four times higher external cost factor for large trucks compared to vans (again, still in absolute terms much smaller than costs for congestion and noise). Replacing a larger vehicle with several smaller ones can thus have a positive effect in the form of a totally reduced risk of accidents with serious consequences. Again, this is however counteracted by an increase in the total external costs from congestion, emissions and noise. In summary, the small increase in accident costs by replacing several small vehicles by one large is by far compensated by the reduction of external cost related to the other parameters.

Thus, an inventory and comparison of the impact of the various transport solutions on air quality and congestion remains. Emissions of air pollutants in the form of nitrogen oxides (NOx), particles (PMx) and hydrocarbons (HC/VOC) are clearly regulated and thus well modelled and measured for all existing vehicle types and fuel variants. The data base for this factor is considered to be good for the analyses relevant for the Smoovit application. The same goes for the emission of GHG gases for different fuel and engine alternatives. Reliable WTT and TTW data is available for most combinations and variants.

As for congestion, methods and metrics are a bit more challenging. How a vehicle contributes to congestion is highly dependent on the situation, both in terms of route choice and time of the journey, as congestion is an effect of all vehicles using a road at a given time. A common method applied in a more indicative analysis is to state the contribution of a heavier vehicle to congestion as the effect on a road's capacity that can be noted as the proportion of heavy vehicles increases. When the contribution to congestion is related to that caused by a passenger car, a truck's contribution to congestion can be measured in the unit ‘passenger car equivalents’. The value of this factor varies depending on the design of the road network (number of lanes, intersections, light regulation, roundabouts, topography, etc.). Simplistically, one can say that the more situations varying speed that occur, the greater the contribution to the congestion on the road from a heavy vehicle.

6.6.3 Co-loading to reach environmental goals

The underlying idea with collective loading of goods supply to city centres, here called co-loading, is that the same (amount of) cargo, presently hauled through inefficient transport solutions, i.e., small cargo vehicles with a low load capacity and low fill rate, are replaced with better utilised larger cargo vehicles. This is done in combination with micro-transport systems, such as cargo bikes and LEFVs (Low Emissions Fuels and Vehicles), to handle the last mile and last metre transports within the city centre. This reduces the number of traffic movements with larger motorized goods vehicles both on access routes in towards, and on the streets inside, the city centre. The environmental improvement potentials connected to co-loaded transport solutions are thus connected to this reduction of traffic movements. The extra benefits with a total removal of a truck trip, compared to just substituting a fossil diesel truck with a biofuel or battery electric truck of the same size, are the additional reduction in total energy used, less congestion and traffic noise, and reduced use of resources. Although the higher pay load on the co-loaded trucks will increase the fuel consumption on these trucks, the overall net reduction in fuel consumption (i.e., energy use) by reducing the total number of trucks will in most cases turn out as a benefit. One concern could however be the additional energy use in any vehicles used in the last-metre distribution inside the city. The availability of light electrified freight vehicles and high-capacity cargo bikes, however, makes these solutions both energy efficient, climate smart and non-polluting options to the use of e.g. vans and SBT[3]s. Co-loading schemes are therefore in most cases well motivated when making the material supply to a city area more energy efficient and more sustainable from a local viewpoint. If electric trucks are chosen for the transport of the co loaded cargo between the sub urban consolidation hub into the city distribution hub, and LEFVs and cargo bikes for the last mile city distribution, one can potentially reach large improvements in several of the sustainability aspects. This is indicated in 9 below where the fully electrified co-loading set up is labelled 'Eco-Co loading', as compared to 'conventional co loading' where standard ICE-vehicles are used. Several other common measures commonly applied in order to reduce the environmental impact from transport are listed for comparison.

[3] *SBT – Small Box Truck. Max 3,5 tonnes trucks with a rigid box cargo structure, often with a lift gate for loading/unloading of pallets and roller cages at ground level.*

Sustainability aspects	Eco Driving	Alternaive ICE-fuel	Battery electric trucks	Eco-Co Loading	Conventional Co-loading
Air pollutants	Potential	Potential	Good	Good	Potential
Climate gases	Potential	Good	Good	Good	Potential
Energy use	Potential	No	Potential	Good	Potential
Resource use	Potential	Potential	No	Good	Potential
Noise	Potential	No	Good	Good	Potential
Congestion	No	No	No	Good	Good
Accidents	Potential	No	No	Good	Potential

No	No (or limited) improvements compared to BAU
Potential	Potential improvements compared to BAU
Good	Good improvements compared to BAU

Figure 9 Sustainability improvement potentials for common measures applied to transport

As indicated in the figure above is the co-loading scheme using all electrical vehicles the option with the greatest potential to improve environmental performance. The environmental assessment of city distribution co-loading schemes is therefore dependent on detailed knowledge about the vehicle propulsion systems (e.g. ICE[4] or electric) and the applied energy carriers/fuels. For a more detailed analysis must also the route details and the time of the traffic motions be known, together with the corresponding level of congestion in the infrastructure. Such analysis is seldom possible to conduct due to resource reasons, why an energy use, GHG emission and air pollution calculation is used using modelled TTW data together with information of general traffic density and road types used for the route. For screening or overview studies could external cost estimates for vehicle-road type combinations be applied. This could be suitable when comparing the potentials of several options, such as different co-loading schemes.

6.6.4 Method for sustainability analysis

Sustainability assessments were made for two main purposes in the Smoovit project. First, in WP6 where a potential assessment for co-loading into the Vallgraven area was evaluated. The exact details of the vehicles accessing the city was not possible to obtain that is why generic model values were applied in the analysis. In the second part of the work were a model developed for emission calculation of separate consignments considered for co-loading. This assessment was then built into the Smoovit model developed in work package 3.

In environmental analyses of transport systems, the methodology applied varies based on the questions to be answered. For example, different selection of parameters and choice of data sources are used if studying the environmental performance of a completed transport or the likely effect of a future larger increase in transport volumes. Here below, the central methodological questions with relevance to the work within Smoovit are briefly commented.

[4] *ICE – Internal Combustion Engine*

Sustainability evaluation parameters

As mentioned above, a full sustainability assessment must cover a wide set of parameters. Limited access to operational data often has the scope to narrow down to one or a few parameters functioning as proxies for a system's sustainability performance. The most common proxy in co-loading environmental assessments are the calculation of GHG emissions, total use of energy and local air pollutants (NOx, PM and HC/VOC).

In the version of the Smoovit IT system developed in WP3 was the total WTW GHG emissions selected as a proxy for the sustainability performance of the transport options. The coarse level of accuracy thus obtained was considered adequate for the purpose of illustrating the differences in sustainability performance between the options in the user interface developed.

In the modelling work performed in WP6 were the sustainability evaluation carried out by applying standard values of external costs for typical vehicle categories in different traffic situations. These external costs include contributions from climate, air pollution, noise, accidents and congestion. As with all generic data sets one should take care to only use it for comparisons of similar options, not as a realistic estimate of the actual external costs for the application at study.

System boundaries

The choice of system boundaries is made so that a balance is obtained between the validity of the result and the scope of the work. For all analysis of road freight transport with ICE vehicles, the analysis is based on emissions from the vehicle's exhaust pipes, so-called Tank To Wheel contribution (TTW). In addition, the system boundary can be extended to also include contributions from the production chain behind the fuel delivery, the so-called Well to Tank contribution (WTT). For fossil fuels, WTT corresponds to approx. 5-10% of the vehicle's TTW emissions in terms of GHG emissions. For alternative fuels, e.g. biofuels, the TTW contribution can however be significantly larger, which is why WTT data should be included if such alternatives are included in the analysis/comparison. As the use of different alternative fuels is widespread, there has been a development towards expanding the system boundary as a standard to also include fuel production and reporting the so-called Well to Wheel (WTW) value.

Production of the vehicle itself is usually not included when comparing different transport solutions operated on alternative fuels. This since the difference in environmental impact from the manufacturing of the fuel systems for diesel and alternative fuels (e.g. compressed methane gas) is normally not large enough to significantly affect the result of a comparison. However, with the introduction of battery-electric powertrains, this situation has changed, and as electric trucks are equipped with ever greater battery capacity, the conditions are changing. Production of batteries is today both resource- and energy-intensive, which is why environmental data from the production of the vehicle will make a significant contribution, even when the vehicle's expected total mileage is taken into account. Thus, in the future it will become more common to include, in addition to WTW, also production, maintenance and recycling of the vehicles. For battery-powered electric vehicles, contributions from charging infrastructure and losses in the electricity grid are usually included in the WTT values that are calculated for the electricity used for charging.

A further contribution to the life cycle emissions for a transport comes from the infrastructure that the vehicles use, i.e. the roads, streets and loading areas and parking. However, the contribution to the inventory from this part of the life cycle is very low (compared to the WTW values) and is normally omitted in analyses. However, it is worth noting that the wear and tear on a paved road or street does not increase linearly with the vehicle's axle pressure, heavy vehicles produce several times more wear than light ones. This could also have to be taken into account in an evaluation where battery trucks are compared with other propulsion concepts, this because the considerable weight of the batteries.

In the Smoovit system, the base for data selection is to include the WTW data for all vehicles assessed. Vehicle production was left out also for battery electric vehicles due to the availability of data. Recent publications[5], however, made such information available as to why contribution from electric vehicle production and supply should be evaluated in further work in this area.

System boundaries must also be defined in relation to geographic coverage and time. Since the Smoovit system addresses the local environment in city centers, evaluations of the external costs should have a focus on the emissions taking place there. The environmental assessment within the modelling work done in WP6 thus took a focus on the TTW emissions from the vehicles. The availability of external cost estimates based on TTW data was a strong reason for this choice. As for system boundaries related to time, the analysis concerns present vehicle technologies, fuel options and ways to operate, no future aspects of these parameters are evaluated.

6.6.5 Environmental data for Smoovit's IT system

Within the project, a data basis for environmental calculations within the Smoovit system was requested. In the first stage of development, the possibility of letting Smoovit receive information about all planned shipments and runs into the area was investigated. Based on this overall picture, an optimization of the transport resources could be created with the aim of consolidating goods so that the number of vehicles driving into the city was minimized. An important thought was not to suggest vehicles with a sufficiently good degree of filling to choose collective loading, as this would be all too uneconomical. In the evaluation of transport alternatives that would then take place, an environmental analysis was also planned, which is why a set of necessary parameters was requested. A first approach to listing parameters was made which is reported in the table below. As this development track was abandoned at a later stage of the project, complete analysis methodology and parameter descriptions were not carried out. However, it is not likely that today's system for planning freight transport (i.e., carriers and hauliers TMS6 systems) could provide Smoovit with data at a sufficiently high level of detail, which is why the list should be seen as a possible gross list to start from. The lack of possibility to provide the system with detailed data is also judged to be lowest among the companies that deliver goods with their own smaller vans, which are the group of vehicles with the greatest potential for environmental improvements through pooling.

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[5] *See Bäckström 2023, available from:*

https://triplef.lindholmen.se/sites/default/files/2023-05/slutrapport_miljoberakningar_for_godstransporter_med_eldrivna_lastbilar.pdf

[6] *TMS – Transport Management System*

Table 3 Gross list of parameters to base sustainability analysis on in case of collective loading. (in Swedish)

Parameterlista			Motivering
Planerad Körning/Rutt			
	Startpunkt		Grund för ruttanalys (om
	Målpunkt(er)		rutt ej angivits eller för
	Planerad körväg, före och efter studerat stop (samt övriga stop vid rutt med multipla stopp)		grund för beräkning av bränsleförbrukning
	Planerade stopp, inkl planerad förändring av last		grund för detaljerd uppföljning av bränsleförbrukning
	Avgångstid		grund för val av trafiksituation
	Körtid	Planerad (ex-ante) och verklig (ex-post)	Grund för kostnadsanalys
	Planerad stopptid (per stopp vid multipla stop)		För tids och kostnadsanalys, men även tomgångskörning
	Ruttens vägtyper och trafiksituation, på länknivå (api)		För val av modelldata där mätvärden saknas
	Geofence styrning av drivlina	såsom el på utpekade länkar/områden	
	Väginfo	Väglag, omledningar, väder etc.	ev. grund för detaljerad kalkyl
Vehicle info			
	Registreringsnummer		Storlek, Euroklass, Bränsletyp, ålder kan hämtas från fordonsregistrets API
	Fordonsstorlek		
		Maxvikt	Används för att koppla fordonet till modelelrad data för förbrukning och emissioner (om sådan inte anges)
		Längd	
		Höjd	
		Antal hjulaxlar	
		Typ av lastutrymme (skåp borde de flesta vara)	
	Lastkapacitet		
		Max lastad vikt	Används för att kunna analysera fordonens kapacitetsutnyttjande, samt för att kunna planera ut godset på oika lastbilar/avgångar/rutter.
		Lastytans längd	
		Lastytans bredd	
		(ev. höjd)	
		Klimatanläggning (typ av energisystem och förbrukning)	
		Begränsningar eller special	
	Drivlina		
		Årsmodell	Ger Euroklass samt ev. åldringseffekter på emissionsnivåerna
		Motortyp1	
		Motortyp2	
		Miljöprestanda (Euroklass, emissionsdata)	
	Bränsledata, per typ av drivlina		
		Typ av bränsle eller elproduktion	
		CO2 (total och fossil) data - Well to Wheel	
		ev. (CO2 (total och fossil) data - Tank to Wheel)	
	Övrig info med bäring på förbrukning och emissioner	system för att hjälpa chaufför att köra miljöeffektivt, effekt/fartbegränsning (geofence?) etc.	
	Bränsleförbrukning		
	l, kg, kWh/vkm i följande fall	LCU = 100%, 75%, 50%, 25%, 0%	Dessa kombinationer finns
		Motorled, stadsgata	i modellerad data, bra om
		Free flow, tät trafik, trängsel	vi kan fånga åkeriernas
	l, kg, kWh/vkm i följande fall	Ex-post	från FMS system
	l, kg, kWh/timme	Klimatanläggning (typ av energisystem och förbrukning)	Variationer över sässong.
Godsdata			
	Stuvens sammansättning Fysisk info, per försändelse/fraktsedel		
	vikt brutto (ev. netto, fraktdragande)		Vi behöver alltid kunna få fram godsets fysiska bruttovikt.
	Yta, projicerad (ev. volym)		Primärt för för planering av
	info om ev. lastbärare		godsflöden, ev. även för
	krav på hanteringsutr.		allokering av
Datapunkter ej nödvändiga för miljökalkyl men för Smooth transportplanering/resursallokering			
	Försändelsedata		
	sista leveranstidpunkt		
	planerad leveranstid		
	gods med speciella behov (farligt gods etc.)		
	koppling till fordon (vilket fordon ska det gå med)		
	Godsets avsändare		
	planerad transportrutt, planerade tider på olika noder längs transportkedjan.	speditör (typ av produkt t.ex. express, styckegods, partigods) eller egen bil,	

In the continued work with Smoovit's IT system, it was decided that an estimate of the environmental impact of various transport options would be calculated and presented to the users. This calculation must be based on the environmental performance of the vehicle fleet that each operator uses today. As an alternative, a calculation is made for a collective loading solution where an assumed combination of vehicles is used, with the respective assumed environmental performance. Through different choices of vehicle size, degree of load capacity utilisation and engine/fuel type, the environmental performance of different designs of Smoovit can then be evaluated.

The system thus needs access to a set of environmental data for the vehicles intended to be used for transport within Smoovit. A functionality was created where the transporter or haulage company could enter representative operating data for the vehicles operating in Smoovit. In this way, a dynamically updated database can be established and used where company-specific vehicle data is used in the calculations in Smoovit. The scope and structure of this 'vehicle list' is shown in Figure 12 below.

Vehicle Fleet Data												
Transport operator	Type of transport		Vehicle	Engine type	Fuel/energy type	Fuel/electricity Consumption TTW	Fuel/electricity Consumption WTW	CO2 Emissions WTW	Load capacity		LCU	
/name of carrier or haulier/	/Long Haul, distribution, shuttle, last meter/	/Haulier or vehicle operator/		(diesel, otto, el)	(MK1, HVO, CNG, CBG, Wind/water, mix)	/Default or specific/	/Default or specific/	/Default or specific/	/Default or specific/	/Default or specific/	/Default or specific/	/Default or specific/
(company)		(company)	(type, size)			(MJ/vkm) (kWh/vkr	IJ/vkm) (kWh/vkr	(g/vkm)	(kg)	(m3)	(%-wght)	(%-vol)
Unknown Transport Company												
	Local Distribution		Truck, 12 tonne	Diesel	MK1		9	600	7000	60	25%	50%
	Last mile/metre		Cargo Bike	Electric	Swe mix		0,05	1,75	150	1	50%	75%
	Own distribution		Van, 3,5 tonne	Diesel	MK1		9	270	1200	12	25%	50%
Unknown Own Account			Van, 3,5 tonne	Diesel	MK1		9	270	1200	12	10%	25%
Carrier A												
	Local Distribution		Default average	Diesel	MK1		9	600	7000	60	25%	50%
		Haulier A1	Default average									
			Truck 20 t.	Diesel	HVO		9	125	7000	60	25%	50%
			Truck 20 t.	Electric	Hydro power	1		0	5600	60	31%	50%
			Truck 7 t.									
			Van 3,5t.	Otto	Compressed Bio Methane				1200	12	25%	30%
			Van 3,5t.	Electric	Hydro power	0,3		0	700	12	43%	30%
			PickUp 2t.									
			Micro van 0,6 t.									
		Haulier A2	Default average									
			Truck 20 t.	Diesel	HVO		9	125	7000	60	25%	50%
			Truck 7 t.									
			Van 3,5t.	Diesel	MK1				1200	12	25%	30%
Carrier B												
	Local Distribution		Default average									
		Haulier B1	Default average									
			Truck 20 t.									
			Truck 7 t.									
			Truck 7 t.									
			Van 3,5t.									
			PickUp 2t.									
			Micro van 0,6 t.									
			Manual Walking									
		Haulier B2										
			....									
Operator X												
	Last mile/metre		Default average	Electric	Swe mix		0,05	1,75	150	1	50%	75%
		OP X own fleet										
			Cargo Bike typeA									
			Cargo Bike typeA									
		OP X sub contractor										
			Micro Truck									
Shuttle SUCC-City HUB												
	Shuttle GBG EAST		Default average	Diesel	MK1		9	600	7000	60	50%	75%
	Shuttle GBG SOUTH		Default average	Diesel	MK1		9	600	7000	60	50%	75%
	Shuttle GBG NORTH		Default average	Diesel	MK1		9	600	7000	60	50%	75%

Measured values for electric vehicles in distribution traffic in Gothenburg, 2 weeks in October 2022.

Figure 11

NOTE! Data not verified, given here as an illustration and used for function tests in the development of IT systems.

Operating data for electric trucks

During the implementation of the project, one of the participating carriers acquired several electric vehicles, which were put into service for the distribution of goods in central Gothenburg. With the help of the haulage company's participation in the project group, a data collection of the electric vehicles' electricity use was carried out as part of WP6. During a period of two weeks, the drivers of the respective vehicles recorded a series of data about each completed trip. In addition to the amount of electricity used, loads loaded and unloaded, distance driven, number of stops, road conditions, etc. were noted, see table below.

Table 4 Measured values for electric vehicles in distribution traffic in Gothenburg, 2 weeks in October 2022

		Volvo FL	**MB Sprinter**	**VW Crafter**
		AVR 9 days	AVR 9 days	AVR 11 days
Körd sträcka	(km)	66,9	40,2	58,0
Laddad el efter turen	(kWh)	58,1	11,9	13,8
Elförbrukning per fkm, mätt i fordon	**(kWh/km)**	**1,0**	**0,30**	**0,23**
Mängd gods ut	(ton)	2,9	0,7	0,6
LCU	(%)	53%	90%	65%
Mängd gods in	(ton)	3,2	0,01	0,07
LCU	(%)	58%	0,3%	8,4%
Totalt hanterad last	(ton)	6,2	0,7	0,7
Väglag		blandat torrt/vått		blandat torrt/vått
temperatur	(C)	13,3	0,0	13,2
Antal stopp	0	32	64	62
Snittsräcka mellan stopp	(km)	2,1	0,7	1,0
Framkörningssträcka	(km)	8,0	8,0	8,0
Återkörningssträcka	(km)	8,0	8,0	8,0
sträcka i distribution	(km)	50,9	24,2	42,0
Snittsträcka mellan stop i distribution	(km)	1,6	0,4	0,7

Average values for each vehicle were calculated (over 9-11 days of traffic) and values for the electric vehicles were noted in the 'vehicle list' for Smoovit above.

6.6.6 Environmental data for model calculations

With the aim of evaluating how big a change a collective loading system can bring about, a current situation analysis was made of the existing traffic with freight vehicles into the area inside the Vallgraven area in central Gothenburg. The analysis was carried out through a further development of the method for calculating the number of delivery opportunities that various businesses generate, the so-called The Freight Trip Generation (FTG) model, see Sanchez (2017)[7]. Based on information about all businesses inside Vallgraven in central Gothenburg, it was calculated how many deliveries are carried out per day. Information on the goods flows of different business types, i.e., quantities (number of packages) and types of goods (pallets, cartons, refrigerated goods, etc.) were taken from the literature (Sanchez 2017) after which the total volumes of goods unloaded within the Vallgraven area could be calculated. In the next calculation step, the goods were distributed among different vehicle types based on the size and number of packages, after which the number of vehicles within each size class could be calculated. The vehicles were divided into larger trucks with cabinets, light trucks with cabinets, and vans/vans. This output of the model was later compared to the observed number of vehicles actually entering the city area during one day, see below and appendix 3. Values for the vehicles' typical utilization rates (i.e. load capacity utilization when departing from the terminal) as well as the total mileage of city distribution routes were obtained from interviews with drivers in the area and from TMS data obtained from a local haulage company, see further below, supplemented with assumptions about how different transport solutions are designed. Based on

[7] *Iván Sánchez-Díaz, Modeling urban freight generation: A study of commercial establishments' freight needs, https://doi.org/10.1016/j.tra.2016.06.035.*

knowledge of in which outer areas large parts of the logistics operations take place, the driving distance for each truck size could be distributed on the different road types that occur along the driving route into the city center and inside the Vallgraven area. The vehicles' total mileage, energy use and emissions to air could then be calculated by applying standard values for the respective combination of vehicle type, load amount and road type. In a final step, values were applied to external costs linked to traffic and emissions which were taken from reference Ricardo (2014)[8]. The total external costs linked to the distribution (last mile transport) of all business-related goods inside the Vallgraven area could thus be calculated.

The model structure described above was validated by carrying out a traffic count during a working day in the fall of 2019. Through manual registration of registration numbers, all cargo vehicles that drove into or out of the study area were observed. Detailed information regarding the vehicles and their owners were extracted from the vehicle register. By comparing observed traffic with the traffic volumes predicted by the model, good agreement was obtained, which indicates that the model's results are relevant for the 'business as usual' case. For more information on the model and the results from scenario evaluation using the model, please refer to the information in appendix 3.

6.6.7 Description of some input data to the city distribution evaluation model

External costs for vehicle traffic

The city distribution evaluation model is designed to compare the total external costs for normal city distribution (BAU) and different co-loading variants. The external cost estimates are used in order to review the total sustainability impact reflecting climate, air pollution, congestion, noise and road accidents. The model calculates the total driving distance for different truck types on the different road types used. Then, standard emission values extracted from 'The Handbook Emission Factors for Road Transport' (HBEFA)[9] is applied in order to find the total emissions of pollutants into air. The HABEFA database provides emission factors for all current vehicle categories (PC, LDV, HGV, urban buses, coaches and motor cycles), each divided into different categories, for a wide variety of traffic situations. Emission factors for all regulated and the most important non-regulated pollutants as well as fuel/energy consumption and CO_2 are included.

	Emissions				
	CO2	NMVOC	NOX	PM	SO2
	[€ct/g]	[€ct/g]	[€ct/g]	[€ct/g]	[€ct/g]
All road types	0,0168	0,0974	0,5247	19,745	0,5389

Table 5 External cost data related to emissions to air from vehicle traffic

In the city distribution evaluation model, the vehicle emissions are all considered to take place within an urban setting why external cost values calculated for urban traffic are applied. Standard values are extracted from the Handbook on External Costs of Transport (Ricardo 2014, see footnote below), see data in table above.

The external costs for congestion, accidents and noise are all dependent on the combination of road type and traffic load. The model does not handle time distribution over the day why an assumption was made as to how the traffic was distributed between different traffic situation. Given that Göteborg is a smaller town with limited problems with congestion we assumed that 70% of the distribution traffic distance was driven under free flow

[8] Ricardo 2014: Update of the Handbook on External Costs of Transport, available from: https://transport.ec.europa.eu/system/files/2016-09/2014-handbook-external-costs-transport.pdf

[9] HBEFA – Available from: https://www.hbefa.net/

conditions and the rest split evenly between saturated and congested conditions (i.e. 15% each). The following external cost values were applied in the calculations, see table below.

Table 6 External cost data related to emissions to congestion, accidents and noise

	MDV	LDV	LEFV	MDV	LDV	LEFV	MDV-ICE	MDV-BEV	LDV-ICE	LDV-BEV	LEFV
	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]	[€ct/v.km]
Motorway - free flow	0	0	0	1,2	0,3	0	19,7	9,8	10,7	5,4	0,0
Motorway - saturated	51	27	0	1,2	0,3	0	8,1	4,1	4,4	2,2	0,0
Motorway - congested	117	62	0	1,2	0,3	0	8,1	4,1	4,4	2,2	0,0
Access road - free flow	2	1	0	1	0,3	0	19,7	9,8	10,7	5,4	0,0
Access road - saturated	269	141	0	1	0,3	0	8,1	4,1	4,4	2,2	0,0
Access road - congested	344	181	0	1	0,3	0	8,1	4,1	4,4	2,2	0,0
local road - free flow	5	3	0	0,9	0,3	0	19,7	9,8	10,7	5,4	0,0
local road - saturated	303	160	0	0,9	0,3	0	8,1	4,1	4,4	2,2	0,0
local road - congested	461	243	0	0,9	0,3	0	8,1	4,1	4,4	2,2	0,0

Supplementary measurement data for traffic in Gothenburg

The city distribution evaluation model distributes the calculated number of freight consignments to transport vehicles to find out how many trips are needed. The allocation of cargo to vehicles is based on load capacity and load capacity utilisation (LCU) of the different vehicle types/sizes. Load capacity of the vehicles are fixed per vehicle type; however the load capacity utilisation is more difficult to assess since this varies due to several factors. In the model, different LCUs are assumed for transports operated by hauliers and carriers and those operated by 'own accounts', i.e., companies distributing their goods by own vehicles. As carriers typically have a larger pool of available vehicle types/sizes and a larger set of daily transport assignments as compared to 'own account' companies, carriers have more opportunities to match freight volumes and vehicle load capacities. Thus, vehicles operated by own accounts are assumed to have a lower average LCU than those of carriers. The actual number of consignments, and their total weight, loaded onto vehicles are investigated by interviewing drivers making deliveries in the area. This information is complemented by examples of actual pay load composition on a number of actual distribution tours. Data extracted from the transport management system were analysed for two trucks and two lorries for a period of two weeks. As an illustration is the driving route for one of the trucks shown in the figure to the right,

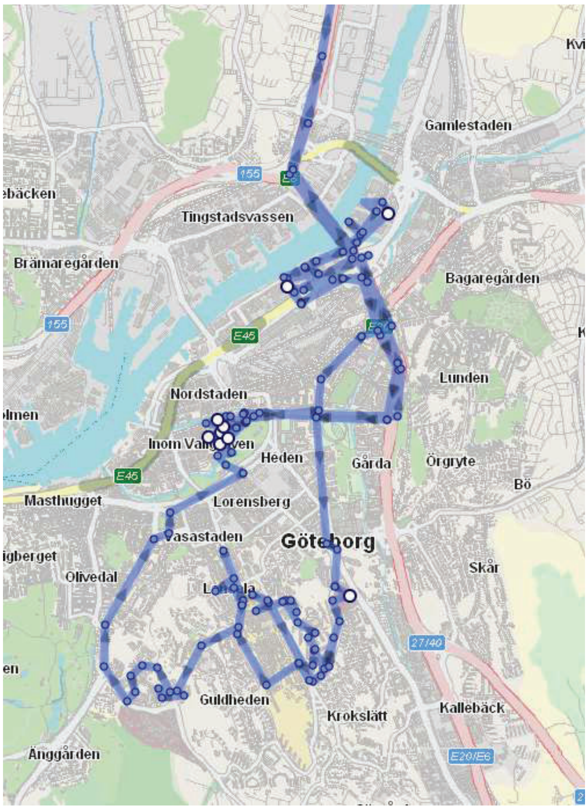

Figure 12 Example of distribution loop for a carrier

From the route and load data for the four trucks were the following average benchmark values calculated for a 5 day week period in 2022, see table 7.

Interesting observation to be made from this data is that the smaller vehicles only have a smaller part of their deliveries in the city center (Vallgraven area) while the larger trucks deliver all their load in the centre, se figure below. The relatively low LCU (at start) for the larger vehicles can be an indication of goods with low density packed on pallets or roller cages, demanding a larger load area in order to fit in one vehicle.

Figure 13 Example of goods unloaded in the city center.

Table 7 Example of goods quantities in distribution vehicles, data from carrier 2022.

Fordonstyp		Lastbil	Van	Van	Lastbil
Lastkapacitet	kg	7745	890	1053	7556
	Flakmeter	6,7	3,3	4,3	7,5
Total körsträcka, per tur	km	43	49,2	54,4	56,8
Längd, tid	hh:mm	**5:05**	**6:47**	**6:36**	**5:32**
Lämnar till Pling?		NEJ	NEJ	NEJ	JA
Lämnar till paketombud?		NEJ	NEJ	NEJ	JA
Antal (stopp för) leveranser	Totalt	**20**	**51**	**52**	**12**
	Vallgraven	**20**	**17**	**10**	**10**
Antal (stopp för) upphämtnin	Totalt				
	Vallgraven				
Antal kollin Levererat	Totalt	**78**	**87**	**81**	**171**
	Vallgraven	**78**	**26**	**14**	**169**
Antal kollin upphämtat	Totalt	**0**	**0**	**0**	**0**
	Vallgraven	**0**	**0**	**0**	**0**
Antal kg Levererat	Totalt	**1520**	**518**	**548**	**1974**
	Vallgraven	**1520**	**149**	**78**	**1860**
Antal kg upphämtat	Totalt	**588**	**54**	**139**	**519**
	Vallgraven	**30**	**53**	**6**	**230**
Utlastningsgrad (LCU at start)		**20%**	**58%**	**52%**	**26%**

6.7 WP6 — Living Lab

6.7.1 *Purpose, Research Question and Method*

The work package focussed on addressing the research question:

- How can the urban logistics stakeholders be involved in implementing a Smoovit demonstrator?

The method used to address the research question was to establish a **living lab to enable** a in close cooperation between the urban logistics stakeholders to leverage previous learnings from initiatives in the city of Gothenburg. In addition, the living lab functioned as a collaboration area to elicit feedback on hypotheses and to perform evaluation of results from the other work packages in the project.

6.7.2 *Background for Living Lab*

Consolidation of goods flows to city centres has been tested through numerous concepts with various technical solutions and business models within the European Union over the past 15-20 years. In general, these different solutions can be categorized as follows:

- "**Sub-carrier"**—Consolidation functions as an integrated last mile component in the supply chain and follows the conditions of the underlying transport service.
- "**Care-off (C/O) address**"—The consolidation hub acts as a formal point for receiving goods where the carrier has fulfilled its commitment upon delivery to the C/O address. Subsequent delivery to the final recipient occurs according to a specific agreement.

In the city of Gothenburg, the C/O address variant has been successfully implemented at Campus Lindholmen, with a terminal servicing the area for both coordinated goods and waste transports. The Campus Lindholmen terminal has been in continuous operation since 2008 and is currently operated by Renova[10].

A one-year pilot test of consolidation via C/O address was also conducted in the Nordstan mall area from 2019 to 2020, where around 20 tenants had their deliveries consolidated through GLC in Gårdsten. The test was conducted as part of the EU-funded project NOVELOG, where a detailed prior freight measurement indicated the potential for having freight traffic to Nordstan through consolidation. While the operation worked well in practice, it was discontinued after the pilot phase due to insufficient volumes which resulting in a high additional cost per shipment.

An example of "sub-carrier" was Stadsleveransen[11], which consolidated goods for DHL and Postnord to the inner city of Gothenburg for several years until 2021. It involved large volumes (up to four electric vehicle units and nearly 1000 shipments per day), but the operation also ceased due to financial difficulties.

6.7.3 *Challenges*

Historically, the most significant challenge has been to find an organizational setup that is commercially viable, as well as attractive from a competitive perspective. The freight transport and distribution industry, particularly city distribution, operates on low margins, making large and regular freight volumes essential.

Regarding competition, it is natural for actors to be reluctant to handing over parts of transport tasks to competitors, even if it corresponds to a relatively small portion. Therefore, it may be crucial for the entity responsible for consolidation/last mile to be "neutral" in some aspect. An independent actor specializing in certain types of last-mile transport in city centres can be considered relatively neutral for major forwarders and transport companies. There are also examples where the main task of such operations is not a pure transport company.

Another cornerstone is the logistical requirements to efficiently handle the relevant goods flows and deliver within the designated area, utilizing smaller electric vehicles and/or bicycles. Typically, a reasonably centrally located space (on the outskirts or near the area to be serviced) is required to avoid excessive lead times from the terminal

[10] https://www.renova.se

[11] https://www.interregeurope.eu/good-practices/stadsleveransen

to the goods recipient, which poses a challenge in many cities. In Gothenburg's case, the ”Nordstans samfällighetsförening” had a significant capacity for freight handling through an underground loading bay, centrally located and favourable for serving the city's central parts.

6.7.4 Pilot Operation within Smoovit

The overall goal of the pilot operation in work package 6 was to establish a well-functioning consolidation setup for deliveries of smaller volumes within various flows to the city centre, which should contribute to tangible traffic effects and lower environmental impact, as well as good prospects for continuation over time.

The focus within Smoovit was on smaller shipments and flows in general, and parcel deliveries in particular, where cargo bikes have proven to have good capacity and functionality for the task. Another major advantage of bicycle deliveries is that there are several independent operators specialized in bicycle deliveries in urban environments that do not directly compete with "conventional" transportation companies.

Nordstan has contributed with centrally located premises to the project, and when it comes to executing transports, the bicycle couriers Pling and Velove have participated as partners in the project. Velove has mainly contributed as a competence resource, while Pling has had the role of establishing the operational consolidation hub function.

Based on previous experiences, a given starting point was to find a reasonably extensive base volume (as mentioned in WP2b), ensuring an efficient and profitable distribution operation at its core. From that, the volume could be built upon with various smaller flows suitable for consolidation. In the establishment of the project consortium, the base volume was ensured through a collaboration with DHL, which already had a stable flow to the inner city of Gothenburg with Pling as the contracted subcontractor. Furthermore, the basis for consolidation was ensured through another partner from the transport sector, BEST Transport, whose considerably smaller volumes to central Gothenburg provided an excellent starting point for consolidation. Another party, Göteborgs Lastbilscentral (GLC), contributed with experiences from previous consolidation of flows to Nordstan, as well as insights into how a potential suburban consolidation hub (Suburban Consolidation Hub, SUCH) could function to further alleviate the freight traffic volume to the city.

With the commitment from the participating carriers within the project, there was a solid foundation to build the consolidation pilot under the management of Pling Transport. An initial agreement was made that the "brand" concerning the last mile would be neutral, as mentioned in WP2b, which later became known as "Smoovit", see the picture below. As part of this, the brand was developed with its own logo, and three cargo carriers for bicycles ("bike containers") were acquired for the coordinated distribution of goods from DHL and BEST.

Figure 14 Smoovit cargo-bike operated in the city of Gothenburg by Pling Transport.

6.7.5 The Smoovit Living Lab

After an initial delivery delay of the bike containers, the pilot operation started in February 2022. The setup for the pilot was consolidation of parcel flows from DHL and Best to a predetermined area in the central parts of Gothenburg, using Nordstan as a hub, see figure below. The goods from DHL were delivered to the hub by an electric truck, while the parcels from Best were collected at their terminal south of the city centre, and transported to the hub by cargo bike. The same feeding system was used conversely when shipments picked up by Pling

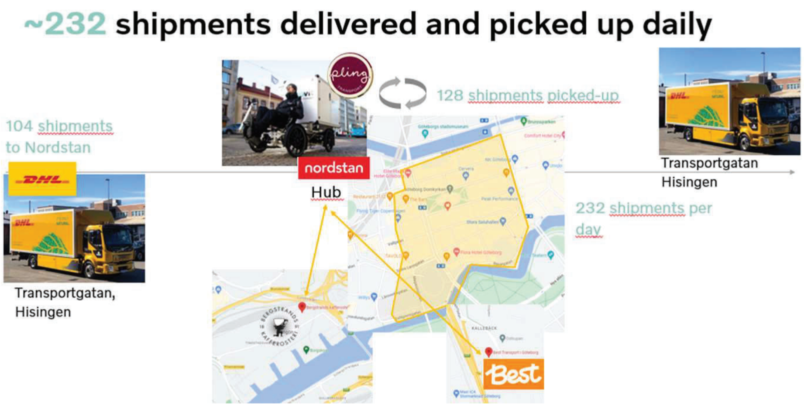

Figure 15 Overview of the Smoovit setup in Living lab.

(also included in the operation from start) was transported to the DHL and Best terminals respectively. During the pilot, the original track and trace systems from DHL and Best was used in parallel since no integrated solution was available.

Both equipment and receiving goods, delivery, and pick-up worked very well basically from the first day. This was likely a result of long and thorough preparation between the collaborating parties, combined with Pling's many years of experience in various types of transport assignments.

Based on a traffic measurement in the city centre previously organized by IVL in 2019, around 30 actors were identified as interesting in terms of consolidation (own vehicles, smaller flows, etc.). Most of these were contacted for further exploration of conditions and possible interest in trying Smoovit for final delivery of goods to customers in the city centre. This work eventually resulted in a handful of actors who had both suitable goods flows and interest and resulted in Pling also being able to add the distribution of coffee (Bergstrands) to the list of assignments.

PostNord currently has a service point in Nordstan, where the supplier also carries out transport of goods to the adjacent city blocks. It turned out that collecting mail was a very suitable flow to incorporate into Smoovit, and during the project, this service was also added, with Pling collecting outgoing mail from about 10 customers daily.

The traffic measurement revealed that a very large proportion of the smaller light trucks in the city centre consisted of various types of service vehicles (e.g., "craftsmen’s vans"). Since service vehicles are also often used for various types of goods transport (e.g., purchasing and delivering materials for different assignments), it was considered interesting to see if these transports could also be connected to Smoovit.

This resulted in a currently ongoing initiative by Nordstan to develop a concept for a "craftsmen’s hub" with an unmanned depot/store for common goods and enable delivery by, for example, bicycle. Furthermore, the possibility of delivering various types of materials through Smoovit from stores on the outskirts of the city was explored, and Ahlsell showed great interest in Smoovit. Initially, the idea is for Smoovit to deliver goods from an Ahlsell store on Ringön, after which the operations may potentially be scaled up.

6.7.6 Results for Living Lab

Smoovit has generated clear results in the form of three vehicles—delivering parcels, coffee, and mail—being fully or partially replaced by emissions-free cargo bikes in the city centre, see figure 12 below. Additionally, an electric truck was added to the flow by DHL to reduce fossil emissions. However, the most important and significant result is that Smoovit was developed into a well-functioning and robust operation that will continue even after the current project ends. Smoovit can thus grow and evolve, contributing to even greater benefits in terms of sustainable urban logistics in the future. The key factors for the success are the good starting position of having a substantial “base volume” that is required to reach a high level off efficiency, combined with a well-established cooperation and a high level of trust between the involved stakeholders and a “neutral” last mile operator. The availability of suitable facilities for the hub adjacent to the city centre, which could be adapted to suit the operation, is also considered as a very important aspect.

To answer the research question in this section, the key insight has been to find a financially and commercially sustainable setup starting with a base volume that is gradually increasing as more actors are included. Furthermore, learning from previous experiences from stakeholders and having their commitment has been important for the success of the implementation under the neutral brand of Smoovit.

Figure 16 Volvo Electric Truck and cargo-bike used in the Smoovit system.

7 Dissemination & Publications

7.1 Dissemination

Hur har/planeras projektresultatet att användas och spridas?	Markera med X	Kommentar
Öka kunskapen inom området	x	Through participation in forums and presentations within urban logtics.
Föras vidare till andra avancerade tekniska utvecklingsprojekt		
Föras vidare till produktutvecklingsprojekt		
Introduceras på marknaden	x	The result from the living lab with collaboration among Pling, DHL and BEST to deliver/pick-up parcels, coffee and mail will continue after project ends.
Användas i utredningar/regelverk/ tillståndsärenden/ politiska beslut		

7.2 Publications

Master thesis during project: *"Ensuring Long-term Operation of Urban Consolidation Centers: How the Business Model Can Be Designed to Provide Financial Viability*" by Jasmina Szczesna Adabaniyan and Yu-han Liu. Stockholm Business Schoo

Andersson, M. and Rylander, D., 2022, June. Wicked Cases and Late Binding in System of Systems. In *2022 17th Annual System of Systems Engineering Conference (SOSE)* (pp. 354-359). IEEE.

Other dissemination activities

Date	Refernce	Organizer
June 5th 2023	Gothenburg 400-year Jubilee	Gothenburg City
May 25th 2023	Urban Logistics Round Table Sweden	Closer
March 31st 2023	Smoovits event om Hållbara stadsleveranser	Smoovit
February 15th 2023	Knowledge sharing with project Move21	MOVE21
January 20th 2023	Knowledge sharing with project REDIG	REDIG
September 13th 2022	Lindholmen Open Days	Lindholmen Science Park
December 1st 2021	Presentation at POLIS	POLIS
28th January 2021	Presentation at Gothen University	University of Gotheburg

8 Conclusions and Future Work

The Smoovit project was undertaken to address the challenge of making last-mile city distribution both profitable and sustainable. This was accomplished through a unique approach combining a system-of-systems engineering perspective and multi-modal cargo flows. The project also focused on developing a business model that incentivizes participation and implementing regulatory mechanisms to support it. The commercial setup was co-developed, tested, and refined in a living lab environment with practitioners. Additionally, a sustainability model was developed to assess the potential of such a system.

The project aimed to evaluate the sustainability potential of urban logistics solutions from a system perspective, considering factors such as transport efficiency, transport quality, traffic safety, and environmental impact. This enabled the management of trade-offs between different transport needs.

Based on the outcomes of the Smoovit project, there are several areas where further research and development can be pursued to advance the field of sustainable last-mile city distribution. The proposed future work aims to address the following key aspects:

Regarding the **integration of IT systems** in the transport industry, it poses challenges due to data sharing issues. The project identified challenges related to the integration of IT systems in the transport industry, particularly in terms of data sharing. Future work should focus on developing standardized protocols and frameworks for seamless integration of IT systems, including track and trace capabilities and reduction of administrative burdens. This will enable efficient coordination and optimization of last-mile logistics operations.

While the Smoovit project explored the potential of new **technology and business models**, it discovered that fewer transporters than expected were willing to abandon their own transport vehicles for the Smoovit concept. Future work should investigate deeper into understanding the barriers and motivations for transporters and develop strategies to incentivize and facilitate the transition to sustainable last-mile solutions. This may involve financial incentives, knowledge-sharing platforms, and collaboration with industry stakeholders.

The **use of policy and regulation** to establish requirements for goods transportation into cities is a viable approach, but it faces challenges such as slow decision-making processes and the need for collaboration from the city authorities. The Smoovit project highlighted the need for policy and regulation to support sustainable last-mile city distribution. Future work should focus on engaging policymakers and urban planning authorities to establish requirements and incentives for goods transportation into city centers. This may include the implementation of congestion pricing, low-emission zones, and preferential treatment for sustainable logistics providers. It is crucial to streamline decision-making processes and foster collaboration between public and private sectors to drive meaningful change.

The **coordination of existing physical infrastructure, vehicles, and goods** was demonstrated in the living lab. Replacing traditional trucks with electric trucks to reduce emissions to hubs is feasible, as evidenced using Volvo Electric trucks in the living lab for transportation to the city hub. Furthermore, Pling cargo bikes have been successfully integrated into the living lab flow for consolidation purposes. The Smoovit project demonstrated the feasibility of coordinating existing physical infrastructure, vehicles, and goods in a living lab environment. Future work should focus on scaling up and replicating successful living lab models in different urban contexts. This will require collaboration with local authorities, logistics companies, and technology providers to establish living labs that can serve as testing grounds for innovative last-mile city distribution solutions. Lessons learned from these living labs can inform policy development and best practices for implementation.

8.1 Summary of conclusion

- The Smoovit project aimed to make last-mile city distribution profitable and sustainable through a system of systems and multi-modal cargo flows.
- Future research should focus on integrating IT systems in the transport industry, developing standardized protocols, and reducing data sharing challenges for efficient coordination.
- Strategies are needed to incentivize transporters to adopt sustainable last-mile solutions, including financial incentives and knowledge-sharing platforms.
- Policy and regulation frameworks should be established to support sustainable last-mile city distribution, involving collaboration between policymakers and urban planning authorities.
- Living lab models have demonstrated the coordination of infrastructure, vehicles, and goods, and future work should focus on scaling up and replicating successful models in different urban contexts.

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Vinnova/FFI:2018-02016

SysteM Of Systems for sustainable urban gOods Transports

Author: Else-Marie Malmek, Volvo Group, Anders B Berle Volvo, Magnus Andersson, Rise,, Sebastian Bäckström, IVL, & Sönke Behrends, IVL. Date: 2019-03-05, Issue: V1, Project with in: FFI/SoSSUM, System of systems in Smart Urban Mobility

11 Appendix

For the smoother transport of urban goods

smoovit

Smoovit Transport model, ver 6

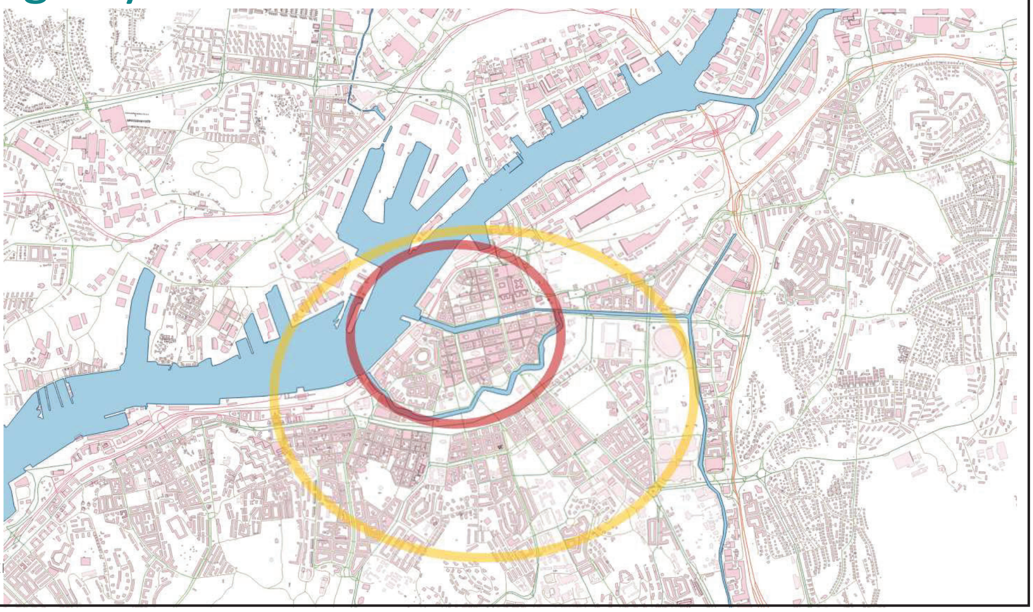
Sönke von Wieding
6 February 2022

1

Göteborg city area

Innanför Vallgraven

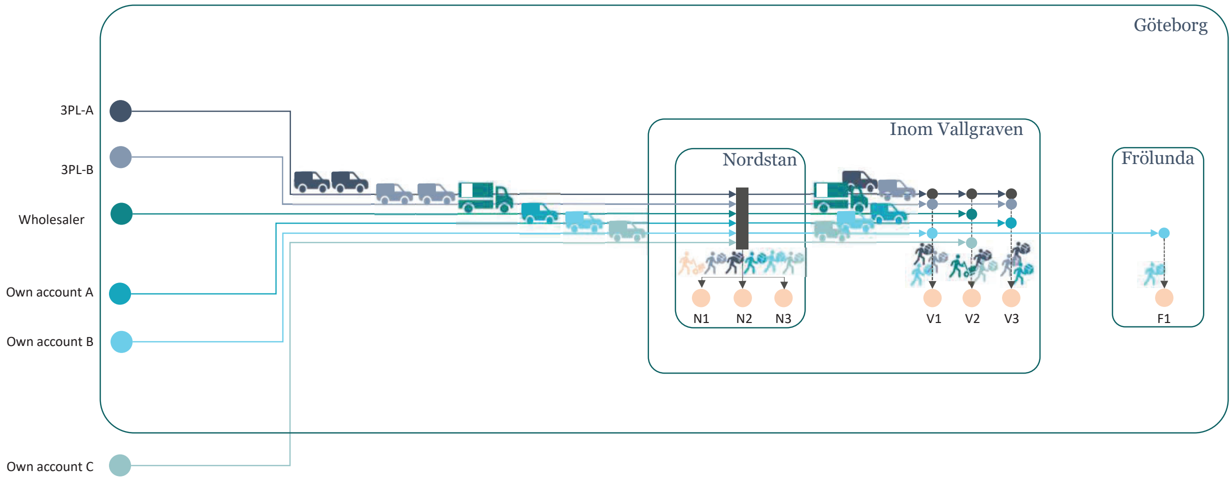
Centrala Göteborg



IVL | PRESENTATIONSTITEL

2

Business-as-usual: Traffic overview



3

Transport plan

- What activities are needed to perform the deliveries?
- What resources are needed to perform the activities?
- What actor performs the activities?
- What actor owns/controls the resources?

4

Transport plan - method

	Activty 1	Activity 2	Activity n
Actor 1	Resource 1 Resource 2		Resource 1
Actor 2		Resource 1 Resource 2	
Actor 3		Resource 1	Resource 1 Resource 2
Actor n	Resource n		

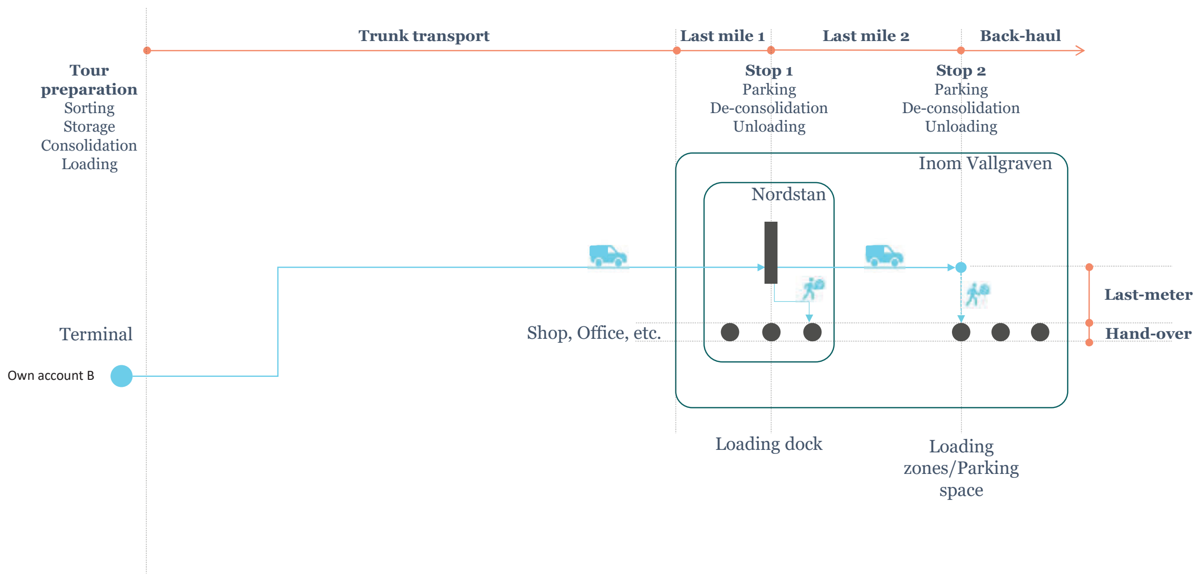
- To perform the deliveries n activities are required.
- Each activity require one or more resources.
- The resources are controlled/owned by different actors.

→Actors who **organise** transport activities use both own and other resources which they do not own/control

→Example: To organise a transport of goods an integrator needs a haulier (external resource), which in turn needs both a vehicle (own resource) and the roadinfrastructure (own by authorities)

5

BAU: Logistics activities (Example: Own account B)



6

BAU: Transport plan

	Tour preparation	Trunk transport	Last mile	Stop 1 (Nordstan)	Last meter	Hand over	Last mile	Stop 2 (inom Vallgraven)	Last meter	Hand over
3PL-A	Warehouse Staff	Driver Van	Driver Van	Driver Van	Driver	Driver	Driver Van	Driver Van	Driver	Driver
3PL-B	Warehouse Staff	Driver Van	Driver Van	Driver Van	Driver	Driver	Driver Van	Driver Van	Driver	Driver
Wholesaler	Warehouse Staff	Driver Truck	Driver Truck	Driver Truck	Driver	Driver	Driver Truck	Driver Truck	Driver	Driver
Own Account A	Warehouse Staff	Driver Van	Driver Van	Driver Van	Driver	Driver	Driver Van	Driver Van	Driver	Driver
Own Account B	Warehouse Staff	Driver Van	Driver Van	Driver Van	Driver	Driver	Driver Van	Driver Van	Driver	Driver
Own Accoun C	Warehouse Staff	Driver Van	Driver Van	Driver Van	Driver	Driver	Driver Van	Driver Van	Driver	Driver
National Transport administration		Access road Regulations								
Local traffic authority			Local road Regulations				Local road Regulations	Local road Regulations	Local road	
Real estate owner				Nordstan - Loading docks	Nordstan – stairs/corridors	Shop/office Rental contract				Shop/office Rental contract
Receiver				Local warehouse Staff (own goods reception)		Staff				Staff

7

BAU: Actors and Resources used

Transport operators

- 3PL-A: 2 vans/drivers
- 3PL-B: 2 vans/drivers
- Wholesaler: 1 truck/driver
- Own account A: 1 van/driver
- Own account B: 1 van/driver
- Own account 3: 1 van/driver

Authorities

- National transport administration: Access roads (incl. regulations)
- Local traffic authority: Local roads (incl. regulations)
- Local traffic authority: Loading zones/parking (incl. regulations)

Real estate owners

- Loading docks
- Premises for shops and offices
- Rental contracts with receivers

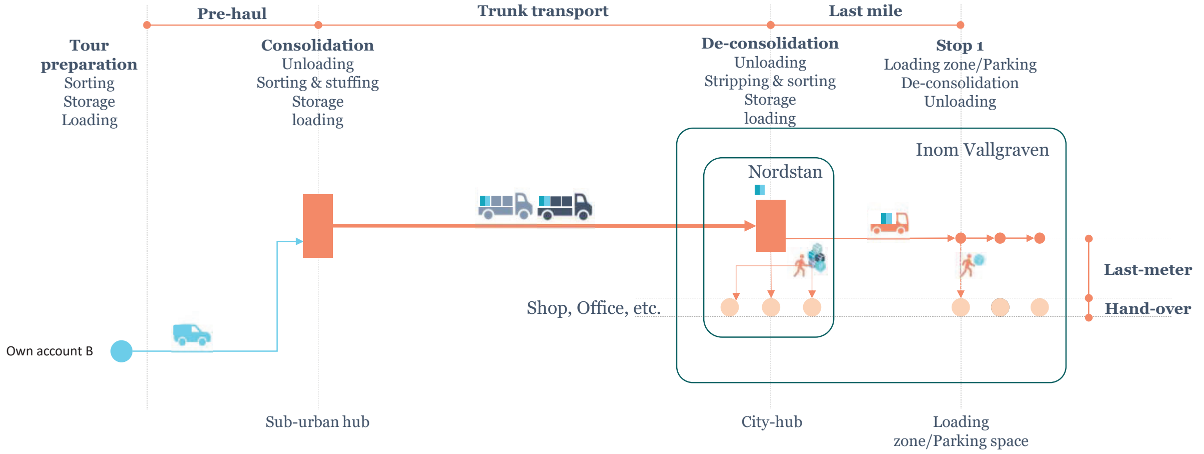
Receivers

- Receiver with own goods reception: Local warehouse and staff
- Receiver without own goods reception: Staff
- Shops/offices space

8

smooth

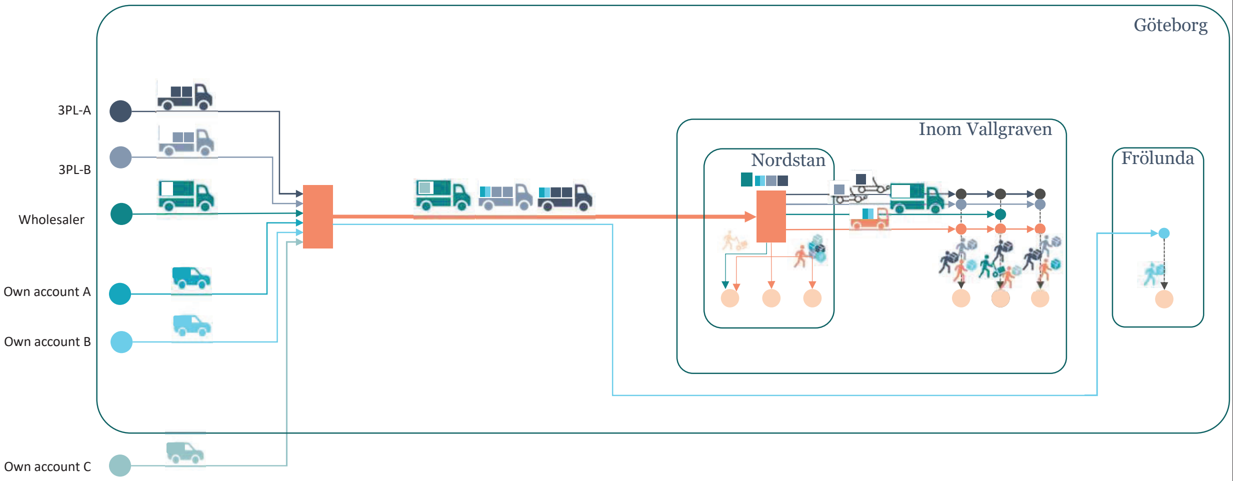
Smoovit system: logistics activities own account



9

smooth

Smoovit system: Traffic overview



10

smoovit Transport plan

11

	Tour preparation	Pre-haul	Consoli-dation	Trunk transport	De-consoli-dation	Last meter (Nordstan)	Hand over (Nordstan)	Last mile (inom Vallgraven)	Stop (inom Vallgraven	Last meter (inom Vallgraven)	Hand over (inom Vallgraven)
3PL-A 3PL-B (Suburban hub operator)	Terminal staff		Terminal Containers Staff (sorting and stuffing) Storage area	Driver Truck Containers	Driver Truck Containers			Driver Truck Containers			
Wholesaler	Warehouse Staff	Driver Truck	Driver Truck (loading extra goods)	Driver Truck	Driver Truck			Driver Truck			
Own Account A Own Account B Own Account C	Warehouse Staff	Driver Van	Driver Van								
Nat. Transport administration				Access road Regulations							
City hub operator					Loading docks Storage area	Staff Roller cages	Staff				
Last mile operator					Driver LEFV Container			Driver LEFV Container	Driver LEFV Container	Driver	Driver
Local traffic authority		Local road Regulations		Local road Regulations				Local road Regulations	Local road Regulations	Local road Regulations	
Real estate owner					Nordstan under-ground level Rental contract	Nordstan building	Premises Rental contract				Premises Rental contract
Receiver							Shop/office Staff				Shop/office Staff

12

Comparison BAU-Smoovit

	BAU	Smoovit
Activities	Tour preparation Trunk transport Last mile Stop Last meter Handover	Tour preparation Pre-haul Consolidation Trunk transport De-consolidation Last mile Stop Last meter Handover
Resources	Terminal/warehouse Vans, trucks Drivers Receiver staff Access roads (incl. regulations) Local roads (incl. regulations) Loading zones/parking (incl. regulations) Loading docks Shops/offices	Terminal/warehouse Trucks, LEFV container Drivers Receiver staff Access roads (incl. regulations) Local roads (incl. regulations) Loading zones/parking (incl. regulations) Loading docks Shops/offices Suburban hub incl. staff City hub incl. staff
Actors	Transport operators Nat. traffic administration Local traffic authority Real estate owners Receivers	Transport operators Nat. traffic administration Local traffic authority Real estate owners Receivers Hub operator

13

Comparison BAU-Smoovit

Fewer traffic resources needed

- Fewer vehicles and drivers (trucks/LFEV instead of vans)
- Fewer vehicle-kilometers

More complex transport chain

- More activities: stuffing & stripping, consolidation, de-consolidation
- More actors: city-hub operator, last-mile operator

More resources

- Suburban hub (area for stuffing and storage)
- City hub (area for storage)
- Container
- Staff for hub operations

14

Resource needs: Comparison BAU vs. Smoovit

Total volumes into area 'inom Vallgraven' per day

- Pallets and cages: 1 800
  - Dry: 1 200
  - Fresh: 600
- Parcels, big: 4 350
  - B2B dry: 4 150
  - B2b fresh: 200
- Parcels, small: 2 500
  - B2B documents: 2 350
  - B2C parcels: 150

Resource	BAU	Smoovit	Difference
Terminals for consolidation (including area and staff)	0	Several SUCCs, 1 City Hub for handling • 1 800 pallets and cages • 7 000 parcels	> +2
Vehicle-km	Trucks: 10 000 Box trucks: 17 000 Vans: 22 000 LEFV (bike): 0 LEFV (van): 0	Trucks: 8 500 Box trucks: 7 000 Vans: 12 000 LEFV (bike): 250 (50 tours) LEFV (van): 200 (45 tours)	Trucks: - 1 500 (-15%) Box trucks: - 10 000 (-60%) Vans: - 10 000 (-50%) LEFV (bike): 250 (50 tours) LEFV (van): 200 (45 tours)
Containers (for parcels)	0	350 (2 units for balanced flows, i.e. 1 empty for each full unit)	+ 350

Data based on modelling results on the improvement potential of SMOOTh.
See presentation: *Smoovit improvement potential inom Vallgraven*

15

Definitions

- **Consolidation:** The suburban-hub is the key facility for consolidating the fragmented logistics flows into one system. The goods from different operators are destination-sorted here, i.e. they are sorted in a way that allows short routes with many stops in the same street(s) in the destination area. Furthermore, these relatively small goods volumes of each operators are consolidated into larger flows so that they are big enough to economically transport them by large-scale modes, such as trucks and urban waterways.
- **Trunk transport:** The transport from (suburban) terminals and warehouses to the (central) destination areas. This transport usually takes place on urban access roads and is relatively long (ca. 10 km) compared to the distribution distance in the destination areas (ca. 1-3 km). There are usually no stops on this part of the transport chain.
- **De-consolidation:** The city-hub is the gateway to the destination area, and transshipment point from feeder-transport (on larger vehicles) to distribution (on smaller vehicles). For example, the destination-sorted loading units are transshipped from the trucks to cargo bikes or micro vans.
- **Last-mile distribution:** the transport in the city area where the receivers are located. This activity is characterised by multiple stops at different receivers, which consumes most of the time of the whole transport chain. The driving distance is limited (1-3 km).
- **Stops:** The stops at the street level include the parking of the distribution vehicle close to the receiver's facility and the unloading of the shipment from the vehicle. In conventional deliveries, this activity takes place in dedicated loading zones (on street) or loading docks (off street).
- **Last-meter distribution:** The transport from unloaded distribution vehicle to the receiver. Usually, the way on the sidewalk from loading zone to receiver.
- **Hand-over:** The hand-over of the goods from the transport company to the receiver. Goods reception areas allow access to an (unmanned) storage area in the facility of the receiver's address. Access is granted to both delivery company and receiver (e.g., with digital keys for recipients, or delivery to cars), allowing flexible deliveries without the limitations of delivery time windows or failed deliveries.
- **Stuffing:** the loading of various small consignments into a single container.
- **Stripping:** the unloading of various small consignments from a single container.

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Smoovit – Definition of policy & demand management scenarios

WP4 Policy and Demand

Sönke von Wieding, ver4 (6 February 2022)

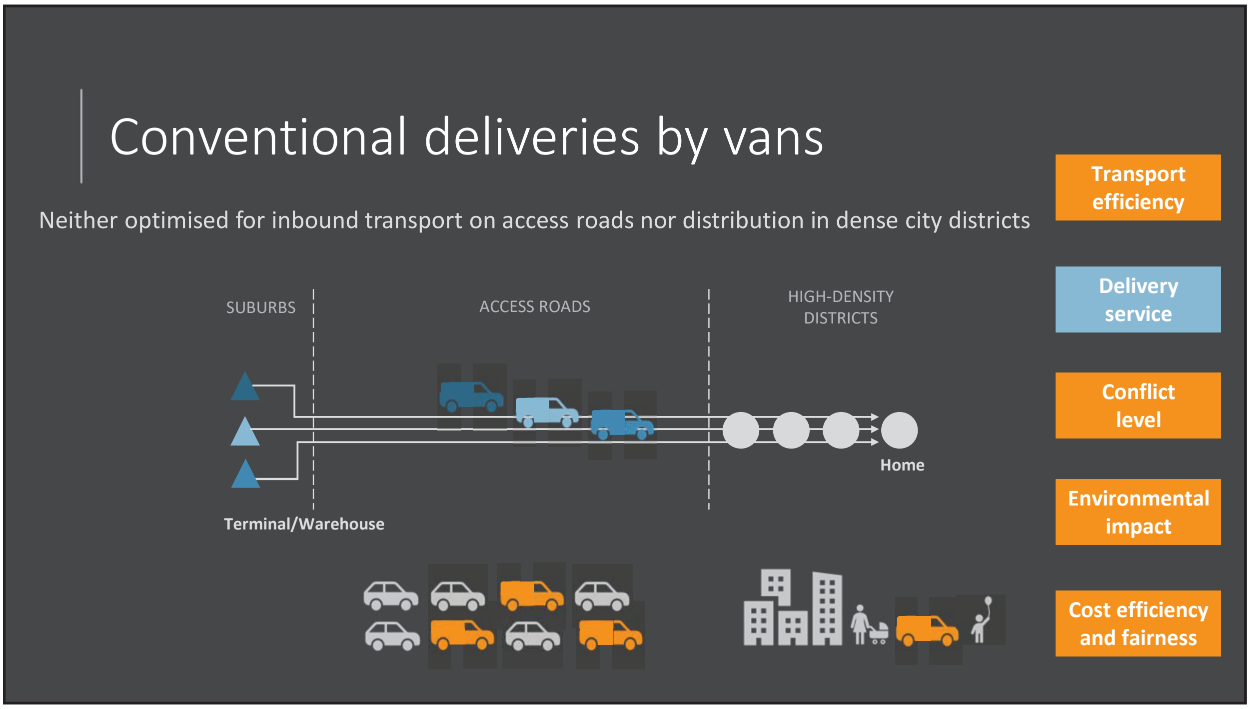
1

Backgorund

2

Criteria for sustainable urban logistics
Transport efficiency
Delivery-service
Conflict-level
Environmental impact
Cost efficiency & fairness

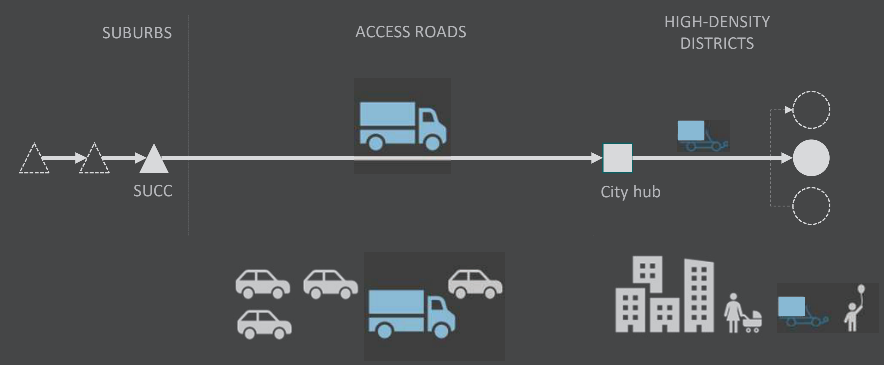
3



Conventional deliveries by vans
Neither optimised for inbound transport on access roads nor distribution in dense city districts
SUBURBS
ACCESS ROADS
HIGH-DENSITY DISTRICTS
Home
Terminal/Warehouse
Transport efficiency
Delivery service
Conflict level
Environmental impact
Cost efficiency and fairness

4

Consolidated and intermodal deliveries



- Transport efficiency
- Delivery service
- Conflict level
- Environmental impact
- Cost efficiency and fairness

- **Intermodal**: using the strength of different vehicles/modes
- **Consolidation**: Large volumes for efficient inbound transport

5

How can policy and demand support the consolidation of freight flows?

Plan and regulate: What regulations can support the consolidation of freight flows?

Manage demand: How can receivers support the consolidation of freight flows?

Package measures: What combination of regulation and demand management is most promising?

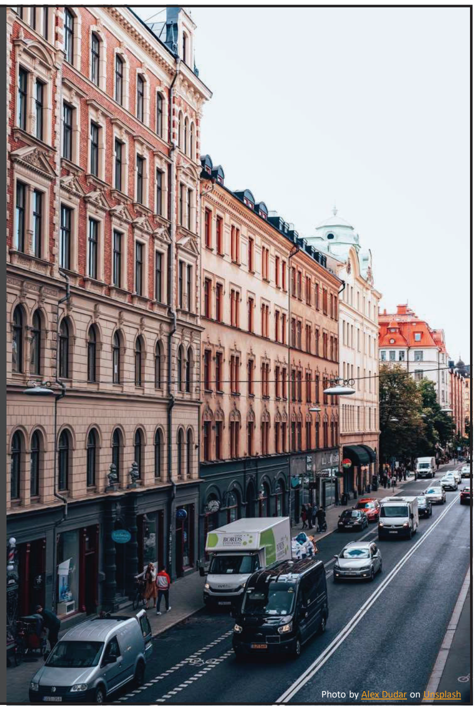


Photo by Alex Dudar on Unsplash

6

Why policy and demand management?

7

Background: Supply chains

- Supply chains that arrange the production, manufacturing, transport, warehouse, and distribution of goods are the demand side of freight transportation systems
  - The multiple stages of these supply chains use the available freight transportation systems to transport goods between the economic agents that produce, ship and consume the supplies
- Supply chain agents must agree on a common operational strategy; otherwise the supply chain breaks down
  - The carriers cannot change their operations if doing so could/would have negative impacts on their customers
- Power in supply chains (in competitive markets)
  - Receivers have the power to dictate delivery constraints to shippers and carriers, and the shippers have power over the carriers.
  - The carriers design their operations to meet the constraints established by the shippers and receivers
- Power relations are not symmetric
  - The most powerful agents are able to resist operational changes that may inconvenience or have negative impacts on them
  - The weakest agents are forced to accept conditions that may not be necessarily the best for them

8

Asymmetry in power relations - Implications for policy

- a policy applied to one of the agents in a supply chain does not necessarily reach the key decision maker
  - policies that target carriers in the hope that they will influence receivers to change behaviour are not likely to be effective
  - the relative weakness of the carriers prevents them from forcing shippers or receivers to change behaviour
- receiver-centered policies, if adopted by the receiver, lead to behaviour changes on the part of the carriers.
  - The receivers will not hesitate to exercise their power to impose their will on the carriers

9

Freight demand management (FDM)

- seeks to induce changes in the demand for freight by altering the frequency, timing and mode of deliveries
- focus on changing the behaviour of the receivers of supplies. Examples include:
  - off-hour delivery programs
  - Receiver-Led Consolidation (RLC)

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Freight demand management (FDM)

- Receivers are the primary customers in supply chains
  - great influence on setting the operational constraints that must be satisfied by carriers and shippers.
  - Convincing them to change their demand patterns is likely to have upstream impacts on supply chains.
- Receivers are sensitive to quality-of-life concerns
  - Enhancing quality of life and sustainability in the shopping districts may translate into more attractive environments and increased profits
- Public policy required to overcome business inertia
  - Receivers not willing to change for benefits to society, they may be convinced to modify their demand patterns if pricing and/or incentives are used. These stimuli are essential to overcome business inertia.

The goal of FDM is to incentivise receivers to change demand behaviour

If receivers adopt these changes in sufficient numbers, they could dramatically alter the operations of shippers and carriers

Examples

- off-hour delivery programs that incentivize receivers to accept deliveries in the off-hours
- Receiver-Led Consolidation (RLC) programs that encourage receivers to reduce their number of deliveries

11

Literature review on policy measures

12

Public sector freight initiatives

1. infrastructure management
   - initiatives that provide and improve the facilities used by freight activity
2. parking and loading areas management
   - enhance the way freight vehicles use urban spaces for pick-ups and deliveries
3. Access regulations
   - Local traffic regulation and control
4. Stakeholder management
   - Influence actors to modify the way in which logistics take place, so that the activity is more consistent with livability and sustainability goals;

Infrastructure and parking	Access regulations	Stakeholder management
Infrastructrure	*vehicle-related restrictions*	*Transport management*
Land for city hubs	Vehicle size and weight	Urban consolidation center
parking management	vehicle emissions	*Demand management*
Freight parking and loading zones	*Time-related restrictions*	off-hour deliveries
vehicle parking reservation systems	daytime delivery restrictions	collaborative purchasing
	nighttime delivery bans	Change of delivery location (c/o)
	Load-factor based restrictions	*Recognition and certification*
	minimum load factor	Recognition programs
	Lane management	Certification programs
	restricted multi-lane use (bus lane)	

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Infrastructure and parking

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Urban transhipment platform (city hubs)

- provide a space where large freight vehicles could transfer the cargo to the smaller vehicles from the same company that would conduct the last leg of the deliveries.
- Eliminates shippers' concerns about loss of contact time with receivers and brand recognition
- These could be implemented at public or private parking lots, empty lots, or other spaces that can accommodate a number of freight vehicles to conduct loading and unloading activities.

In the city of **Malaga (Spain),** parcel carriers reacted to a truck ban in the city center by renting space at a former UCC, and using it as an urban staging area.
The carriers transport the supplies to the city hub using single unit trucks, and then transfer the cargo to small electric vehicles to make the deliveries.
Interestingly, other carriers chose not to use the city huband, instead, make deliveries using hand carts from the loading areas outside the city center.

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Freight parking and loading zones

- allocate curb space for parking and loading activities.
- mitigate conflicts among the various user segments that need curbside space by means of restrictions.
  - Special truck-only loading zones
  - time-of-day restrictions for parking, e.g. available to commercial vehicles during peak delivery times, while becoming open for passenger cars at other times

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Access restrictions

These initiatives use restriction(s) to limit access of freight vehicles to a congested or environmentally sensitive area. The nature of the restrictions varies in terms of

- vehicle type (e.g., size, weight, engine type)
- time of travel
- Load factor

These restrictions are not well received by most carriers, as they result in operational changes and higher costs.

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Vehicle size and weight restrictions

- limit access on the basis of vehicle size or weight, and are often implemented because of concerns about the perceived congestion or traffic accidents produced by large trucks
- However, if carriers are forced to replace large trucks with multiple small trucks, they are likely to increase vehicle-miles-traveled and congestion.
- to minimize social costs, policy makers should foster the use of the largest vehicles that could safely use the network without excessive infrastructure damage
- Access restrictions motivated by the need to protect pavements and structures not capable of handling large trucks are justified, because these are externalities not accounted for by the carriers.

→Vehicle size and weight restrictions should be enacted only if careful evaluation of their impacts reveals benefits larger than the costs.

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Low emission zone

- Low Emission Zones (LEZs) are used in environmentally sensitive areas where vehicle access is restricted to reduce pollution levels.
- LEZs are relatively popular in Europe, and have started to be implemented in other parts of the world, like Mexico City.
- LEZs typically lead to large reductions in emissions and noise, especially when combined with incentives or other policies that encourage the shift to alternative fuel vehicles.

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Day-time delivery restrictions

- Limit freight vehicle access to the target area during specific periods of time.
- Duration, its geographic scope, and the type of freight vehicles affected vary from case to case.
- Unintended network effects: can lead to longer routes and longer travel times in the network, which increase congestion and pollution.

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Night-time delivery bans

- designed to protect local communities from night noise
- However: can increase daytime congestion by forcing deliveries that under normal conditions would take place during the off-hours to be conducted during the daytime
- Use of low-noise truck and handling technologies can mitigate this problem

→if the rational for a Night-time Delivery Ban is night noise, the implementation of low-noise delivery programs is a better solution than night-time delivery bans

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Differentiation from restrictions – indirect subsidies

Most regulatory measures can be implemented by introducing some degree of differentiation between the vehicles affected in order to promote sustainable distribution or to take into account the special needs of specific categories of vehicles.

Combination of regulations and indirect subsidies is also politically attractive as it is not entirely punitive (can increase acceptance for regulations

They come in various forms (next slide).

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Differentiation from restrictions – Examples

- Type of operation
  - restrict own account but allow 3PL operators
- Environmental performance
  - based on type of propulsion, on emission class or on vehicle age
- Minimum load factor
  - have proven ineffective: cities that implemented these have phased them out
    - difficult to measure (volume, weight, etc. Beginning or end of the route)
    - Difficult to enforce (inspections produce congestion)
- Vehicles carrying out distribution services from UCCs
  - for example, by given exemptions from time-window access restrictions or allow access to bus lanes
- Type of operation or type of goods
  - to avoid imposing constraints on the delivery of certain goods or services

Gothenburg: Pilot on minimum load factor differentiation, voluntary participation of a few transport companies. Incentives for hauliers to achieve a higher load factor:
- Access to attractive loading zones
- Access to bus lanes
- Exception from access restrictions for freight

Results:
- Time savings for participating companies
- but no significant increase in load factors
- Hence, it was phased out.

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Restricted multi-use lanes

- These initiatives impose restrictions on the type(s) of vehicles to use certain (priority) lanes.
- The lane access can be allocated to different users and/or different time windows
  - “No car” lanes: segregate large vehicles from standard size vehicles, hence improving lane mobility and safety
  - lanes that allow buses, trucks, and high occupancy vehicles.
- Access to priority lanes reduce travel delays, hence can be used as incentives for the implementation of other strategies.

Barcelona created seven multifunctional lanes in its commercial center that, by using variable message signs, established hours of operation for different activities taking place on the streets

Gothenburg allowed clean freight vehicles in public transport lanes to promote the use of environmentally friendly trucks.

Bristol allows freight vehicles that use its consolidation center to use the bus lane to foster the use of its consolidation center.

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Stakeholder management

Influence freight actors to modify the way in which logistics take place, so that the activity is more consistent with livability and sustainability goals. Stakeholder management includes both

- The supply side of freight transport (Transport companies)
  - Urban consolidation center
- The demand side (receivers) --> Demand management
  - off-hour deliveries
  - collaborative purchasing
  - Care-off delivery address

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Urban Consolidation Centers (UCCs)

- facilities that seek to reduce freight traffic in a target area by consolidating cargo at a terminal.
  - carriers that otherwise make separate trips to the target area with relatively low load factors, instead transfer their loads to a neutral carrier that consolidates the cargo and conducts the last leg of the deliveries.
  - Carriers pay the UCC operator a fee per delivery made, and save money by not having to make the final leg of the delivery themselves.
- Actors' perspectives on UCC
  - Carriers are inclined to participate → potential to save money
  - Shippers oppose the use of the UCC → loose contact with receivers/brand recognition
  - Receivers do not care (as long as the supplies arrived on time)
- Public subsidies are often necessary, and if the subsidies stop, most UCC operations also come to an end; explaining why only a handful of UCCs are in operation
- An UCC is more likely to be successful if:
  - there is a strong public-sector regulatory mandate for its use
  - significant congestion/pollution problems within the area

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Voluntary off-hour delivery (OHD) program

- Goal: induce a shift to deliveries made during the off-hours to reduce congestion and pollution during daytime hour
- Approach: Provide incentives to receivers for their commitment to accept OHD.
- Once the participation of receivers is secured, the support of suppliers will be forthcoming, as they stand to gain from the lower costs of OHD.
- Incentives, financial or otherwise, are needed to overcome the initial resistance and inertia of the receivers.

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Collaborative purchasing

- Reducing the number of vendors delivering or providing a similar service to multiple businesses in the same building/area
  - it enables the remaining vendors to do more work and serve a larger number of clients with the same number of vehicle trips
- Receivers order larger quantities which provides an opportunity to renegotiate and get discounts from their vendors
- Can also include services for waste and recycling pick-ups

Business improvement districts (BID) in the UK offer collaborative purchasing to their members. In most cases these initiatives start with office materials and waste and recycling materials.

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Change of delivery address

- To convince receivers to change the destination of the deliveries they receive, e.g., to a UCC or to 3PL distribution center, from where consolidated deliveries are made to the receivers
- Receivers' participation is key to counteracting market pressures, such as the desire to foster brand recognition that may deter shippers from participating in UCCs.
- Challenge: cost for last-mile deliveries need to be recovered either by fee for real-estate owners, receivers or a voluntary fee for operators (as they are only obliged to deliver to delivery address

The Netherlands: Binnenstadservice

- the promoters convinced the receivers to ask their suppliers to send the deliveries to the UCC, as a way to help the environment (the receivers were promised no increases in delivery rates).
- Once the receivers committed, the promoters approached the carriers and offered to conduct the last leg of the deliveries in return for a small fee, which the carriers agreed to pay because it was smaller than their own costs of making the deliveries.
- Since its inception, the Binnenstadservice has expanded to other cities.

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Collective purchasing of common logistics functions in shopping centers

- In many shopping centres drivers have to bring all items from common unloading areas to individual shops.
- Common logistics functions can include
  - Receive and distribute goods at, to and from the loading docks
  - Handle, quality check and process the waste
  - Extra services, e.g. Internal transports of goods and waste – Simple craft services. Moving and storage
- Potential effects
  - Fewer loading docks needed
  - Fewer deliveries to shops
  - Time savings for carriers
- Challenge: business model because unequal distribution of benefits and costs

Emporia Malmö:
All tenants, apart from two large supermarkets, are forced to use the internal logistics operation as part of their tenancy.

- The internal logistics operation also covers waste disposal.
- Tenants have to pay a landing fee for each incoming delivery, which encourages consolidation.
- They typically operate using only 7 loading docks compared to the industry standard of 35 and also operate just 3 waste compactors compared to the average of 16

30

Recognition and certification programs

- Public acknowledgement encourages others to follow. Recognition of good behaviour fosters good behaviour.
- recognize participants who achieve a minimum level of performance, and follow a clear path to certification.
- Voluntary programs that set specifications for reaching different achievement levels, such as bronze, silver, or gold.
- Can include many aspects of a company's operations such as driver skills and driver management, vehicle maintenance, transport operations, and performance management.
- Area-specific recognition programs often concentrate on environmental impacts
- such programs tend to improve relations between private and public sectors, paving the way for further collaborations to tackle other challenging issues

Utrecht: Recognition scheme for urban distribution. Requirements include:

- Minimum 100 addresses per day in city centre (pick up or delivery)
- Distribution centre within 5 km of highway exit and within 10 km of Utrecht city centre
- Obligation to accept third parties' goods for delivery to / pick up from city centre

Certified companies get in return:

- Exemption for time windows in city centre for max 5 vehicles
- Access to bus lanes for max 5 vehicles

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Market-based measures

aim is to "modify" the market prices of the goods or services whose production generates negative effects. Changes in prices usually have a direct impact on the behaviour of the freight industry because it is highly competitive and so the individual freight operators have to respond to changes in their costs in order to remain competitive.

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Mobility credits

- establishes the total amount of "acceptable" number of vehicles within a zone of a city and then allocates them to economic operators such as receivers and carriers to "purchase" freight transport services that are not subject to additional access charges or restrictions.
- Where the credits have been used up, more credits can be purchased from the city authority or, if a market has been established, can be purchased from economic operators who have surplus credits.
- It provides a financial incentive to analyse and carefully plan the deliveries to avoid exceeding their mobility credit budget.
- In theory, a powerful tool to influence behaviour
- In practice, however, complex to design, are not seen as being equitable by stakeholders and expensive to administer.

A **mobility credits scheme** has been implemented in Genova (but later been suspended) and has been considered for implementation in the centre of the city of Krakow.

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Policy measures and demand management scenarios

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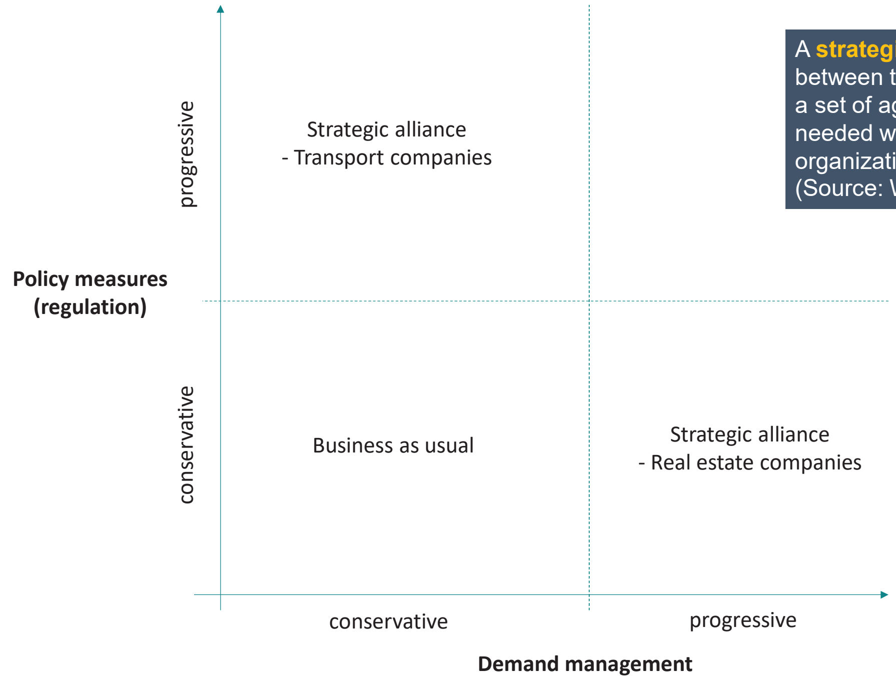

A **strategic alliance** is an agreement between two or more parties to pursue a set of agreed upon objectives needed while remaining independent organizations.
(Source: Wikipedia)

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Business-as-usual

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Begränsad fordonslängd

Nr	Namn
1	Rosenlundsgatan
2	Surbrunnsgatan
3	Södra Hamngatan
4	Norra Hamngatan
5	Nedre Kvarnbergsgatan
6	Torggatan

Nr	Namn
7	Östra Hamngatan
8	Nils Ericsonsgatan
9	Slussgatan
10	Södra Vägen
11	Raoul Wallenbergs Gata
12	Viktoriabron
13	Rosenlundsbron

Förbudet för lastbilar över tio meters längd gäller alla dagar i veckan dygnet runt, förutom mellan klockan 6-8. Förbudet gäller inte dig som kör buss.

https://goteborg.se/wps/portal/start/foretag/tillstand-och-regler/trafik-och-transporter/langa-fordon

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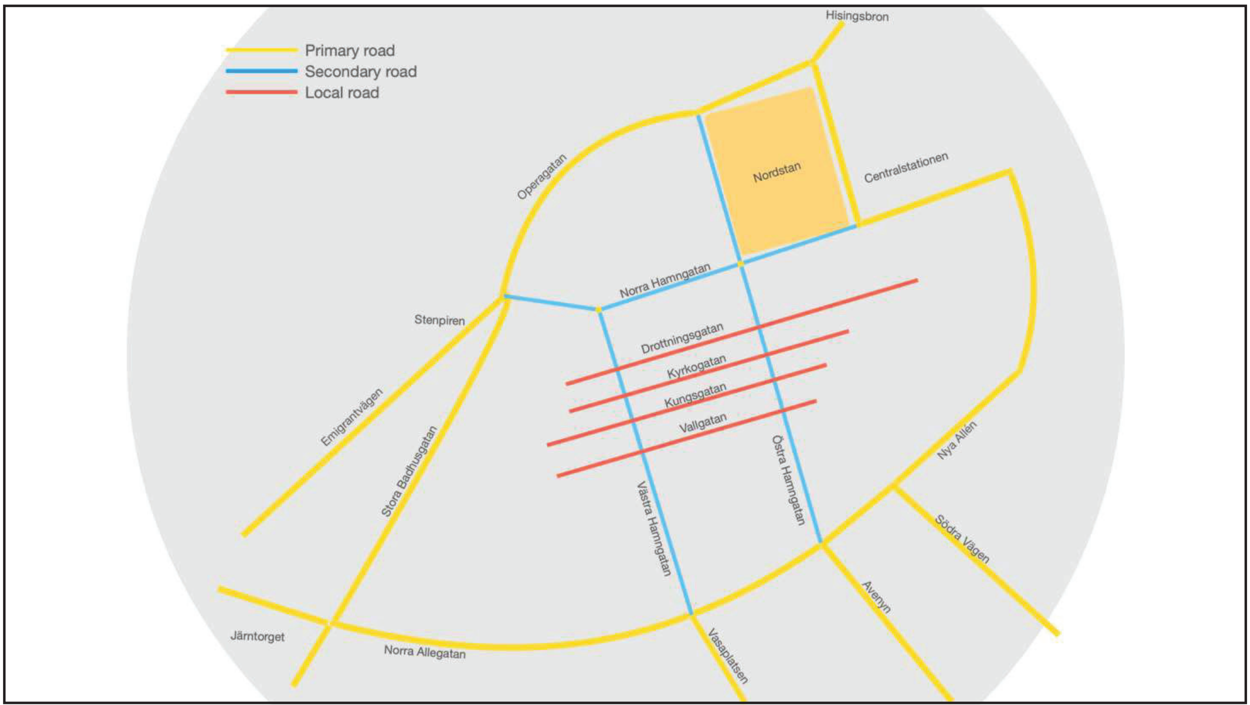

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Policies

Traffic regulations

- Whole zone/Primary roads
  - no HDVs (> 10m) allowed (>10 m), expect kl 06-08
- Local roads
  - time restrictions for MDV (<10m)
  - Time restrictions on some shopping roads (gågator/gångfartsområden) for all road vehicles between kl 10.00 – 05.00 (11.00 – 05.00 on some roads).

Effects

- No effects on van traffic
- Limited effect on MDV traffic as they still can enter the zone all time and park on secondary roads

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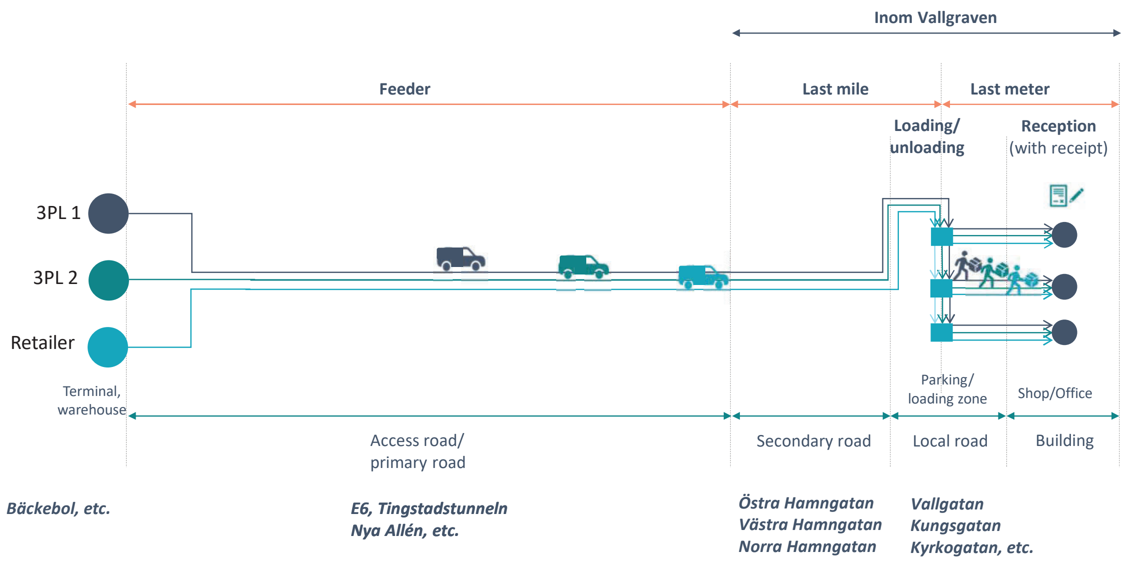

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Scenario 1: progressive policy

Inducing strategic alliances between transport companies by banning of trucks and vans in the whole area during daytime

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Policy actions

Infrastructure
- Provide area/building for city hubs, free to use for transport companies
- Companies using the city hub must accept to transport third party deliveries

Access regulations
- Restricted for trucks and vans during daytime
- Access for light electric freight vehicles only (LEFV), e.g. cargo bikes and micro-vans
- Trucks serving the transhipment platforms get access to bus lanes

Stakeholder management
- Companies using the city-hubs are recognised publicly by authorities

Infrastructure and parking	Access regulations	Stakeholder management
Infrastructrure	*vehicle-related restrictions*	*Transport management*
Land for city hubs	**Vehicle size and weight**	Urban consolidation center
parking management	vehicle emissions	*Demand management*
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	Load-factor based restrictions	*Recognition and certification*
	minimum load factor	**Recognition programs**
	Lane management	Certification programs
	restricted multi-lane use (bus lane)	

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Effects

- Big 3PLs forced to switch from van deliveries (several vans in the area) to combined truck-LEFV deliveries
  - operate own city hubs (costs are reduced due to free access to suitable sites)
  - or buy the services of dedicated last-mile specialist (e.g. DHL-Pling)
- Smaller actors who cannot afford own micro-terminals can hand over their deliveries to a micro-terminal in the area or even to a 3PLs main terminal in the suburbs
  - Already possible today (OMEX, Pling, Velove) but so far only niche applications
- Incentives
  - Free land for city hubs
  - Access to bus lanes for feeder transports

Could result in several alliances operating independently, i.e. each 3PL forms an alliance with "own" last mile specialist, or operates own LEFV fleet.
→ Limited consolidation effect for receivers (deliveries from several alliances)

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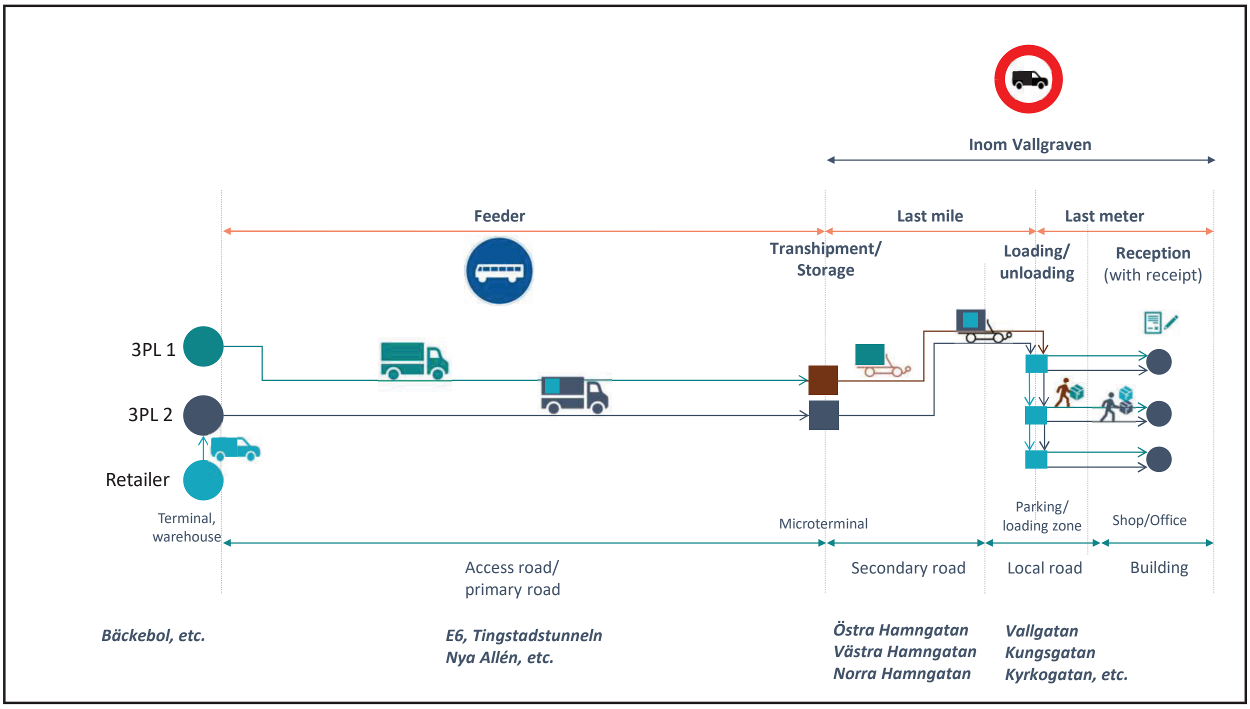
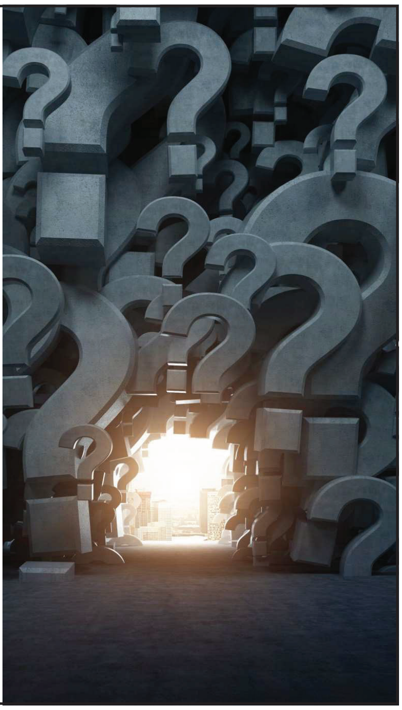


45

Policy measures: Questions and challenges

- Is it legally possible to ban vans but to allow passenger cars (in case this is desired)?
- Is it legally possible to regulate LEFV (cargo bikes and micro-vans)? Are they allowed to enter in case of a general vehicle ban?
- What are the consequences for service and construction vans? Is there a need for alternatives even for these vehicles?
- Is the city allowed to provide public land/buildings to transport companies free of charge?
  - Can the city do this conditionally, i.e. require the those who use the site commit themselves to delivery third party goods for a certain cost (e.g. own account operators)?



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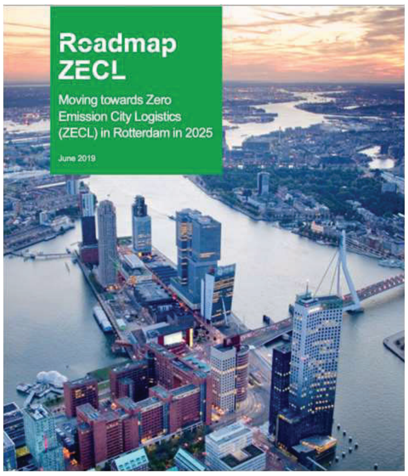
Examples: zero-emission zones



The Netherlands: 30–40 cities to implement harmonized ZEZ-Fs by 2025
The Dutch National Climate Agreement requires the logistics sector to significantly reduce CO2 emissions. One of the recommended tools is the implementation of ZEZ-Fs in the country's 30-40 largest cities.

London: From "ultra low" to zero emission
London is planning a series of progressively larger ZEZs to support Mayor Khan's goal that by 2050 London will be a "zero carbon city" and enjoy the best air quality of any major city in the world. The London Mayor's Transport Strategy (2018) declares goals for zero-emission zones in town centres from 2020; a ZEZ in central London from 2025; larger ZEZs in inner London by 2040, and a ZEZ throughout greater London by 2050.

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Scenario 2: progressive demand management

Real estate owners see the value of vehicle-free and emission-free shopping environment and therefore take control over deliveries

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Demand actions

Real estate owners establish a company for logistics services for their tenants

1. The company purchases the operation of both terminal and transport services
   - SUCC
   - Feeder
   - Microterminal
   - Last-mile
2. Requirement on operators to use zero-emission vehicles for feeder and LEFV for last mile transport
3. Requirement on tenants (receivers) to change their delivery address to the SUCC
4. The logistics service company charges a fee per delivery from the tenants
   - Differentiated fees, e.g. lower fee for allowing longer lead time, etc.
5. Joint order system for ancillary goods (office supplies and other non-critical products)
6. Company purchases waste and recycling services for whole area

Infrastructure and parking	Access regulations	Stakeholder management
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	Load-factor based restrictions	*Recognition and certification*
	minimum load factor	Recognition programs
	Lane management	Certification programs
	restricted multi-lane use (bus lane)	

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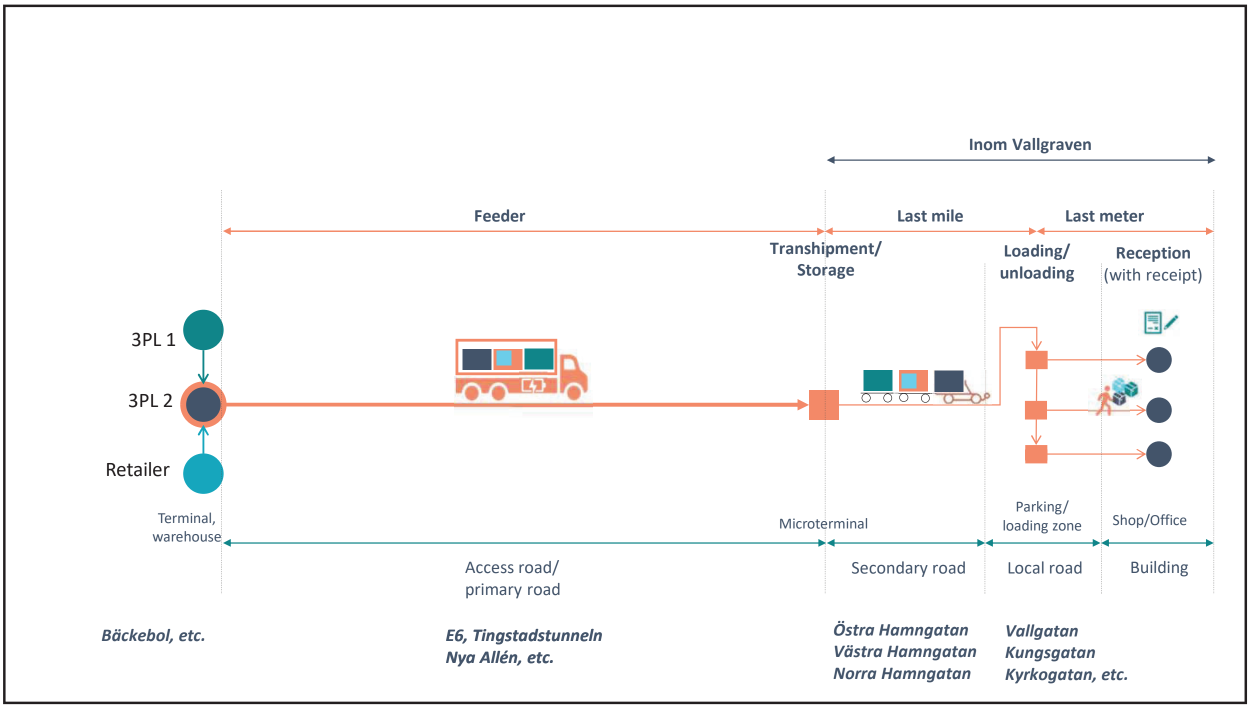
Potential effects

- Combined truck-LEFV deliveries
  - Reduced traffic on access roads
  - Vehicle-free inner city (only LEFV with reduced conflict level)
- Zero-emission deliveries
  - Attractive shopping environment
  - ”green marketing”
- Reduced number of deliveries
  - Incentive for receivers for less frequent orders
  - Incentive for allowing larger time windows enabling higher load factors
  - Consolidated ancillary deliveries
- Effects for receivers
  - Better logistics quality
  - Potentially higher logistics costs
- Potentially balanced flows on feeder link
  - Inbound: goods
  - Outbound: waste and recycling

50



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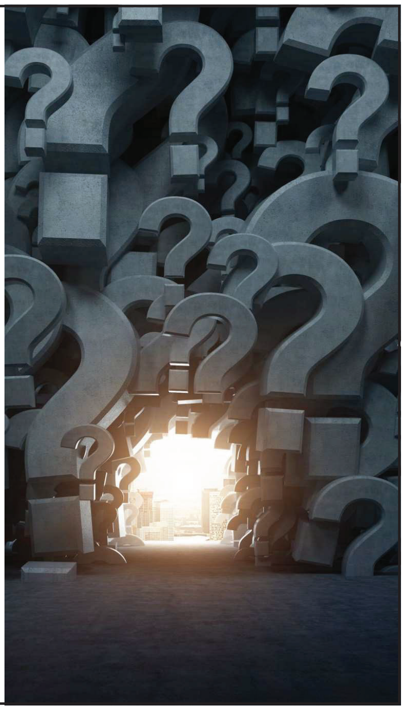
Demand management: Questions and challenges

- Can real-estate companies require tenants with existing contracts to use common logistics services?
- Can they introduce a fee per delivery?



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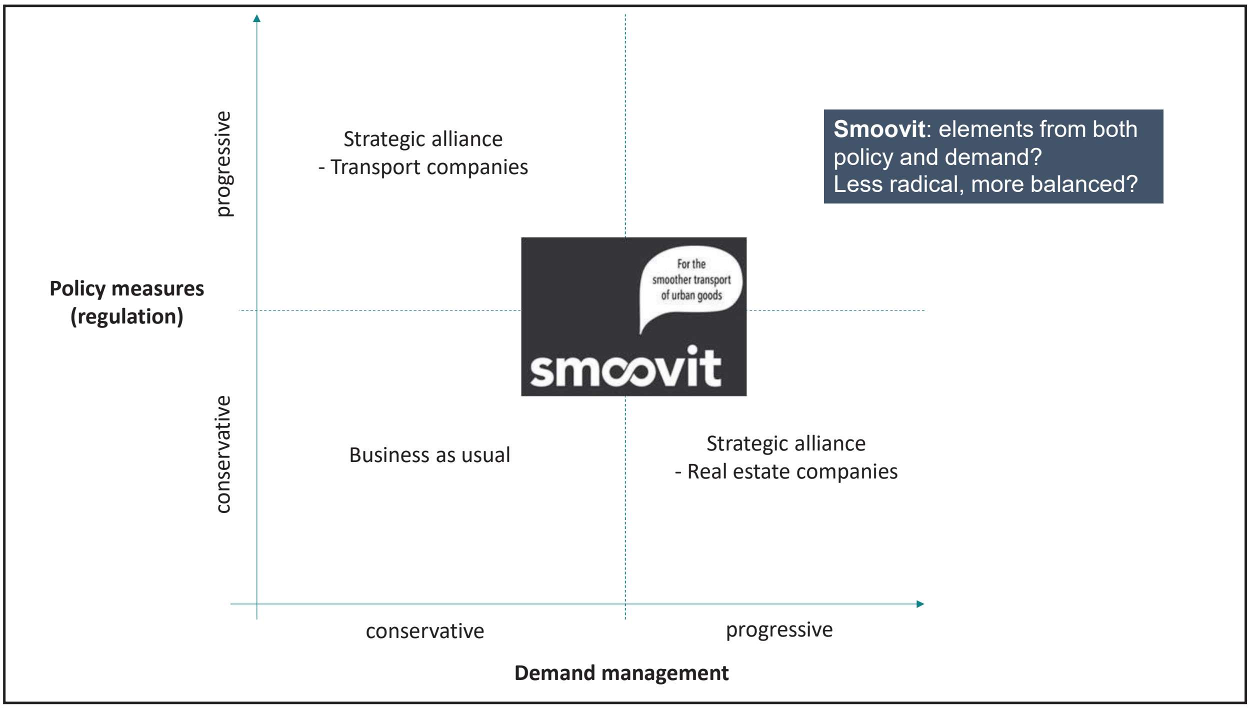
Policy measures (regulation)
progressive
conservative
Strategic alliance
- Transport companies
Smoovit: elements from both policy and demand?
Less radical, more balanced?
For the smoother transport of urban goods
smoovit
Business as usual
Strategic alliance
- Real estate companies
conservative
progressive
Demand management

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SMOOTh sustainability potential

Freight Traffic Generation Modelling and Sustainability Assessment

Case study: Gothenburg, inom Vallgraven

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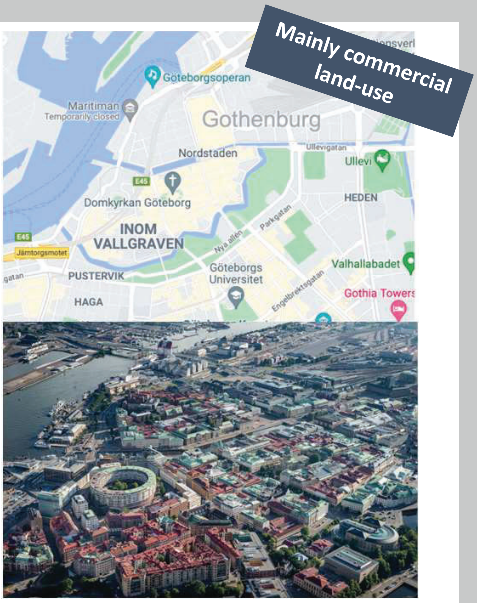
Case study: Gothenburg, City area 'inom Vallgraven'

Research Questions

1. Present situation: What are the external costs of delivery traffic that enters 'inom Vallgraven' today?
2. How large is the theoretical reduction potential by freight consolidation systems?



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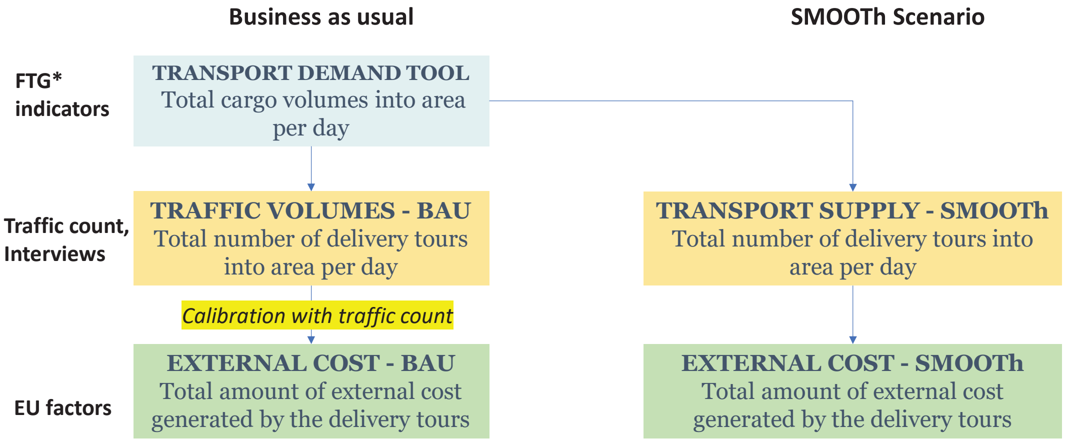
Model design



FTG* = Freight Transport Generation

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Calculation model - Background

"The relationship between technological innovation and environmental impact has been conceptualized mathematically by the IPAT equation. IPAT is an identity simply stating that environmental impact (I) is the product of population (P), affluence (A), and technology (T)."

→I = P x A x T

- P: number of persons (=consumers)
- A: consumption per person
- T: Environmental impact per unit of consumption

Source: Chertow, M. R. (2000). The IPAT equation and its variants. *Journal of industrial ecology*, *4*(4), 13-29.

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SMOOTh Calculation Model

Transport demand | Transport Supply | Impact Assessment

$$\textit{External costs} = \#\,Receivers \times \frac{\#Deliveries}{Receiver} \times \frac{\#load\ units}{Delivery} \times \left(\frac{\#load\ units}{Vehicle\ tour}\right)^{-1} \times \frac{\#veh.km}{veh.tour} \times \frac{\#impact}{veh.km} \times \frac{\#external\ cost}{impact}$$

Urban density
Size of zone

Receiver type
Number of employees

Transport operator type

Origin & Destinations, Route planning

Vehicle type and technology

Geography/ Density/Traffic conditons/time of day

Written in key factors:

$$\textit{External costs} = \#\,Receivers \times \text{Delivery intensity} \times \text{Delivery size} \times (vehicle\ load)^{-1} \times \text{tour distance} \times \text{impact intensity} \times \text{cost intensity}$$

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SMOOTh Calculation Model – Example

Transport demand | Transport Supply | Impact Assessment

$$\textit{External costs} = \#\,Receivers \times \frac{\#Deliveries}{Receiver} \times \frac{\#load\ units}{Delivery} \times \left(\frac{\#load\ units}{Vehicle\ tour}\right)^{-1} \times \frac{\#veh.km}{veh.tour} \times \frac{\#impact}{veh.km} \times \frac{\#external\ cost}{impact}$$

Urban density
Size of zone

Type of econ. activity

Transport operator type

Origin & Destinations, Route planning

Vehicle type and technology

Geography/ Density/Traffic conditons/time of day

$$\textit{External costs} = 10\ Receivers \times \frac{10\ Deliveries}{Receiver} \times \frac{1\ load\ unit}{Delivery} \times \left(\frac{10\ load\ units}{Vehicle\ tour}\right)^{-1} \times \frac{10\ veh.km}{veh.tour} \times \frac{10\ \text{gram PM10}}{veh.km} \times \frac{10\ €}{kilogram\ PM10}$$

= 10 €

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Factors in the calculation model

- Number of receivers: number of shops, hotels, restaurants, offices, etc. and residents in the zone which is served by SMOOTh
- Delivery intensity: average number of deliveries per receiver type
- Delivery size: amount of goods per receiver (e.g. number of load units)
- Vehicle load: amount of goods per vehicle tour (e.g. number of pallets)
- Tour distance: distance of vehicle tour (e.g. number of kilometers)
- Impact intensity: The vehicles emissions, noise, size per kilometer driven (e.g. gram PM10 per km)
- Cost intensity: The external costs generated by impacts (e.g. € per kg PM10)

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Data sources

Factor	Data source	Comment	Certainty
# Receivers	Official statistics	From SCB	
Delivery intensity	FTG Tool	Based on receiver type and number of employees	
Delivery size	Receiver survey	Data from receivers in Stockholm	
Vehicle load	Driver survey Traffic count	Too few observations Simplified transport operator types (3pl, own account, etc.)	
Tour distance	Driver survey	Too few observations	
Impact intensity	HBEFA	Good emission data, but simplified vehicle fleet data (only 2 categories used)	
Cost intensity	External cost reports	Average data for Europe from 2014	

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Traffic volume calculations – main process

Statistics no. of business and employees

postnr	SNI	Beskrivning av SNI kod	Antl anställda per verksamhet	antal verksamheter	Antal anställda
116 20	73111	eklambyråverksamhet	34,5	2	69
116 21	56100	estaurangverksamhet	14,5	4	58
116 21	85201	rundskoleutbildning och förskoleklass	149,5	1	149,5
116 21	85311	tudieförberedande gymnasial utbildning	74,5	1	74,5
116 21	85593	tudieförbundens och frivilligorganisationernas tbildning	74,5	1	74,5
116 22	47112	ivsmedelshandel med brett sortiment, ej varuhus ller stormarknad	74,5	1	74,5
116 22	56100	estaurangverksamhet	7	9	63
116 22	56100	estaurangverksamhet	74,5	1	74,5
116 22	69201	edovisning och bokföring	74,5	1	74,5
116 24	66190	ndra stödtjänster till finansiella tjänster utom örsäkring och pensionsfondsverksamhet	149,5	1	149,5
116 24	74102	rafisk designverksamhet	74,5	1	74,5
116 24	94990	erksamhet i andra intresseorganisationer	149,5	1	149,5

Use of existing FTG-tool calculating **number of deliveries** per day to businesses

Developed by Ivan Sanchez-Diaz and Atkins for the City of Stockholm

Cargo volume per delivery based on survey among business in Stockholm 2017

Yields **total volume of cargo delivered** to 'inom Vallgraven' each day

Receiver type	Number of load units per day					
	Pallets/cages (dry)	Pallets/Cages (fresh)	Parcels B2B (dry)	Documents	Parcels (fresh)	Parcels (B2C)
Accommodation and Food	110	454	176	59	176	0
Health care services	41	0	210	124	0	0
Offices	114	0	1749	1255	0	0
Public services and education	7	0	105	75	0	0
Retail non-perishable	646	0	1867	826	0	0
Retail perishable	261	202	34	22	34	0
Private households	7	0	0	0	0	133
Total	1187	656	4141	2361	210	133

Separate calculation for e-commerce

Combined with data for load factors, route distances and number of stops for delivery vehicles. Data from interviews with drivers.

OUTPUT: Total traffic volume per day with vehicles delivering cargo

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Traffic count Gothenburg

- All cargo vehicles in + out
- Tuesday 6 October between 07:00 - 22:00
- 26 people engaged in manual registration of truck- and van traffic

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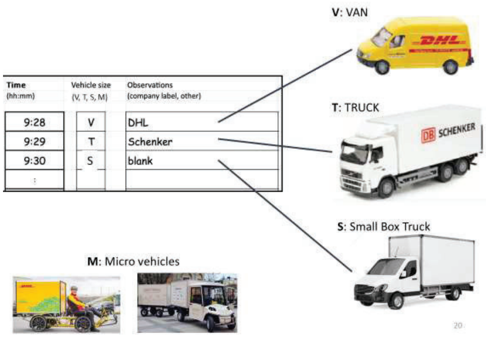
Calibration of Freight Traffic generation Model

Data from traffic count

Uniqe trip/'visit' (in->out > 15 min) → Vehicle registration number → Company using the vehicle → Business area of the company → Categorisation of the traffic by business type



No of unique visits to the zone	Trucks	Small Box Trucks	Vans
Network transport companies (Big 3PL) (e.g. PostNord, DHL, Schenker)	11	8	48
Transport companies (T)	151	115	95
HotellRestCater (H)	20	66	114
Own Account (OA)	19	46	153

Calibration of traffic generation model

Comparing with traffic volumes yielded by model

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Validation

- We compare the output from the model with the observations from the traffic count.
- Practically no difference on total traffic.
- +/- 10% difference within vehicle categories
- Expected differences due to assumptions made in the model
- Further analysis of the data from the traffic count planned.
- We will review our assumptions in the model in order to see if the modell can be made to fit the observation better.

Parcels Big

	modelled	observed	difference
Small box truck - Big 3PL	8	8	0%
Van - own account+HORECA	254	267	-5%
Total	262	275	-5%

Parcel Small

	modelled	observed	difference
Van - Big 3PL	67	48	28%
Van - Small 3PL	130	95	27%
Total	197	143	28%

Pallet eq

Vehicle Size	modelled	observed	difference
Truck - all	197	221	-12%
Small box truck - all	222	227	-2%
Total	419	448	-7%

Total daily incoming traffic to 'inom Vallgraven' with goods vehicles for deliveries and pick up

Vehicle Size	**modelled**	**observed**	**difference**
Truck	197	221	-12%
Small Box truck	230	235	-2%
Van	451	410	9%
Total	**878**	**866**	1%

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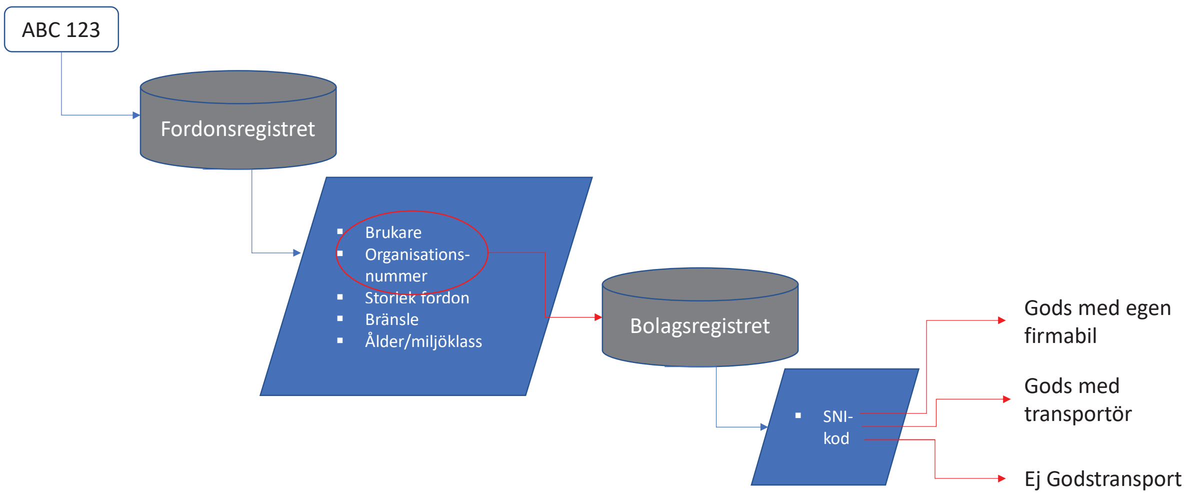
Metod



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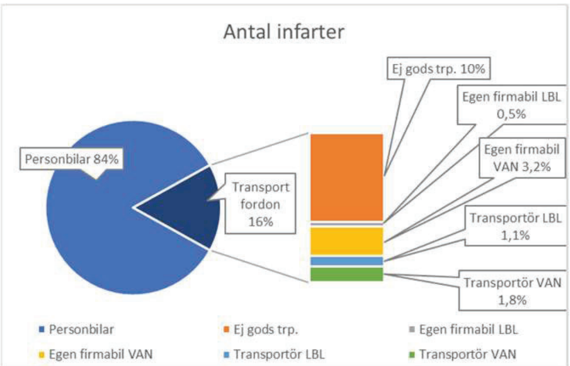
Results from traffic count Vallgraven 2019

Total 15 000 vehicle entries registred during one day (07-21)



Entries with freight vehicles

Category	**number of entries**
Own Account	560
Carrier/transporter	450
Non-transport	1460 (of which aprox. 600 crafts men/real estate)

<u>Co-loading potential example:</u>
If co-loading were to succeed in removing 80% of all 'own account vehicles' and 50% of carriers' vehicles:

Then 670 entrances disappear, corresponding to **27%** of transport vehicles, **4%** of all vehicle traffic

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Some observations form the traffic count

Entries with freight vehicles 2019
per fuel type

Diesel och bensin: 89%
El: 3%
Gas: 3%

Infarter med godsfordon 2019
per kategorier

	Bygg o Fastighet	Hotell	Gods med eget fordon	Private	Service	Gods med transportör	Avfall	Ej kategoriserade	**Total**
Lastbilar	11	19	21		17	171	35	16	**290**
Vans	416	180	198	46	647	272	17	378	**2154**
Antal totalt	**428**	**200**	**221**	**47**	**669**	**459**	**52**	**404**	**2480**
Andel av totalt	17%	8%	9%	2%	27%	19%	2%	16%	100%

Vistelsetid inne i zonen, medelvärde (hh:mm)			
Fordonstyp	Ej transport	Gods med eget fordon	Gods med transportör
Lastbil	00:47	00:30	00:26
Van	01:40	00:46	00:26

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Modelling results

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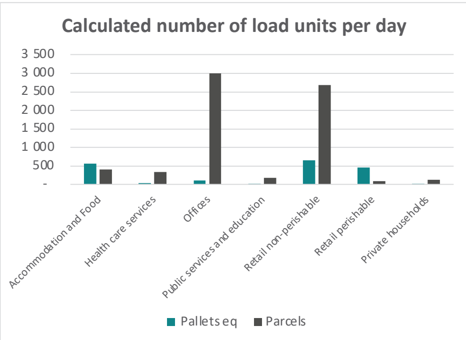
Business as usual: Demand and resulting traffic

TRANSPORT DEMAND
Total cargo volumes into area **per day**

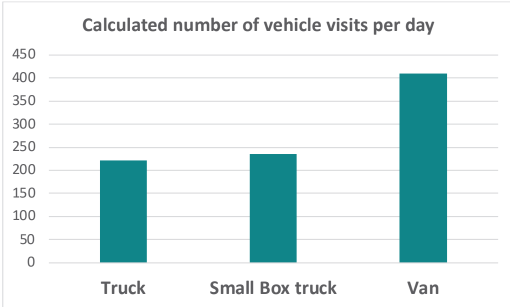
- Approx. 1 900 pallets and cages
- Approx. 6 800 parcels



TRAFFIC VOLUMES
Total number of delivery tours into area **per day**

- Approx. 200 trucks (observed 221)
- Approx. 230 small box trucks (235)
- Approx. 450 vans (410)

- 12 pallets/cages per vehicle
- 15 parcels per vehicle



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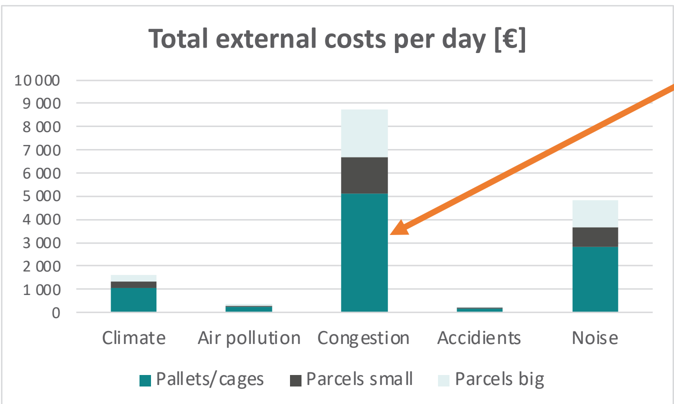
Business as usual: External costs

- Approx. 16 000 € per day
- Congestion accounts for approx. 55%



Large number of small box trucks with low capacity utilisation

→ Potential for consolidation!

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Scenarios

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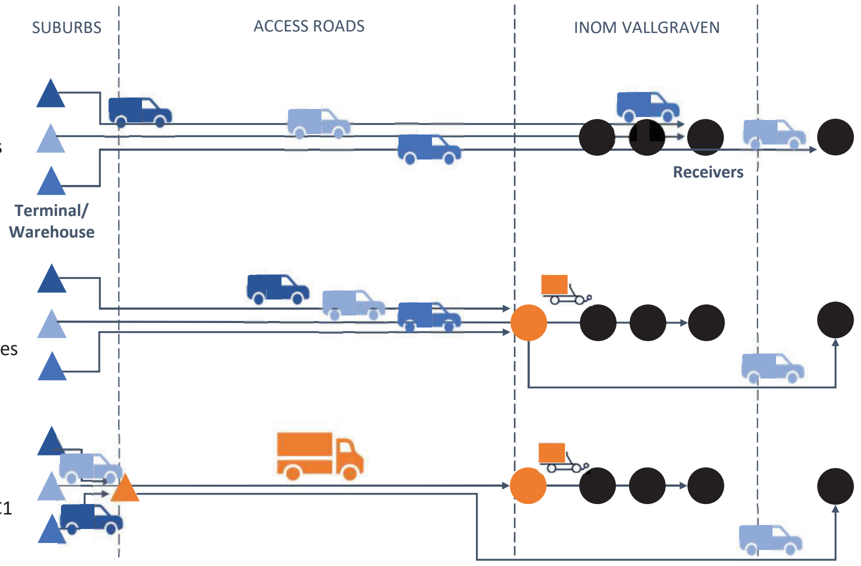
Scenario analysis A: Parcel deliveries (big and small parcels)



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Assumptions for Sc2 - SUCC and city hub

- several strategically located SUCCs (North, South, East and West) so that detours are avoided.
- Big 3PL can replace 100% of the tours (as they have large volumes and large fleet operating in the city).
- Own account operators can replace 25% of the tours (not so many actors who have a larger fleet enabling redistributing of the deliveries.
  - The remaining 75% deliver the goods for the target area to the SUCC and continue than as in BAU.
  - We assume no detours.
- Shuttle between SUCC and City Hub is a conventional truck (Diesel Euro 6)

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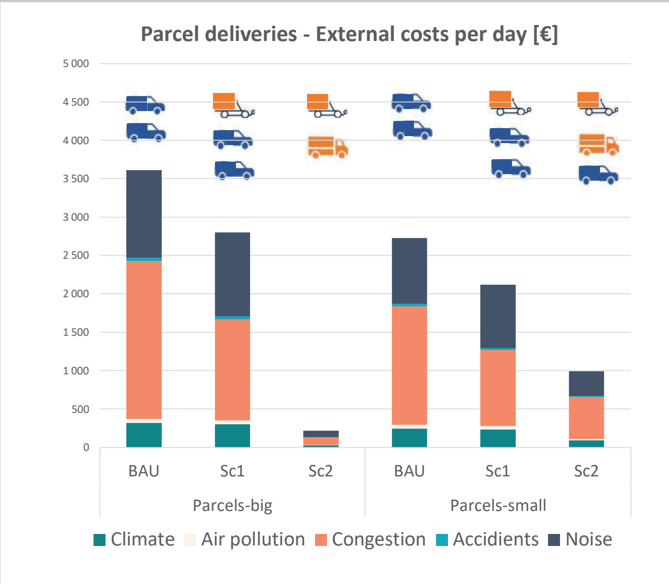
Results: Parcel deliveries

- **BAU:** Fragmented deliveries
- **Sc A1 Conventional UCC:** Consolidated last-mile with light (electric) vehicles
- **Sc A2 Suburban consolidation and city transhipment hub:** Sc1 + consolidated trunk transport by truck



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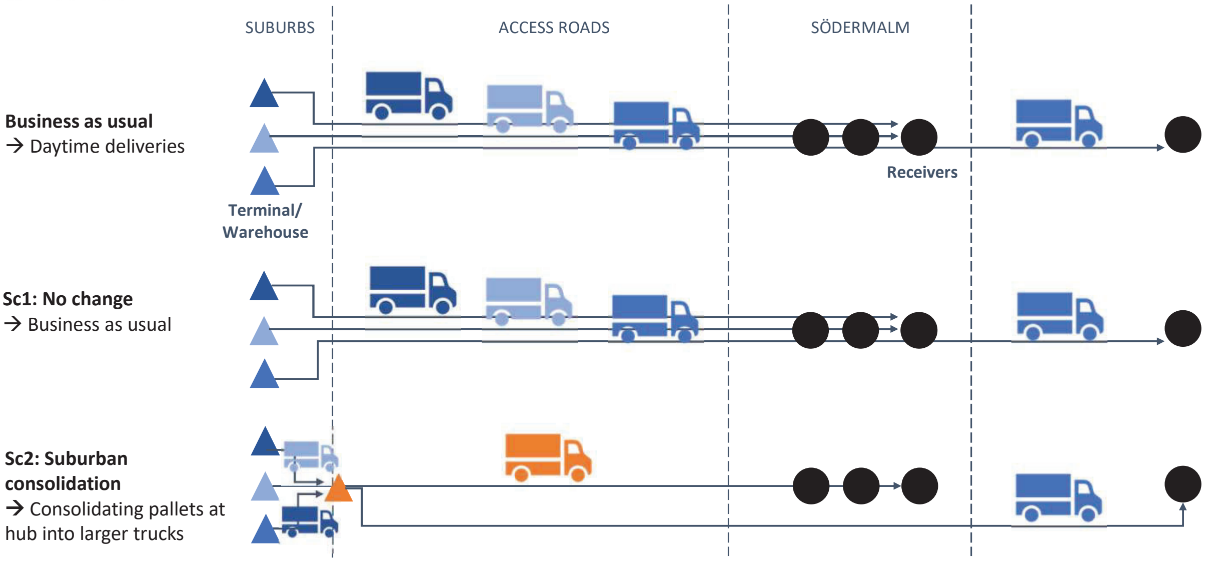
Scenario analysis B: Pallet/roller cages delivery by trucks



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Assumptions Sc2 – Consolidation at SUCC

- All trucks and small box trucks drive to SUCC. From there SUCC-trucks take over deliveries to receivers in the zone.
- Only 50% of the tours can be replaced completely (as there are not so many actors who have a larger fleet enabling redistributing of the deliveries).
- The remaining 50% deliver the goods for the target area to the SUCC and continue than as in BAU. We assume no detours for the trip to the SUCC.

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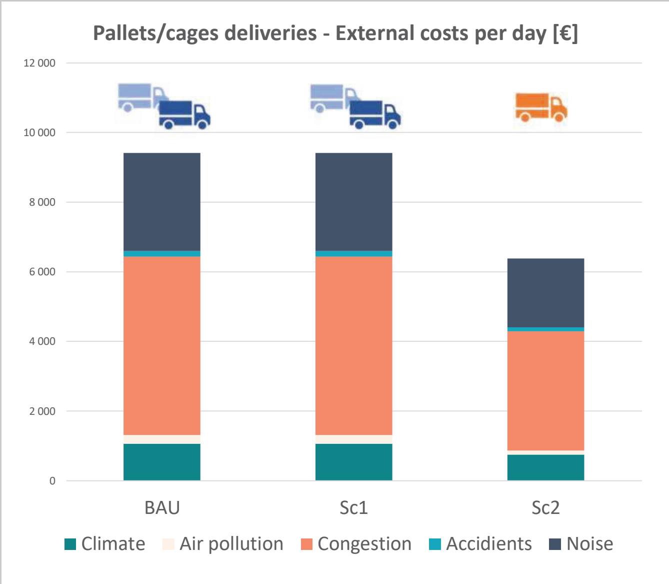
Results: Pallet deliveries

- **Business as usual:** Daytime deliveries
- **Sc1:** no change
- **Sc2 Suburban consolidation:** Consolidating pallets at hub into larger trucks



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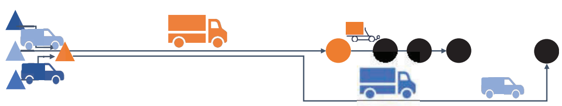
Traffic work SC2 vs. BAU



	Number of veh.km		
	Truck	**Box truck**	**Van**
Pallets/cages	8 252	7 225	
Parcels big	156		9 028
Parcels small	45		2 968
Total	**8 453**	**7 225**	**11 996**
BAU (for comparison)	10 239	16 641	22 438
Change	-17%	-57%	-47%

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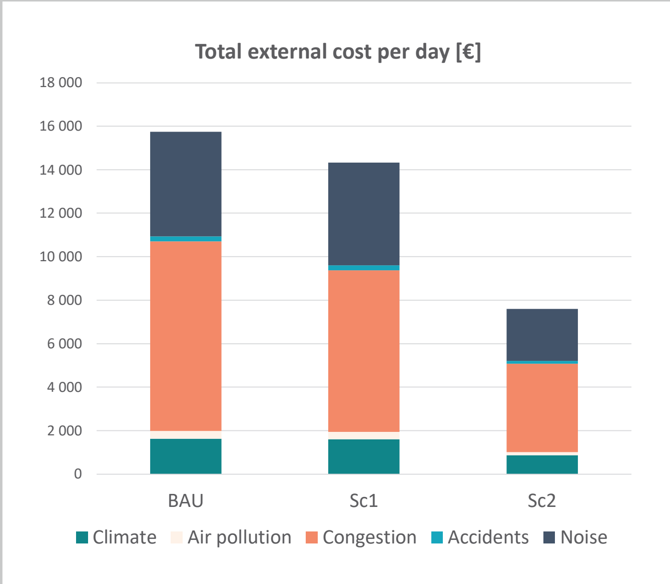
External costs comparison

- Limited reduction if consolidation at city hub only (-10%)
- Significant reduction requires consolidation at SUCC (-50%)



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Conclusions
(or rather "Our Model Calculations Indicate …")

- Congestion is largest contributor to external costs
- Consolidation system yield large potentials for reduced external costs
- Suburban consolidation required to achieve the higher consolidation potential
- 'Deliveries outside consolidation zone' limits reduction potential
- Results are indicative
  - Assumptions on capacity utilisation, route distances, etc.
  - Based on conventional technology

→**Further research** suggested in order to reduce data uncertainties, e.g. more interviews with drivers, receivers and better vehicle data

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Thank you!

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Registration number (ABC 123)	Direction (mark with x) In	Direction (mark with x) Out	Time (hh:mm)	Vehicle size (V, T, S, M)	Observations (company label, other)
ABC123	X		9:28	V	DHL
EFG456		X	9:29	T	Schenker
HIJ789		X	9:30	S	blank
			:		

V: VAN

T: TRUCK

S: Small Box Truck

M: Micro vehicles

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30