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Preface

The project was funded by the Swedish Energy Agency. The project participants, Chalmers Industriteknik and VTI, have received funding from the Swedish Energy Agency corresponding to 77% of the project budget. CargoSpace24, JM, Lidl, NCC, Sweboat, Sveriges Åkeriföretag and Veolia have financed 23% of the project's budget with inkind. The project started in August 2018 and ended in December 2020.

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Sammanfattning

Sverige ska ha ett fossilfritt inrikes transportsystem år 2045. Idag är cirka 20% av godstransporterna med lastbilar i Sverige tomma, mätt i fordonskilometer (Trafikanalys, 2017). När man inkluderar underutnyttjade transporter blir denna andel ännu högre. USECAP-projektet har fokuserat på tre områden för att bidra till ökad transporteffektivitet 1) uppskatta andelen underutnyttjad kapacitet som utgör en realiserbar effektivitetsförbättringspotential på nationell nivå, 2) analysera hur varuägare och transportörer mäter och följer upp nyckeltal för transporteffektivitet för att realisera effektivitetspotentialen och 3) utveckla en konceptuell modell för ett digitalt verktyg som innehåller funktioner som gör det möjligt för varuägare och transportörer att bättre matcha efterfrågan och utbudet och därigenom utnyttja överkapacitet. Metoderna var en litteraturstudie, intervjuer, workshops, praktikfall inklusive både kvantitativa och kvalitativa data, en mobil etnografistudie och en kvantitativ analys baserad på resultat från den svenska godstransportmodellen Samgods.

De strukturella obalanserna i den geografiska fördelningen av efterfrågan på transporter är betydande. Detta innebär att man kan förvänta sig betydande nivåer av tomgångskörning, som inte kan minskas genom effektiviseringsåtgärder. Brist på lämpliga empiriska data har dock inneburit att dessa resultat inte kunde valideras empiriskt. Egenskaperna hos Samgods-resultaten skapar källor för samtidig och obetydlig över- och underskattning av efterfrågans obalanser, vilket i sin tur skapar ett behov av empirisk validering av de resultat som nås här. Dessutom utvecklades en alternativ modell för att beräkna dubbelriktad tom körning i nätverkets länkar för varje varutyp. Användningen av detta illustreras även om inga användbara resultat erhålls på grund av samma brist på empiriska data som beskrivits ovan.

I projektet analyserades hur nyckeltal för transporteffektivitet i form av kostnad, tid, fordonsanvändning och miljöpåverkan mättes och följdes upp av transportörer. Resultaten visar att transportörer ofta har egna nyckeltal för kostnad, tid och fordonsanvändning. Kostnader följs upp regelbundet, men tid och fordonsanvändning analyseras oftast bara när problem uppstår. För miljöpåverkan finns det delvis standardmetoder som transportörerna använder. Det var vanligast för transportörer att dela nyckeltal för tid och miljöpåverkan. Det finns ett behov av mer strukturerade och branschövergripande sätt att mäta och följa upp nyckeltal för transporteffektivitet för att identifiera var de största förbättringarna kan göras.

Ett digitalt verktyg som ska göra det möjligt för varuägare och transportörer att dela data om transportbehov och tillgänglig kapacitet och därmed hitta matchningar för ökad transporteffektivitet måste ha funktionalitet inom sex kategorier: marknadsplats, transportplanering, användarvänlighet, hållbarhetsinformation, samarbete och ekonomisk information. För att kunna använda verktyget måste varuägare och transportörer göra anpassningar i nuvarande samarbets- och affärsmodeller samt i den dagliga verksamheten.

Summary

Sweden shall have a fossil-free domestic transportation system by 2045. Today, about 20% of freight transports by trucks in Sweden are empty, when measured in vehicle kilometres (Trafikanalys, 2017). When considering underutilized transport, this percentage becomes even higher. The USECAP project has focused on three areas to contribute to increased transport efficiency 1) estimating the proportion of underutilized capacity that constitutes a realizable efficiency improvement potential at a national level, 2) analysing how shippers and transport providers measure and follow up transport efficiency Key Performance Indicators (KPIs) to realize the efficiency potential, and 3) developing a conceptual model for a digital tool containing functionalities that enable shippers and transport providers to better match demand and supply and thereby utilize overcapacity. The methods used are a literature study, interviews, workshops, cases including both quantitative and qualitative data, a mobile ethnography study, and a quantitative analysis based on results from the Swedish National Freight Transport Model Samgods.

The structural imbalances of the geographical distribution of transport demand are substantial. This means that significant levels of empty running, that cannot be reduced by efficiency improvement measures, are to be expected. However, lack of suitable empirical data has meant that these results have not been empirically validated. The properties of the Samgods results create sources for simultaneous and unquantifiable over- and underestimation of the demand imbalances, in turn creating a need for empirical validation of the results reached here. Furthermore, an alternative model is developed for calculating bi-directional empty running in the links of the network for each commodity type. The use of this is illustrated though no useful results are obtained due the same lack of empirical data described above.

In the project it was analysed how KPIs on transport efficiency for cost, time, vehicle utilization and environmental impact was measured and followed up by transport providers. The results show that for cost, time, and vehicle utilization the transport providers often have their own KPIs. Costs are followed up regularly, but time and vehicle utilization are mostly only analysed when problems occur. For environmental impact, there are partly standard methods that the transport providers use. It was most common for transport providers to share data on KPIs for time and environmental impact. There is a need for more structured and cross-industry ways of measuring and following up on KPIs for transport efficiency to identify where the largest improvements can be made.

A digital tool that should enable shippers and transport providers to share data on transport needs and available capacity and thereby find matches for increased transport efficiency must have functionalities within six categories: marketplace, transport planning, user friendliness, sustainability information, collaboration, and financial information. To be able to use the tool the transport providers and shippers must make adaptations in relation to their existing collaboration and business models as well as adaption in their daily operations.

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1 Introduction/Background

The transport sector accounts for approximately one third of the Swedish CO2 emissions (Naturvårdsverket, 2017). Sweden has the goals of reducing greenhouse gas (GHG) emissions from domestic transport (except from air transport) by 70% by 2030 compared to 2010 and being fossil-free by 2045. Today, measured in vehicle kilometres, about 20% of freight transports by trucks in Sweden are empty, i.e. transport is completed without any cargo (Trafikanalys, 2017). The figure is considerably higher when including units with underutilized capacity. Sweden's goals of reducing GHG emissions in the transport system can be reached by focusing on two measures: (a) The increase of (energy) efficiency in the transport system; and (b) through technological development. Commonly accepted is the idea that a combination of both measures is needed to reach the goal in time. This project has its focus on increasing transport efficiency, foremost through collaboration of actors and a more structured approach to measuring and following up efficiency measures, but also links to digital development in that field.

One important area to increase transport efficiency is by better utilizing capacity that is underutilized. Empty running or underutilization of capacity can arise for different reasons. Knowing the reason for empty running is indispensable to realize the efficiency improvement potential. Empty runs can occur due to structural imbalances, meaning that the demand for transport between two points is not symmetrical i.e. there is more to transport in one direction than the other (Lumsden, 2007). Empty running due to this reason cannot be eliminated by efficiency improvement and thus is a poor estimate of the efficiency improvement potential of the system (Trafikanalys, 2011). Conversely, there can be empty runs in both directions between two points. This can be due to a host of reasons like temporal distribution of transport demand or market failures meaning that some of the empty runs can potentially be removed by increased efficiency. On the one hand, the fact that there is considerable underutilization and empty running within the Swedish freight transport system is evident. On the other hand, there are no reliable analysis at national level that show how much of the observed overcapacity constitutes a realizable efficiency improvement potential (Trafikanalys, 2016a). To be able to estimate this improvement potential, it is indispensable to understand how much an increased load factor can reduce the energy usage in the transport system in Sweden.

For the flows where the underutilization or empty runs represents a realizable efficiency improvement potential, there are several solutions to increase transport efficiency. Increasing load factors and thus reducing underutilized capacity has been the focus of previous research. Regarding causes and solutions for reducing empty runs and underutilization, Trafikanalys, the Swedish Transport Administration, the Swedish Transport Agency and Vinnova performed, on the behalf of the government, an in-depth analysis in 2010–2011 of empty running and low load factors in the Swedish transport system with the aim of proposing measures to increase transport efficiency. The results pointed to several difficulties in capturing the scope of the problem and the proposals for measures aimed at improving the possibilities for further analysis through further development of the official statistics (Trafikanalys, 2011). The issues are still highlighted as being current according to Trafikanalys (2016a). In 2013–2016, a large Vinnova project was carried out in collaboration between Chalmers University of Technology and the University of Gothenburg, which aimed to increase transport efficiency through better utilization of loading capacity (increased load factor). Results from this venture were, among other things, operationalisation of the concept of transport efficiency, where the degree of loading is included as a component (Arvidsson, 2013), operationalisation of the concept of transportation as indicator of transport efficiency (Pahlén and Börjesson, 2012), and the effect of shippers on transport efficiency, both with respect to the shippers' logistics and procurement processes (Santén, 2016 and Rogerson, 2016). Other, recently completed projects address similar problems and seek to find solutions for increased transport efficiency by helping to realize the efficiency potential of the existing transport system (Halldorsson, 2018) such as through the investigation of causes of overcapacity (Wehner, 2018), and through horizontal collaborations (Arvidsson, 2017). This previous research provides understanding of why the transport efficiency is often low. However, for shippers and transport providers it is important to understand where there is potential to improve the transport efficiency. Björklund et al. (2012) presented advantages of measuring transport performance, including the evaluation of performance, improvement processes and the identification of success factors. McKinnon et al. (2003) suggested categories of transport efficiency KPIs that can be used to measure transport performance. However, there is a gap in previous research providing understanding of which KPIs are measured at present in Sweden. This is a current issue, considering that there is an increased demand on lowering the environmental impact, while at the same time the technological development has come a long way in recent year. The combination of those is opening for new ways of measuring and sharing data. Beyond sharing data on KPIs, technological advancements can also enable shippers and transport providers to better match shipments and utilize capacity in transport systems. However, for both KPI measurements and data on transport capacity it is important to understand how data should be shared between actors, followed up, and what functionalities digital tools need to include.

The research in this project will therefore contribute to the transition to a transport efficient society by exploring what data is available at both national and industry level and how it can be analysed and shared between actors by exploring the following three areas:

> (1) Estimating the proportion of underutilized capacity that constitutes a realizable efficiency improvement potential at the national level,
>
> (2) analysing how shippers and transport providers measure and follow up transport efficiency Key Performance Indicators (KPIs) in order to realize the efficiency potential, and

(3) developing a conceptual model for a digital tool containing functionalities that enable shippers and transport providers to better match demand and supply and thereby utilize overcapacity.

The academic parties in the project are Chalmers Industriteknik (CIT) and VTI, both with long experience in freight transport research and applications in supply chain management. The industry partners represent three important groups for reducing the overbalances: Transport providers (Sveriges Åkerier), shippers (JM, Veolia, NCC, Lidl and Sweboat) and a tool provider (CargoSpace24).

The report is structured in accordance with the project's work packages WP1 to WP3. WP4 and WP5 were part of conducting the project but are excluded from the report. An overview of the work packages is presented in Table 1.

Table 1. Work packages

WP	Title (English)	Title (Swedish)	Responsible
1	Realisable efficiency improvement potential	Realiserbar potential för effektivitetsförbättring	VTI
2	Measure and follow up on transport efficiency from an industry perspective	Mät och uppföljning av transporteffektivitet ur ett industriperspektiv	Chalmers Industriteknik
3	Development of functionality of a digital tool	Utveckling av funktionalitet av ett digitalt verktyg	CargoSpace24
4	Dissemination of results	Resultatspridning	Chalmers Industriteknik
5	Project management	Projektledning	Chalmers Industriteknik

2 Method

In this section, motivations and descriptions are presented of the applied methods.

2.1 WP1 – Realisable efficiency improvement potential

The purpose of the first work package is to estimate a measure of realizable efficiency improvement potential of the domestic Swedish road freight transport system.

The amount of empty running in a transport network, in and of itself, is not a sufficiently precise indicator of the transport efficiency improvement potential of that system. Empty running that is the result of structural imbalances in the transport demand cannot be eliminated by increased efficiency. One can correctly argue that the empty running in those instances is a feature and not a bug. For illustration consider transports in mining, fishery, or petroleum sectors. Running empty units back to the mines, wharfs, or wells is not a sign of inefficiency, rather a necessary step to enable moving goods from where they are to where they need to be.

Hence, estimating structural imbalances in the geographical distribution of transport demand in a network can serve as indicator for the level of empty running that is to be expected when the transport capacity in the network is "perfectly" efficiently utilized i.e. the maximum efficiency potential of the system expressed as capacity utilization. Comparing the expected empty running due to the structural imbalances with the empty running occurring in the network creates a better estimate of efficiency *improvement* potential of the network than the measure of empty running alone. It is still possible that some of the remaining empty running cannot be eliminated due to coordination losses and market imperfections, but as an estimate of realizable efficiency improvement potential, the new indicator ought to be much more accurate.

Another way to approach the same concept is to study the flow of empty units in the network. What signifies empty running due to structural imbalances is the fact that empty units run only in one direction. This means that when empty units are running in both directions in the links of the network, some of it can be eliminated through increased efficiency. There is no established terminology for distinguishing between empty running due to structural imbalanced (in one direction) and bi-directional empty running. For reasons of clarity in this report the term ER1 is used to denote unidirectional empty running i.e. empty running due to structural imbalances in the geographical distribution of transport demand and ER2 for bi-directional empty running which is an indicator for realizable efficiency improvement potential.

The major obstacle for performing these types of analyses is access to empirical data. Necessary data needs to be on network level and capture both transport demand and performed transport on commodity level. To remedy the lack of access to adequate empirical data, a novel approach was taken to base the analyses on model results from the Swedish National Freight Transport Model, Samgods.

Samgods, the Swedish National Freight Transport Model, includes freight transport to, from and through Sweden. The emphasis is on long-distance transport; the model is not adapted for analysis of local or urban transport, especially intra-municipal transport. The Swedish Transport Administration is responsible for administration and development. Input data for the model is i.a. product flow matrices, so called producer-consumer matrices (PWC matrices), which describe the quantity of transport demand for different commodity types from zone to zone during a year. These matrices have been developed, among other things, through a special statistical survey – the Swedish Commodity Flow Survey (VFU) – which is carried out by Trafikanalys.

Samgods produces a large amount of output about the transport solutions: Tons of goods and number of vehicles flowing on the links and through the nodes in the network, fill rates in the vehicles, transport costs, etc. At the aggregate level (nationally) a number of different indicators are obtained: Ton-kilometres, vehicle kilometres, cost, etc. The model estimates are made by, in principle, calculating the transport solution that minimizes the total logistical cost in the system. This is a reasonable model assumption because the players in the transport industry try to act in the most cost-effective way possible.

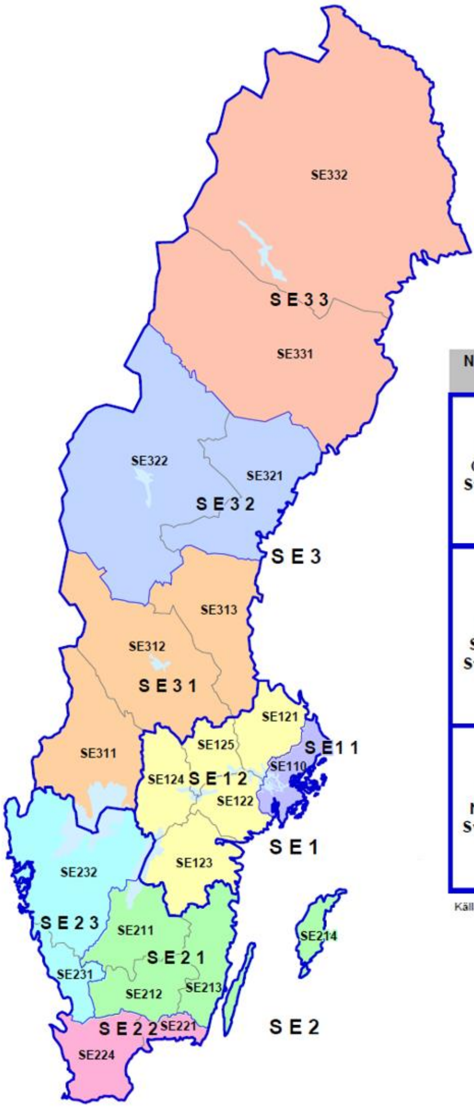
Calculation models are developed to calculate ER1 and ER2 for Swedish domestic road freight transport system. Results from the models are used to estimate the maximum achievable efficiency potential and realizable efficiency improvement potential of that network. The novel approach of using model results from Samgods as input for these analyses are evaluated and discussed.

2.1.1 ”Data” from Samgods

The data used in the calculation models developed here are in fact model results from Samgods. For enhanced readability, the term "data" is used to refer to these inputs to our calculation models. But the reader should always be aware that the data is not empirical data.

Data from Samgods consists of so-called origin-destination (O-D) matrices for domestic truck traffic. The matrices with the highest geographical resolution are at the municipal level, where the transport demand to/from a municipality is estimated based on its geographical centroid, i.e. 290 unique geographical points in Sweden. The matrices can then be aggregated to larger geographical areas (lower geographical resolution) NUTS3-1. NUTS is the regional division used within the EU for statistical reporting. In Sweden, NUTS 1 consists of three parts of the country, NUTS 2 of eight national areas and NUTS 3 of the 21 counties[1] (Figure 1).

[1] https://tillvaxtverket.se/download/18.7e784787153f0f33aa514e33/1463574736744/NUTS_1_2_3_20080101-2.pdf



NUTS 1	NUTS 2	NUTS 3	Län	Länskod
SE1 Östra Sverige	SE11 Stockholm	SE110	Stockholms	01
	SE12 Östra Mellansverige	SE121	Uppsala	03
		SE122	Södermanlands	04
		SE123	Östergötlands	05
		SE124	Örebro	18
		SE125	Västmanlands	19
SE2 Södra Sverige	SE21 Småland med öarna	SE211	Jönköpings	06
		SE212	Kronobergs	07
		SE213	Kalmar	08
		SE214	Gotlands	09
	SE22 Sydsverige	SE221	Blekinge	10
		SE224	Skåne	12
	SE23 Västsverige	SE231	Hallands	13
		SE232	Västra Götalands	14
SE3 Norra Sverige	SE31 Norra Mellansverige	SE311	Värmlands	17
		SE312	Dalarnas	20
		SE313	Gävleborgs	21
	SE32 Mellersta Norrland	SE321	Västernorrlands	22
		SE322	Jämtlands	23
	SE33 Övre Norrland	SE331	Västerbottens	24
		SE332	Norrbottens	25

Källa: SCB RM/REN, 2008
www.scb.se

Figure 1. NUTS division of Sweden

In this version of Samgods (2012), the O-D matrices are divided into 32 different commodity types and five different vehicle types. The commodity type division of this version of Samgods is based on NTS/R which contains 35 commodity types, but Samgods only uses 32 of these. The data also contains estimates of empty running per vehicle type. However, it is not possible to deduce from the data, within which commodity type's flows the empty running occurs. Conversely, empty running is not included in data sets that are divided in commodity types. In order to include both commodity type division and estimation of empty running, two different datasets from Samgods have been used in the analyses. The data sets are referred to as "O-D Matrix" (ODM) and "Total Transport" (TT).

ODM contains information on transports between all municipalities expressed in number of tons, number of vehicles and vehicle type as well as the number of empty running transports also per vehicle type. ODM data in its original form is presented at the highest resolution (municipality level) and has been supplemented with additional geographical data to enable aggregation to NUTS3-level. ODM only includes domestic road freight transport. ODM does not contain information about transport distances or fill rates, although it is possible to estimate these at an aggregate level based in the data included.

TT contains the same information as ODM, except for the estimate of empty running. TT also contains information on average distance for transports between two points per vehicle type, total number of vehicle kilometres per O-D relation and vehicle type, total transport work per relation and vehicle type and an estimated of average fill rate (load factor) for transports between O-D pairs per vehicle type. The data set contains foreign and transit flows as well as domestic ones. TT has been supplemented with additional geographical data to enable aggregation from municipality level to NUTS3-level.

2.1.2 Data analyses

The estimates apply to interregional transport at NUTS-3 level i.e. domestic road freight transport between different counties. Foreign transports, transit transports and intra-regional transports are not included in the analysis. International transport refers to transport that has its place of departure or destination outside Sweden. Transit transports include transports that have both a place of departure and a destination outside Sweden. Intra-regional transports refer to transports that have both their place of departure and destination within one and the same region, which in this report is NUTS-3 or county, unless otherwise stated. Commodity types[2] 13, 14, 15 and 35 are also excluded from the analyses. In all cases, these transports take place in closed systems which, for technical or legal reasons, cannot be shared for other transport needs than those for which they are specifically intended.

The choice of NUTS-3 as a geographical division is not a matter of course. There is a balance between sufficiently high resolution to get meaningful results and reliability of the results. The way the Samgods model is structured, the higher the geographical resolution, the greater the risk of deteriorating reliability of the results i.e. results at the municipal levels are not as reliable as national or regional results. At the same time, too low of a geographical resolution, i.e. division into too large regions, for example NUTS-2 or NUTS-1, would contribute to the quality of the analysis results being too low due to the size of the loss of intra-regional flows that would be considerably larger than the more granular alternatives. Our assessment is that NUTS-3 is the most appropriate level which would include approximately half of the total amount of road freight by ton and roughly 80% by tonne kilometre and still lead to reliable enough model results from Samgods as input to our analyses.

2.2 WP2 – Measure and follow up on transport efficiency from an industry perspective

To understand how shippers and transport providers measure and follow up transport efficiency Key Performance Indicators (KPIs) in order to improve the

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[2] 13: crude oil, 14: petroleum products, 15: iron ore and 35: air freight

transport efficiency, both in theory and in practice, a literature review alongside interviews and case studies were conducted.

2.2.1 Literature review

A literature search was performed using Business Source Premier and Google Scholar which cover many of the major logistics journals. A broad array of keywords was used, which were: “transport efficiency”, “transport efficiency KPIs”, “horizontal collaboration”, “horizontal cooperation”, “vertical collaboration”, and “vertical cooperation”. The abstracts were screened by several researchers of the project and the academic papers then read. The literature search was used to deepen the knowledge in the field and to relate the empirical findings from WP2 and WP3 to those found in earlier research. In the literature review the knowledge on the following areas were explored: (1) Transport efficiency, and how it is measured and followed up, (2) types and ways of how transport is executed and (3) levels of collaboration between actors. Based on these literature areas, an analytical framework was constructed for the empirical data collection.

The scope of the literature review focused on transport efficiency for long-haul road freight transport (i.e. trucks), while rail and sea transports are excluded. Studies that assessed transport efficiency in relation to the physical infrastructure of the logistics network, for example that focused on the location and number of hubs to optimise load factors (e.g. Harris et al., 2011), have also been excluded.

2.2.2 Interviews

Data collection in form of interviews has been performed in this project. Interviews in Part A refer to data collected from shippers and transport providers, from which an analytical framework was developed, and the work resulted in an academic paper. Interviews in Part B were conducted for a bachelor thesis in the project and data was collected from shippers in the construction industry.

Interviews – Part A. In total, 23 semi-structured interviews were conducted with shippers (10) and transport providers (13) in Sweden. The interview respondents were chosen based on their position within the company, foremost in the higher management and with a comprehensive knowledge of the phenomena under study. The transport providers were of all sizes and could be divided into (a) hauliers that can be described as mostly independent, one-person businesses, (b) haulier centres (from Swedish: *lastbilscentral*) that are a collective of hauliers sharing an administration office, and (c) logistics service providers (LSPs) with a large, and often international, service offer. An emphasis was set on interviewing shippers within the food industry as they are seen to be one of the most developed industry in terms of transport and not as conservative as many other industries. The interviews were conducted over a period of five months, between October 2019 and February 2020.

Two interview guides were prepared, one for transport providers and one for shippers, and used as a basis for all interviews, including questions important for measurements, collaboration levels, and information sharing. The interviews were conducted through a 30- to 60-minute phone call. Most often two researchers participated in the interviews and notes were taken. Table 2 gives an overview of the collected data.

Table 2. Data collection from Interviews – Part A

No.	Type	Turnover*	Industry	Interviewee position
H1	Haulier	Low	Special transport	Owner
H2	Haulier	Low	Short distance	CEO
H3	Haulier	Low	Diverse	CEO
H4	Haulier	Low	Temperature-controlled	Logistics manager
H5	Haulier	Low	Recycling	CEO and owner
H6	Haulier	Low	Recycling	Transport manager
H7	Haulier	Low	Agricultural	CEO
HC1	Haulier centre	Low	Diverse	CEO
HC2	Haulier centre	Medium	Diverse	Traffic manager
HC3	Haulier centre	Low	Diverse	Transport/market/IT
HC4	Haulier centre	Medium	Diverse	CEO
LSP1	LSP	Medium	Diverse	Business developer
LSP2	LSP	High	Diverse	Environmental affairs
S1	Shipper	Low	Food	CEO
S2	Shipper	Low	Food	Distribution manager
S3	Shipper	Medium	Food	Head of supply
S4	Shipper	Medium	Food	Supply chain manager
S5	Shipper	Medium	Food	Demand planner
S6	Shipper	Medium	Food	Supply chain director
S7	Shipper	Medium	Construction	Distribution manager
S8	Shipper	Medium	Food	Transport manager
S9	Shipper	High	Food	Logistics manager
S10	Shipper	High	Food	Head of supply

**Note. Low: <1’000; medium: 1’000-5’000; high: >5’000. Turnover is given in thousand Swedish kronor.*

The analysis followed three steps (Fawcett et al., 2014) in an iterative process: First, open codes derived from the data were used to understand the respondents’ answers; second, codes were re-sorted to understand the internal relationship and how they relate to theory; and third, the findings were set in relation to the analytical framework.

The analytical framework consisted of the following codes: (1) Cost, (2), Time, (3) Vehicle utilization (including (3.1) Load factor, (3.2) Vehicle time utilization, (3.3) Empty running), and (4) Emission (including (4.1) GHG emission, (4.2) Alternative fuel, (4.3) Euro class). In addition, the data was analysed in regard to different collaboration levels i.e. vertical and horizontal collaboration, and transport execution types.

Interviews – Part B. Data was collected through 11 semi-structured interviews with shippers in the Swedish construction industry. For this, the 30 largest construction and civil engineering companies in Sweden were contacted and 11 wanted to participate. The interviews were conducted in May 2020 and were around 60 minutes long. They were conducted through phone or online, and the interviews were recorded and then transcribed. The interview guide included four topics: transport efficiency, KPIs, digital tools and collaboration. Table 3 gives an overview of the data collection.

Table 3. Data collection from Interviews – Part B

No.	Type	Turnover*	Operating in	Interviewee position
S11	Shipper	High	Construction and civil engineering	Transport manager
S12	Shipper	High	Construction and civil engineering	Head of development
S13	Shipper	High	Construction and civil engineering	Head of purchase
S14	Shipper	High	Construction and civil engineering	Head of operative
S15	Shipper	Medium	Construction	Director of product development
S16	Shipper	Medium	Construction	Head of purchase
S17	Shipper	Medium	Civil engineering	Head of purchase
S18	Shipper	Low	Civil engineering	Head of logistics
S19	Shipper	Low	Civil engineering	Head of operative
S20	Shipper	Low	Civil engineering	Head of sales
S21	Shipper	Low	Construction	Purchaser

**Note. Low: <5'000; medium: 5'000-20'000; high: >50'000. Turnover is given in thousand Swedish kronor.*

The analytical framework that was developed in Part A, was also used to analyse the interview data from Part B.

2.2.3 Cases

Three cases were conducted with project partners to understand more about what data different shippers have access to and what kind of analyses can be made with them, particularly linked to the KPIs identified in the literature review. The cases were chosen to represent different transportation execution types (also defined from the literature reviews).

The cases focused on flows of product groups from industries divided into (a) the construction industry (*Case 1 and 2*) and (b) the food wholesale and retail trade (*Case 3*). These segments have been selected for several reasons. Wholesale and retail trade accounts for large domestic shipments (32 million tons) (Trafikanalys, 2016b), whose flows are characterized by high time sensitivity but there might be room for downgrading time requirements for some goods. The construction industry receives 28 million tons of goods as domestic shipments every year (Trafikanalys, 2016b) and many of those go empty. At the same time, the construction industry generates, after the mining industry, the second largest amount of waste (9 million tons) (Naturvårdsverket, 2016), which leads to the potential to reduce bi-directional empty running (ER2 in WP1); ingoing products to a site with outgoing waste from the construction site.

For all the cases, the case companies shared the data that they had regarding their transports.

Case 1 assembled data from email communication with material suppliers which was summarized in O-D matrices also including volumes.

Case 2 included data from a transport administration (TA)-system. The data was received in an Excel file with information on shipments and addresses of senders and receivers. In total there were 2,973 shipment numbers and all shipments were sent from and received in Sweden. Furthermore, the data included information on several packages within each shipment number, as well as packaging type and weight.

Case 3 included data from route planning received as Excel files. Information in the Excel files included for example store numbers and names, stops on the route, number of pallets (total and per route), load factors, time for each leg, distance from warehouse, total distance for the route, total pallets-km per leg of the route, empty pallets per leg of the route.

The data from the cases was analysed using Excel and Python where the results were visualized with help of Google maps. At least one complimenting interview was also conducted to get additional information for each case.

2.3 WP3 – Development of functionality of a digital tool

To identify what functionalities a digital tool should provide in order to utilize overcapacity better, user groups and their needs were identified, application areas evaluated, the potential of the tool tested in cases and from that functionality of the tool identified.

The work in WP3 has been conducted in close collaboration with the project partner Cargospace24 (CS24). The company launched a platform in 2018 with the purpose of matching shippers and transport providers in more efficient ways by using real-time tracking. The existing platform has given valuable input on tool functionality needed as well as serving as a test in one of the cases.

The data collection in the WP3 consisted of interviews, workshops and project meetings, cases, and a mobile ethnography study.

2.3.1 Interviews, workshops, and project meetings

During the interview study in WP2, questions relating to how transport providers and shippers work today to match shipments with empty capacity as well as their need for a tool were raised. These, combined with discussions during project meetings and workshops, have given input to application areas for the tool, challenges and solutions as well as led to the development of functionality of a digital tool.

2.3.2 Cases

Five application areas of the tool were identified through interviews, workshops, and project meetings. From these application areas, three cases were chosen: Two cases with project partners and one case in collaboration with another project. The results from the cases enabled an analysis of challenges and solutions for implementing such a tool on a large scale in Sweden, as well as a test of the tool. Below the cases are described.

Case 1 – Construction sites. The need and application of the tool for transportation to and from construction sites was discussed and developed during several project meetings and workshops. To get wider input, the Case 1 group was extended to also include a transport provider (a haulier centre that has multiple transport assignments to and from construction sites), a material supplier and rental firm for tools and machines. In August 2019, a larger workshop with around 20 participants was also carried through to get more input. From these meetings and discussions, a new model was suggested for how transport efficiency can be improved to and from construction sites by new collaboration models and the role of the digital tool for this model.

To validate the need for this new model, an observation study took place at a construction site during one week in June 2020 in Gothenburg by observing and measuring the trucks arriving at the site. The observation included type of vehicle, customer/shipper, type of delivery/pick up, amount or approximate size of delivery/pick up (weight, volume, or surface), load factor (percentage of weight, volume, or surface) of vehicle at arrival and departure from construction site, load factor at beginning of tour, total amounts of stops of tour, identification number of each stop etc. The observation resulted in a total of 34 shipments, of which 27 deliveries and 9 pick-ups were counted. The observation helped to understand the current situation and by that, understanding the need for new collaboration models and that of a tool.

Case 2 – Small scale produced food. To have small-scale produced food as a case came from the project manager's involvement in the project Lokal Meny. Lokal Meny's purpose is to increase the sales of small-scale food producers to restaurants in their vicinity. While working in Lokal Meny it became apparent that the small-scale food producers had three of the characteristics defined as application areas for the tool. Since developing a logistics system was part of the Lokal Meny project but not with a focus on finding efficient transport solutions, the opportunity was taken to collaborate between the projects to give richer results to both projects. The collaboration resulted in two tests:

> 1) Producers used GPS-trackers for transports they executed themselves: eight producers used GPS-trackers to map their transportation from May to September 2020. The purpose of this part of the test was to identify the potential of having real data information in the platform for producers to identify how they can help each other with transportation tasks when they have the same customer or customers close to each other.

2) Producers use the CS24 platform to find transport providers: 24 producers and three transport providers (plus already existing transport providers in the platform) used the CS24 platform during May – September 2020. The purpose of the test was to test the functionality and usage of the platform.

Case 3 – Waste flows. The third case focused on waste flows and the potential for the tool and linked to five application areas. It was divided into two parts, where each part was focused on one project partner.

Part 1) Pickups of containers, and

Part 2) Pickups of boats that are going to recycling.

Both parts developed a model for how a tool could create value within their organisations. The data collection was mainly meetings and discussions with the project partners. In Part 2, the case group was enlarged to also include a network for collection of old boats as well as a transport provider. In Part 2, quantitative data regarding origin points of the flows was also analysed.

2.3.3 Mobile ethnography study

To understand what functionality is required to make the tool user-friendly, as well as providing an effortless onboarding process, a mobile ethnography study was conducted by two product designers (within Chalmers Industriteknik). Four users representing two transport providers were included in a mobile ethnography study conducted from distance, since the circumstances due to Covid-19 would not allow for traditional observation studies. For one week, drivers were asked to share their workday through text messages and photographs in a conversation via iMessage/WhatsApp/SMS. This was followed up with an interview (telephone, approximately 30 minutes) to verify insights and get a deeper understanding of selected topics that arose during the week. The results are indicative, given the small sample, however theory supports and/or enhances the findings.

3 Results and analysis

In this section results and analysis of the three different work packages is presented.

3.1 WP1 – Realisable efficiency improvement potential

To estimate the bi-directional empty running (ER2) as a proxy indicator for realisable efficiency improvement potential, the flows of empty units between all O-D-pairs need to be calculated. The calculation model for achieving this is presented in 3.1.1. For estimating the structural imbalance of the geographical distribution of transport demand (ER1) as an indicator for maximum efficiency potential of the network, the demand imbalances for every commodity type between all O-D pairs need to be calculated. This is presented in 3.1.2 along with an alternative approach where the calculations are based on clusters of commodity types with similar transport characteristics. For a discussion about validity issues arising from data quality and model assumptions, please refer to 3.1.3.

3.1.1 Calculation model ER2 – estimation of bidirectional empty running

The KPIs that are calculated based on the ODM data set have certain common characteristics that follow from the fact that the data is not grouped by commodity type. This will likely lead to an overestimation of the calculated ER2 values. This means that the realizable efficiency improvement potential will appear to be greater than what can reasonably be assumed to be the case. This is mainly due to the fact that not all commodity types can use the same transport units and in the calculations it is not possible to distinguish whether an identified ER2 is actually two ER1 separated by commodity type or a true ER2. Even so, this estimate of efficiency improvement potential based on calculated ER2 values will be more accurate than if just the amount of empty running is considered alone since this measure does not account for any imbalances at all whereas ER2 here is prone to underestimating these.

The calculations below are mainly based on the number of directional empty running per vehicle type between all O-D-pairs in the network. Mean values and aggregations of measurements across different vehicle types are, where applicable, weighted by load capacity. Light trucks (3.5 ton or less total weight) have been excluded from the calculations as these constitute a negligible proportion of the interregional flows at the county level (NUTS3).

Below, a list of the terms used in the equations following are presented:

A = Number of transports
Q = Transport volume (ton)
G = Vehicle type
C = Maximum loading capacity
N = Network node
R = Relation, i.e. directionally dependent link between nodes
E = Empty running
L = Loaded transport
T = E + L i.e. all transport
O = ER1, i.e. unidirectional empty running (demand imbalance)
Ö = ER2, i.e. bidirectional empty running
F = Load factor
V = Commodity type

Initially, ODM data were represented as flows between municipalities, an excessively disaggregated level for our analyses. In a first step, data was therefore aggregated to county level (NUTS3). For example, the number of empty running road freight transports from county i to county j, which are denoted by AE_{ij}, was calculated as the sum of all empty running from the municipalities in county i to the municipalities in county j. Since all intra-regional transports were here ignored, it could be set to $AE_{ii} = 0$.

ER2 between county i and county j were then defined as equal to the smallest amount in either direction:

Equation 1

$$Ö_{ij}^{R} = \min(AE_{ij}, AE_{ji})$$

Here, R, denotes the fact that this is regarding a single relation i.e. to and from a pair of counties. If there is no empty running in one direction, the ER2 value for that relation would be 0. It should be noted that even though the flows in the links are directional, the measure for ER2 is symmetrical, or without direction, i.e. $Ö_{ij}^{R} = Ö_{ji}^{R}$.

The ER2 from a single relation, *ij*, can be aggregated to higher level, e.g. a node or the entire network, through summation. For instance, the ER2 for a node, i.e. county n, $Ö_{n}^{N}$, is defined as:

Equation 2

$$Ö_{n}^{N} = \sum_{l \in L} Ö_{ln}^{R}$$

Here, L, denotes the total number of counties or nodes in the network. ER2 for a node is calculated by adding the values for the ER2 for all relations in which the county is included. To aggregate the same value at the network level, in this case the Swedish road freight transport system at NUTS3-level:

Equation 3

$$Ö^{S} = \sum_{l \in L} Ö_{l}^{N}$$

The system level measure of ER2 is the sum of the same regarding all nodes in the network. All calculations above are per vehicle type. Data permitting, also commodity types should be considered, however, these could not be considered due to lack of data. Separating vehicle types is necessary as the calculations are performed on the number of transports and disregarding transport capacity would yield invalid results. To calculate the ER2 at the network level as a share of all empty running, denoted $\%Ö^{E}$:

Equation 4

$$\%Ö^{E} = \frac{Ö^{S}}{\sum_{ij} AE_{ij}}$$

The summation is performed for all combinations of i and j, i.e. for all relations in the network. Restricting the scope of i and j will enable the calculation of the same for sub-sections of the network or specific nodes or relations.

To calculate the ER2 at the network level as a share of all transports, empty and laden, denoted $\%Ö^{T}$:

Equation 5

$$\%\ddot{O}^{T} = \frac{\ddot{O}^{S}}{\sum_{ij} AT_{ij}}$$

The main reason for calculating this measure of ER2 is that this measure, as opposed to the previous one (ER2 as share of total empty running) also contains information about the proportions regarding efficiency improvement potential in relation to the total output of the transport network.

Since all the measures above are calculated per vehicle type, the values need to be weighted with regards to the capacity of the different vehicle types before these can be combined into a single value. The range of maximum loading capacity for the four vehicle types included here are between 9 and 47 tons. To calculate the capacity weighted average of ER2 as a share of empty running, $\%\mu\ddot{O}E$:

Equation 6

$$\%\mu\ddot{O}^{E} = \frac{\sum_{g\in G} C_g \ddot{O}^{S,g}}{\sum_{g\in G}\left(C_g \sum_{ij} AE_{ij}^{g}\right)}$$

Here, g denotes a specific vehicle type and G denotes the number of vehicle types. Finally, C_g denotes the maximum loading capacity for each vehicle type. Analogous to this approach, to calculate the capacity weighted average of ER2 as a share of total transports, empty as well as laden, $\%\mu\ddot{O}^{T}$:

Equation 7

$$\%\mu\ddot{O}^{T} = \frac{\sum_{g\in G} C_g \ddot{O}^{S,g}}{\sum_{g\in G}\left(C_g \sum_{ij} AT_{ij}^{g}\right)}$$

Same calculations can be used at lower levels of aggregation by restricting the scope of i and j. to calculate the capacity weighted empty running as a share of total transport, $\%\mu AE$:

Equation 8

$$\%\mu\mathrm{AE} = \frac{\sum_{g\in G}\left(C_g \sum_{ij} AE_{ij}^{g}\right)}{\sum_{g\in G}\left(C_g \sum_{ij} AT_{ij}^{g}\right)}$$

$\%\mu AE$ is a relevant indicator for calculating the system efficiency as utilization rate. Other measures for utilization rates of interest are average load factor of vehicles (loaded) and average load factor at system level. To calculate average load factor as a system level, including empty running, F^{T}:

Equation 9

$$F^{T} = \sum_{g\in G} \frac{\sum_{ij} Q_{ij}}{\sum_{ij} C_g AT_{ij}}$$

To calculate the average load factor of loaded vehicles in the system, F^L:

Equation 10

$$F^L = \sum_{g \in G} \frac{\sum_{ij} Q_{ij}}{\sum_{ij} C_g AL_{ij}}$$

F^T and F^L differ in that F^L indicates the average degree of load capacity utilization for loaded trucks, while F^T states the degree of load capacity utilization of the system, including empty running. It follows that $F^T \leq F^L$. The results from the calculations above are reported in Table 4. The table indicates for each truck type, regarding truck transports between all counties; share of empty transports *(%AE)*, ER2 as a share of the total number of transports ($\%Ö^T$), ER2 as a share of the total number of empty running *($\%Ö^E$)* and load factor with (F^T) and without (F^L) empty running included. The last column labelled "Weighted averages" indicates the corresponding measure weighted by capacity.

Table 4. Results of ER2 calculations

KPI	MGV16	MGV24	MGV40	MGV60	Weighted average
%AE	42%	43%	37%	39%	39% (%µAE)
$\%Ö^T$	36%	28%	22%	27%	27% ($\%\mu Ö^T$)
$\%Ö^E$	84%	66%	59%	69%	68% ($\%\mu Ö^E$)
F^T	42%	45%	45%	47%	46%
F^L	73%	79%	72%	77%	76%

It should be stressed here the values in the table are for illustration purposes only and not valid unless the calculation model is fed with valid empirical data.

3.1.2 Calculation model ER1 – estimation of structural transport demand imbalances

The KPIs below are calculated using the dataset TT, where transport data is separated by commodity type and includes data about transport volume, vehicle type, average distance, load factor, O-D data and more. However, TT does not contain data about empty running. Where ER2 calculated above is a measure of maximal potential for *efficiency improvement*, ER1 is a measure of a transport networks *maximum efficiency* potential, i.e. the maximum achievable utilization rate when the system is run at maximum efficiency. Comparing accurate ER1 measures with the utilization rate of a network or part of a network e.g. network level load factors is a necessary step for estimating the realizable efficiency improvement potential of transport network. The estimation based on ER2 is by default more accurate than viewing empty running or ER2 in isolation. It can be argued that calculations of structural imbalances of the geographical distribution of transport demand (ER1) in this context is a more reliable measure than the calculations of ER2 above. Partly because one can consider demand for different commodity types and, because load factors do not come into play as in the case of ODM data, since TT data only consists of total aggregate demand in each O-D-relation and for each commodity type.

All the calculations below are performed for individual commodity types. No account has been taken of vehicle types as the calculations based on the transport demand for each product group in each relation and not transport capacity. The calculations are focused on estimating structural imbalances in the geographical distribution of transport demand for each commodity type. In order to counterbalance the overestimating effects of too granular a commodity type division, the same calculations have also been performed for clusters of commodity types.

In the same way as before, we used the term Q_{ij} to describe total volume of transport flows (in tons) from counties i to counties j. As before, intra-county flows are ignored and thus set $Q_{ii} = 0$ for all counties. In this section, Q_{ii} may refer to one or more commodity types, this is left to be implied without explicitly marking this in the designations.

The imbalance in volume of flows in tons from county i to county j, O_{ij}^{R}, are defined:

Equation 11

$$O_{ij}^{R} = Q_{ij} - Q_{ji}$$

In contrast to ER2 values which are symmetrical, i.e. directionally independent, ER1 values are directional. A positive ER1 value denotes a source i.e. the transport demand for transport from that node is higher than to it and conversely, a negative ER1 value denotes a sink, meaning that the demand for transport to that node is higher than from it. This necessitates special care when aggregating ER1 values from individual nodes to parts or whole of the network. If all values are just added together, the sum would be zero, as the total sum of a networks sources and sinks would cancel each other out.

To calculate ER1 for a given commodity type in a node n, O_{n}^{N}, where L denotes the total number of nodes, here counties in the network:

Equation 12

$$O_{n}^{N} = \sum_{l \in L} Q_{nl} - Q_{ln}$$

When aggregating ER1 values from individual relations to a value for a specific node, and regarding a specific commodity type, the values for all relations in which the node is included is summed. This is based on an assumption that surplus transport resources from one link can be used to satisfy demand in another link connected to the same node. This assumption is reasonable and coherent with the logic of Samgods, given the constraint that it does not apply across commodity types. To calculate ER1 for a node *n* regarding a specific commodity type as share of the total transport demand for transport for that commodity type $\%O_n^N$:

Equation 13

$$\%O_n^N = \frac{O_n^N}{\sum_{l \in L}(Q_{nl} + Q_{ln})}$$

$\%O_n^N$ is the relative measure corresponding to O_n^N and denotes the structural transport demand imbalance for a specific commodity type in a node (here, county). To aggregate this value across commodity types would create a measure that cannot be meaningfully interpreted as specific commodity types, or clusters of commodity types, cannot share the same transport resources. Because of this, network aggregate ER1 measure can only be produced regarding specific commodity types or clusters of commodity types. To calculate ER1 regarding a specific commodity type, or cluster of commodity types for the network, $\%O^S$, where S denotes the whole or included part of the network:

Equation 14

$$\%O^S = \frac{\sum_{n \in L} \%O_n^N \times |O_n^N|}{\sum_{ij} |O_n^N|}$$

The interpretation of ER1 values stated as a share of total transport demand is not self-evident. For an intuitively simpler interpretation of ER1, one can convert $\%O$ to a measure of the expected share of empty runs at maximum resource utilization (EE):

Equation 15

$$EE = 1 - \frac{1}{1 + \%O}$$

EE indicates the share of transports that are expected to run empty only due to the imbalance in the demand for transport in a relationship, node, or the whole system. EE is a minimum estimate because it is only based on the imbalance in aggregate demand and does not take into account temporal dynamics, seasonal variations or other operational and market considerations and trade-offs that can also cause empty runs which are therefore not due to inefficiencies in the transport system either.

Combined with estimates of underutilization, this forms a basis for estimating the realizable efficiency potential. What makes it difficult to utilize this measure is the fact that in the data material there is no access to empirical data about empty runs divided into corresponding commodity types or clusters of commodity types. Without this information, the estimation of imbalances becomes difficult to interpret as a measure of realizable efficiency potential. It rather denotes the maximum achievable efficiency of the network. What can be achieved with the existing data base is to aggregate the estimation of imbalances across all commodity types, for which overcapacity measures are available, by calculating the weighted average of all ER1 measures for all of the different commodity types. To calculate the weighted average ER1 value for the network across all commodity types as a share of the total transport demand, $\%O^{S'}$:

Equation 16

$$\%O^{S'} = \frac{\sum_{v \in V}\left(\sum_{n \in L}\left|O_n^{N,v}\right|\right) \times \%O_v^S}{\sum_{v \in V}\left(\sum_{n \in L}\left|O_n^{N,v}\right|\right)}$$

The interpretation of this measure should be approached with caution for the purposes of estimating realizable efficiency improvement potential of the network. ER1 is only meaningful for that purpose when compared to ER2 values for the same network. However, the data from ODM is not empirical but endogenously calculated in the Samgods model. For a comparison of ER1 and ER2 to be meaningful, the ER2 value, which is an output value, needs to be empirically based. In absence of such data, the ER1 value can only estimate the maximum achievable network efficiency which in and of itself is not enough for determining the realizable efficiency improvement potential.

The results from the network wide, commodity type specific ER1 values regarding interregional transport demand are presented in Table 5.

Table 5. Estimation of commodity specific structural interregional transport demand imbalances (ER1) in Sweden based to Samgods data

No.	Commodity type	Total demand (ton)	$\%O^S$	EE
1	Cereals	1 034 381	37%	27%
2	Potatoes, other vegetables, fresh or frozen, fresh fruit	43 49 366	52%	34%
3	Live animals	251 549	70%	41%
4	Sugar beet	26 091	21%	17%
5	Timber for paper industry (pulpwood)	23 884 311	59%	37%
6	Wood roughly squared or sawn lengthwise, sliced or peeled	6 359 966	67%	40%
7	Woodchips and wood waste	6 425 386	57%	36%
9	Textiles, textile articles and man-made fibers, other raw animal, and vegetable materials	155 891	73%	42%
10	Food stuff and animal fodder	9 691 876	23%	19%
11	Oilseeds and oleaginous fruits and fats	1 127 410	54%	35%

No.	Commodity type	Total demand (ton)	%O^S	EE
12	Solid mineral fuels	4 835 976	78%	44%
16	Non-ferrous ores and waste	1 021 275	73%	42%
17	Metal products	8 081 186	64%	39%
18	Cement, lime, manufactured building materials	4 049 757	53%	35%
19	Earth, sand, and gravel	11 389 920	60%	37%
20	Other crude and manufactured minerals	3 942 191	39%	28%
21	Natural and chemical fertilizers	750 903	78%	44%
22	Coal chemicals	34 432	75%	43%
23	Chemicals other than coal chemicals and tar	12 947 726	42%	30%
24	Paper pulp and wastepaper	3 666 053	80%	44%
25	Transport equipment, whether or not assembled, and parts thereof	803 982	40%	29%
26	Manufactures of metal	1 996 280	28%	22%
27	Glass, glassware, ceramic products	273 330	46%	32%
28	Paper, paperboard; not manufactures	4 603 099	87%	47%
29	Leather textile, clothing, other manufactured articles than paper, paperboard and manufactures thereof	5 187 505	21%	18%
31	Timber for sawmill	6 337 299	82%	45%
32	Machinery, apparatus, engines, whether or not assembled, and parts thereof	3 616 820	15%	13%
33	Paper, paper board and manufactures thereof	3 326 385	67%	40%
Total		130 211 512	62%	38%

The division of commodity types in Samgods is done without concern for the different commodity types physical properties regarding their requirements for transport and handling. This means that several different commodity types that are assumed in the Samgods model to be unable to share the same transport resources, in reality can and do utilize the same transport units. This property leads to an underestimation of the maximum achievable efficiency in the calculation model presented above. To mitigate this, we have clustered commodity types that can reasonably be assumed to have similar enough physical properties that would enable them to co-utilize the same transport resources into clusters of commodity types.

In Table 6 the results of these revised calculation are presented. The commodity type numbers in the first column show which commodity types that are included in the clusters. The %OS' and EE (%OS') columns show respectively the results of the weighted average ER1 value, and the corresponding expected empty running value, of the commodity types in the cluster i.e. still assuming that the individual commodity types in the cluster do not utilize the same transport resources. The columns marked %OS and EE (%OS), show respectively, the results of the ER1 calculation and corresponding expected empty running calculations when assuming that all commodity types in a cluster can utilize the same transport resources and thus mitigating parts of the underestimation problem outlined above. The final row presents the weighted average values for the entire network and including all commodity types and/or commodity type clusters. The results show that the original calculation model, without clustering of commodity types, underestimated the maximum achievable efficiency of the network around 20 percentage points (32%) regarding ER1 which corresponds to around 9 percentage points (24%) regarding EE.

Table 6. Calculation of ER1 values based on clusters of commodity types

Cluster of commodity types	Total demand (ton)	$\%O^{S'}$	EE ($\%O^{S'}$)	$\%O^{S}$	EE ($\%O^{S}$)
1,2,4,10,11	16 229 125	41%	29%	28%	22%
5,6,7,28,31	47 610 060	69%	41%	32%	24%
16,18,19,20	20 403 143	59%	37%	32%	24%
9,25,27,29,32,33	13 363 913	48%	32%	26%	21%
17,26	10 118 631	62%	38%	40%	28%
Total	130 211 512	62%	38%	42%	29%

3.1.3 Validity issues arising from quality of data

The data set ODM, containing empty running data but not commodity type division, is used as input in the calculation model for bidirectional empty running, ER2. The data set TT, containing transport demand per commodity type between all O-D-pairs, is used as input for the calculation model for structural imbalances, ER1. These results are to be interpreted with great caution as there are significant validity issues arising from the fact that the calculation models are not used on empirical data due to lack of availability of such data and also due to some of the characteristic of the Samgods "data".

For one, the empty running is endogenously calculated in Samgods. This means that in order to avoid pile up of vehicles in the model, where imbalances exist, the empty trucks are repositioned to accommodate the optimal solution that Samgods arrives at. This means that without empirical data, it is strictly speaking not possible to identify instances of ER2 let alone estimating a valid measure of it. In this instance, then, the results from the ER2 calculations should only be regarded as an illustration of how the calculation model works and how results from it can be interpreted. The actual values on their own are basically useless without valid empirical inputs.

Furthermore, in Samgods it is assumed that commodity types cannot share the same transport resources. This assumption results in an unquantifiable overestimation of the structural imbalances in the network. It was tried to group together commodity type clusters that have similar transport characteristics with regards to loading, storing, and handling and thus are likely to be able to be transported in the similar units. Finally, there is no temporal dynamic in Samgods, i.e. the transport demand between O-D-pairs and per commodity type is expressed as total annual amount in tons. This leads to an underestimation of the structural imbalances, or ER1. However, it is argued that, though to a lesser extent, even this is mitigated by clustering of commodity types with similar transport characteristics.

3.1.4 Concluding analysis

Based on the reasoning that all overcapacity or underutilized capacity in the road freight transport system is probably not due to inefficiency or is desirable to get rid of, the aim should be to develop ways to differentiate realizable efficiency potential from empty running in general. Empty runs that arise as a result of structural imbalances of the geographical distribution of transport demand are inevitable and necessary to ensure the efficient functioning of the transport system. One way of estimating the realizable efficiency potential is to identify the system's maximum *efficiency potential* by estimating the proportion of empty runs that would arise as a result of structural imbalances in demand (ER1), if the system otherwise functioned as efficiently as possible. Another way is to estimate the realizable *efficiency improvement potential* by estimating the existence of empty runs in both directions in the links the network (ER2). Of course, there may be other reasons for why empty runs occur in both direction in a given link than inefficiency, but even if the ER2 value would mean an overestimation of the realizable efficiency improvement potential, it is still a much better estimate of it, than just statistics on empty runs.

In the absence of the necessary empirical data, the authors of this report wanted to see if a viable way was to use model results from Samgods as a basis for analyses for addressing the issues above. In its design, Samgods is not intended for this type of application, which has created a need for development and adaptation of calculation models. This also means that the results from these analyses must be interpreted with great caution until the results can be validated and calibrated through further analyses based on corresponding empirical data. Attempts were made during this study to employ data from the national road freight survey for this purpose. However, data compatibility and quality issues proved to be an insurmountable obstacle within the scope of this project.

There is a crucial problem regarding the assessment of the validity of the results from the calculation models which are based on model results from Samgods, rather than empirical data. ER1 is a property of the asymmetrical geographical distribution of transport demand and as such it is a description of the system's boundary conditions that help inform the maximum achievable efficiency potential of the system. ER2 on the other hand, is an outcome variable that follows the way in which the transport demand is satisfied and is dependent on the transport system's operational performance. Therefore, in Samgods structural demand imbalances are part of the input whereas empty running is an endogenously calculated output variable. Since Samgods is a cost minimizing model, the empty running is also going to be minimized and thus not being very informative as a measure of the real-life system's empirical performance. In Samgods, there is thus a mechanical connection between two quantities that are in reality independent of each other. It is the cargo model that, based on the demand pattern, optimizes the execution of the transports. Since the purpose of Samgods is not to create a basis for analyses of transport efficiency, the model is not validated/calibrated with regard to these factors. Hence, absent empirical data about the performance of the real-life system, the ER2 values calculated on Samgods data are not useful and have been included only as an illustration of the application of the developed calculation model.

Consequently, the lack of empirical data regarding system performance cannot be mitigated by our dual approach of trying to calculate both ER1 and ER2, i.e. maximum achievable efficiency potential and realizable efficiency improvement potential. This is because Samgods has estimated both demand and execution, in sequence and depending on each other with the aim of minimizing the system's total cost. This effect is most evident in the fact that the outcome of calculations of the share of land transport in current national flows is almost identical to the share of land transport that is expected to follow due to the structural imbalances in transportation demand. At the same time, it is also seen in the results that ER2 values, corresponds to about two thirds of the interregional road freight transport in total. These results are not compatible with each other. It is suspected that the outcome is due to an effect that follows two specific conditions in the Samgods model.

The Samgods model, as applied here, is based on 28 commodity types that are assumed not to share the same transport resources. The division of the commodity types does not, except in certain specific cases, have any immediate bearing on the types of load units/transport resources that can be used to transport these. This means that large volumes of goods are assumed, in Samgods, to be handled in separate subsystems that do not share the same transport resources, which is not the case in reality. This in turn leads to an overestimation of the structural imbalances and thus the extent of expected empty runs that are inevitable, i.e. maximum achievable efficiency potential.

Conversely, in the estimation of empty runs, which is the basis for estimating the ER2 values, i.e. the realizable efficiency improvement potential, there is no commodity type division, which means an overestimation of ER2. Given that several of the largest commodity types, by volume, both show large flow imbalances and are likely to be handled in closed systems to a large extent (timber, metal products, gravel, etc.), it can be suspected that the overestimation of ER2 can probably be greater than the overestimation of ER1 resulting from the simplifying assumptions in Samgods described above. We have sought to mitigate this effect by clustering commodity types with similar physical transport properties into groups of commodity types. As expected, this results in a higher efficiency potential at the system level than when using the commodity type split of Samgods without modification.

Furthermore, the Samgods model does not include temporal distribution of demand, i.e. the demand is expressed as total yearly demand per commodity type in each O-D-pair. This leads to an underestimation of ER1since even if the geographical distribution of demand is balanced on a yearly basis, the temporal imbalances still lead to empty running that cannot be eliminated by increased efficiency. Consider as an illustration a public transit busses used for work commuting. On a daily basis, the transport demand is fairly balanced in both directions, even though the imbalances in the temporal distribution of demand still leads to a considerable amount of empty/underutilized runs in different directions during different time of the day. Same principal, perhaps not as accentuated, applies in temporal and geographical balance of freight transport demand.

In short, when estimating the ER1 value for the network, i.e. the maximum achievable efficiency potential at the system level, there are factors that simultaneously lead to over- and underestimation of the sought value. The magnitude of these effects is not quantifiable based on the available data. This is a decisively detrimental circumstance for the validity of the results and should be investigated further based more suitable empirical data. In the judgement of the authors, the necessary data is not present in any to them known sources and, thus, needs to be collected for this purpose.

Finally, it should be noted that the intra-regional transports that are excluded from the analysis does not constitute a negligible share of the total transport at the national level. Just under 20% of transports measured as transport work (TonKm) and just over 50% measured in tons take place within the counties. The choice of county as a geographical division was based to a large extent on the quality and nature of model results from Samgods. In the further development of the models above, one should also examine whether a higher geographical resolution is possible and/or desirable to achieve.

3.2 WP2 – Measure and follow up on transport efficiency from an industry perspective

To analyse how shippers and transport providers measure and follow up transport efficiency Key Performance Indicators (KPIs), results from a literature review and interview and case studies are presented, together with a concluding analysis.

3.2.1 *Literature review*

The literature review was conducted to understand earlier research on how to measure and follow up KPIs and to develop an analytical framework. In the following sections, the most used terms and concepts are presented and related to literature. The first section focuses on transport efficiency and its measures, i.e. KPIs. The second section addresses transport execution types, from the point of who purchases, plans, and executes the transports. The third section highlights different levels of collaboration between shippers and transport providers (Figure 2).

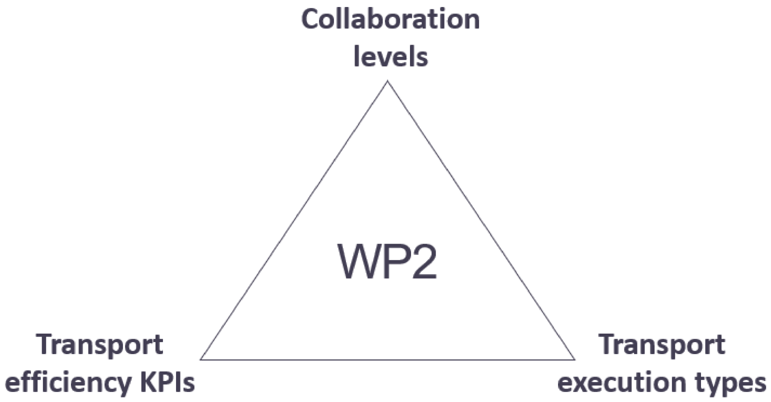

Figure 2. The three building blocks of work package 2 (WP2)

It was identified to be important to analyse these jointly, since the insights into the different KPIs varies between different transport execution types and the possibilities to influence the KPIs are different depending on the collaboration level.

Transport efficiency KPIs

Increasing transport efficiency is an important strategy to achieve more sustainable transport (Santén & Rogerson, 2016). Efficiency commonly refers to a ratio between costs and benefits, resources and products, or inputs and outputs of defined processes (Ruzzenenti & Basosi, 2009). Transport efficiency can be achieved through all kind of changes – technological and behavioural. Behaviour changes of actors includes all actors, such as transport providers, shippers, and end consumers, and can be achieved through inclusion and involvement of the end customer in the provision of the logistics service and the restructuring of the logistics system (Wehner, 2018). In order to follow up on transport efficiency and to measure the performance of transport operation, *Key Performance Indicators (KPIs)* can be used. Björklund et al. (2012) list several reasons why performance measuring can be of interest for transport operations, such as to improve processes, identify success, report and evaluate performance, see progress and compare different operations. McKinnon et al. (2003) suggest five categories of transport efficiency KPIs: Vehicle fill which is measured by payload weight, pallet numbers and/or average pallet height, empty running, vehicle time utilization, deviation from schedule, and fuel consumption. Based on these categories, and with the addition of cost, the following categories were developed by the authors that will be used in the analytical framework:

(1) *Cost*: commonly used as performance metric for transportation and can be measured as per order, kilogram, pallet, truck, etc. Vehicle utilization and transport distance are also indirectly related to costs (García-Arca et al., 2018).

(2) *Time*: often used in connection with measuring customer satisfaction and can be measured in many ways such as through order cycle time, on-time delivery, and processing time for orders (Garcia-Arca et al., 2018) or through KPIs of on-time arrivals and on-time departures (Bongsug, 2009).

(3) *Vehicle utilization* (including (3.1) *Load factor*, (3.2) *Vehicle time utilization*, (3.3) *Empty running*): Constraints on vehicle utilization can be market-related, regulatory, inter-functional, infrastructural, and equipment-related (McKinnon et al., 2015). The *load factor* measures the actual carried load in a vehicle to the load that could be carried (McKinnon et al., 2004) and can be expressed through occupied floor space, volume, or unutilized capacity (Santén & Rogerson, 2018). *Vehicle time utilization* aims to measure the impact of productive and unproductive usage on the vehicle and the driver (Garcia-Arca et al., 2018) and can be expressed as the average percentage of operability (Pérez-Martínez, 2009). *Empty running* describes the absent ability to fill a vehicle in both directions of a round trip by acknowledging that there is a backload, since the vehicle returns empty (McKinnon & Ge, 2006; Pérez-Martínez, 2009). Empty running can be measured in terms of kilometres or operations (Pérez-Martínez, 2009).

(4) *Emission* (including (4.1) *GHG emission*, (4.2) *Alternative fuel*, (4.3) *Euro class*): GHG emissions refer to all kinds of pollutants and are often measured in tons of CO2 equivalent (tCO2e) (Pérez-Martínez, 2009). Alternative fuels, such as biofuels, can contribute to reduced emissions, which also links to the need for technical development necessary to do in combination together with improvements in transport efficiency. The euro class sets emission standards for new vehicles sold in the European Union (European Commission, n.d.).

KPIs help to make the transport data tangible and that in turn helps to measure and follow up the data and improve the transport efficiency. But it is also important to see this as part of the large system that also includes the material flow and the infrastructure, as Wandel et al. (1992) explained in their framework of three levels of the freight transport system for an efficient flow, (1) the material flow, (2) transport operation and (3) the infrastructure need to be cooperated. Transport organisations, retailers and all other companies that are involved with the shipment of goods, focus on the first two levels (material flow and transport operations), but often the jump from material flow to transport operations is difficult for them to make. The developed frameworks in this project should help companies to close this knowledge gap.

Transport execution types

How the transport is executed, from the points of who purchases, plans and executes the transports is important to understand in relation to how KPIs are measured and followed up. To identify different transport execution types, literature of purchasing of transport was used:

When purchasing transport services, the procurement process becomes critical, especially in terms of selecting the service provider and how to work with them (Hedvall et al., 2017). Hedvall et al. (2017) explore cases with different transportation purchase decisions. Decisions such as if shipper should use their own vehicles to transport or contract external transport providers. The advantage to use own vehicles was to get knowledge and access to up-to-date transport costs and to have a better overview, but this knowledge is also important when negotiating contracts with external transport providers. Other decisions include who does the transport planning (the transport provider or the shipper) and should the transport provider work exclusively for the transport buying firm or can the vehicle also be used for other customers and purposes.

An important distinction for types when the shippers purchases from transport providers is if the shipper buys full truck loads (FTL) or less-than-full truck load (LTL) (e.g. Rogerson et al., 2014). Hedvall et al. (2017) studied a case where both LTL and charter distribution were used. In the LTL case, load was going to several different customers and the transport providers were responsible for the daily transport planning. The transport plans indicate needs and demands for each specific customer. Charter distribution in this case was when the shipper was responsible for the transport planning and the transport concerned a full vehicle load.

Based on Rogerson et al. (2014) and Hedvall et al. (2017), the authors of this report have developed six transport execution types that will be used in the analytical framework. Type 1-5 take the perspective of the shipper and Type 6 has the perspective of the transport provider. This implies that Type 6 will occur jointly with Type 2-5.

Type 1: Shipper uses own vehicle for transport,

Type 2: Transport is included in the purchase of goods,

Type 3: Shipper purchases LTL,

Type 4: Shipper purchases FTL,

Type 5: Shipper does transport planning but sources trucks and drivers, and

Type 6: Transport provider’s role in Type 2-5.

Figure 3 summarizes and illustrates the six different transport execution types.

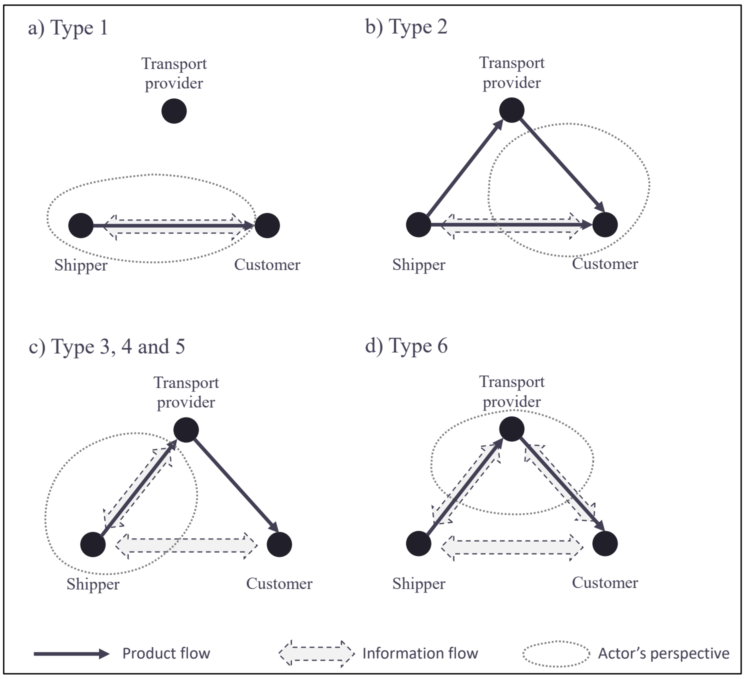

Figure 3. Transport execution types

Collaboration levels

Collaboration of different transport actors is crucial when improving transport efficiency (Bahinipati & Deshmukh, 2012). The literature differentiates between horizontal and vertical collaboration. *Vertical collaboration* describes collaboration between different organisations along the supply chain, namely organisations on different levels; this can be shippers and transport providers who share information, execute work together and jointly solve problems and improve processes (Chopra and Meindl; Bahinipati & Deshmukh, 2012). *Horizontal collaboration* describes collaboration of organisations on the same level of the supply chain, namely between shippers or between transport providers (Bahinipati et al., 2009). Horizontal collaboration between both shippers and transport providers has been studied in previous projects and assignments, e.g. in a governmental assignment conducted by the Swedish Transport Administration[3] and in a pre-study done by the Swedish Transport Administration and CLOSER[4].

Figure 4 illustrates the different collaboration levels.

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[3] https://www.trafikverket.se/contentassets/1160ae4fe6504bba8e3629eee4b60d7c/horisontella-samarbeten-och-oppna-data.pdf

[4] https://trafikverket.diva-portal.org/smash/get/diva2:1464721/FULLTEXT01.pdf

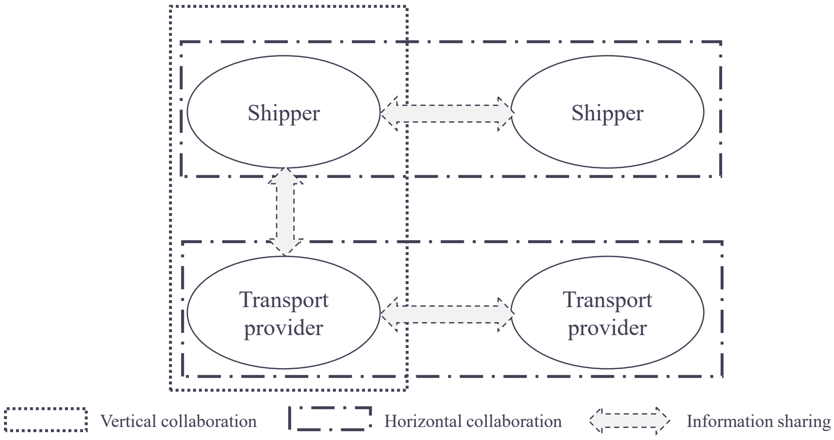

Figure 4. Collaboration levels

The previous literature on horizontal and vertical collaboration is extensive and in this project the purpose is not to add to this literature, but instead connect this previous research with the measuring and follow up on KPIs to understand how these can be improved. For this also research on information sharing was consulted, such as Jacobsson et al. (2019) who highlight the need for better data access and real time exchange of information to improve logistics processes.

Analytical framework

Based on the three parts in the literature review, transport efficiency KPIs, transport execution types and collaboration levels, an analytical framework was defined in order to structure the results and analysis of the empirical data.

The framework (see Table 7) combines the different transport execution types with transport efficiency KPIs to be able to create a structure for understanding what is being measured and how, within each different transport execution type. The analytical framework also includes a level of how data is accessed.

Table 7. Analytical framework including KPIs and transport execution

KPIs	**Type 1:** Shippers use own vehicles	**Type 2:** Transport is included with purchased goods	**Type 3:** Shipper purchase LTL	**Type 4:** Shipper purchase FTL	**Type 5:** Shipper does transport planning but sources trucks	**Type 6:** Transport provider
Cost						
Time						
Load factor						
Vehicle time utilization						
Empty running						
GHG emission						

Alternative fuel						
Euro class						
Data access						

The part in the analytical framework with collaboration types is added in the analysis of how to improve the transport efficiency based on increased measurement and follow up on KPIs.

The interviews and cases provide data for different parts of the analytical framework (3.2.2 – 3.2.3) and the results are combined with the framework in a concluding analysis (3.2.4).

3.2.2 Interviews

The data from the interviews was analysed in different steps. First (see Section 3.2.3.1 below), the data from the 13 transport providers from Part A were analysed regarding transport efficiency KPIs. Second (see Section 3.2.3.2 below), the data from all 23 interviews from Part A and 11 interviews from Part B was analysed regarding different collaboration levels between actors.

Analysis regarding transport efficiency KPIs

The analysis was structured according to the analytical framework and describes how transport providers measure and follow up on transport efficiency KPIs, as well as how these KPIs are communicated and followed up together with the customers (for an extended analysis see Appendix I).

Costs were followed up by all transport providers yet to different extends. Transport providers did not base their cost measurements on any certain model and only three transport providers followed up costs with customers.

Time was regularly followed up by nine transport providers, especially on-time delivery was most often followed up. Other KPIs in regard to time, such as delivery time windows or order cycle time, were not as often followed up. Communication with customers about time, was done in four different ways. First, four transport providers only communicated when there were problems in regard to on-time deliveries. Second, two transport providers followed up through reports and meetings. Third, three transport providers added a section in reports to their customers in terms of the percentage of successful and unsuccessful on-time deliveries. Fourth, the transport providers were those receiving information on on-time deliveries data from other supply chain members.

Vehicle utilization was measured through load factor by nine transport providers, empty running by three transport providers and vehicle time utilization by three transport providers. Compiled statistics on vehicle utilization were only rarely followed up and almost never communicated with customers. Instead transport providers stated that they used cost as an indicator that the vehicle utilization might be low and when the costs were high, they looked back at load factors, empty running, and vehicle time utilization.

Emissions was followed up by eleven transport providers, commonly emissions per tonne-kilometre (seven respondents) were used for measurement, followed by total emissions for all transport tasks (two respondents) and fuel per tonne-kilometre or per truck (two respondents). Twelve transport providers followed up on the percentage of fossil-free fuel in relation to the total amount of used fuel. The Euro class was followed-up by twelve transport providers. It was highlighted that the Euro class only played a role in the procurement process rather than during transport activities.

Table 8 provides and overview of all KPIs and their measurement and follow up by transport providers.

Table 8. Measurement and follow up by transport providers

KPIs	Measurement and follow up with transport providers
Cost	Measured by everyone, no certain type of model or structure used, is not followed up with customers
Time	Measured by 9 out of 13, follow up with customers if there is a problem
Vehicle utilization	Is not measured in a structured way (usually only when cost is too high) and is seldomly followed up with customers
• **Load factor**	Measured by 9 out of 13 (the reason is often not to exceed the legal maximum weight limit)
• **Vehicle time utilization**	Measured by 3 out of 13
• **Empty running**	Measured by 3 out of 13
Emissions	Only followed up with customers if it is requested (is then done with an environmental report) – the most in-demand KPI category from customers.
• **GHG emission**	Measured by 11 out of 13 (Use tools such as NTM, well-to-wheel and SÅ klimatcal)
• **Alternative fuel**	Measured by 12 out of 13
• **Euro class**	Measured by 12 out of 13

From the interviews with the shippers (Part B), all shippers except for one followed up on transport prices either by looking at cost per shipment or total cost. Six of the shippers followed up KPIs relating to time. One shipper mentioned that they follow up on whether orders are delivered on time and in the right quantity, another shipper mentioned that only deviations are looked into manually, and a third shipper said that the delivery windows are narrow, and that the delivery reliability must be at least 85% on time delivery. The shippers interviewed used various transport execution types, and the most common ones were Type 1, 2, and 3. Therefore, data around vehicle utilization and emission KPIs differed depending on if the shippers used their own resources to do the transport or if the shipper was able to get access to the data from their transport providers. According to the interviews, four shippers followed up on load factor as a KPI and empty running and vehicle time utilization was used by three shippers. Regarding emission KPIs, six followed up on GHG emission and alternative fuel and Euro class was mostly regulated through the procurement specification, but not necessarily followed up on.

Analysis regarding different collaboration levels between actors
Different collaboration levels emerged from the data collected on collaboration between transport providers and shippers, which can be compared to vertical and horizontal collaboration found in literature.

The empirical data from 23 interviews (all from Part A) showed that the constraints for *vertical collaboration*, collaboration between transport providers and shippers, relate to the following: (1) Demand fluctuations, (2) just-in-time delivery and (3) poor coordination of purchasing, sales and logistics. By sharing KPIs on vehicle utilization on a regular basis, or even in real time, between transport providers and shippers could help to overcome transport inefficiencies related to demand fluctuation, and efficient transport could be made possible. In terms of just-in-time deliveries, if KPIs on order cycle time would be collected, followed up and shared between shippers and transport providers, this constraint could be overcome. Transport could be planned more long term and not as ad-hoc as it is done at present. Poor coordination of purchasing, sales and logistics between departments/organisations can be overcome by a common understanding of which the follow-up and sharing of all types of KPIs is important.

From the interviews conducted with shippers in the construction industry (Part B), one shipper mentioned that using an ERP system would make vertical collaboration easier. Most of the shippers were interested in increasing collaboration with transport providers, for example by using a logistics hub that a transport provider is responsible for.

A stronger *horizontal collaboration between shippers* was wished for by many interviewees from Part A. Good examples were collected of horizontal collaboration of shippers with the same customers, where they ship their products with different densities together. Another examples, that was given during the interviews, was a “lighter version” of horizontal collaboration in which shippers make joint procurements with a transport provider with advantages for all parties due to longer-term contracts. A third version of horizontal collaboration is achieved through shippers sending their freight in opposite direction and to avoid empty running. Most of the respondents in the interviews conducted with shippers in the construction industry (Part B) mentioned that information sharing could be an obstacle when collaborating with other shippers, especially competitors. Confidential and business-critical data were mentioned along with working methods regarding what data might be sensitive. Other obstacles mentioned were that there is a potential that flexibility is reduced when collaborating with others and that it was difficult to even find the right partner for horizontal collaboration. It is difficult for shippers to find other shippers to collaborate with since they are lacking the network that transport providers have. Therefore, measuring and sharing KPIs on vehicle utilization, in regard to certain geographical areas, and time between shippers would strengthen the horizontal collaboration between them and increase transport efficiency.

Horizontal collaboration between transport providers could also improve the load factor, especially for return flows for non-regular shipments. For the longer flows, challenges for horizontal collaboration included geographical imbalance and the fact that the transport providers have limited time windows. Most transport providers have a network of other transport provider they collaborate with to improve the load factor. Communication between transport providers about days and distances where they had available capacity or when they needed transport capacity from other transport providers was mostly done via phone calls, email lists and chat groups. Digital tools were missing. Here, the transport providers saw no need to share data about several KPIs, but rather information regarding geographical areas, days, time, type of truck etc. for when load factor was low. This will be elaborated on in WP3.

3.2.3 Cases

Case 1 (shipper, Transport Execution Type 2). Case description: The shipper works within the construction industry with a focus on project developments of new housing construction on metropolitan areas in Sweden. The shipper mostly works according to Transport Execution Type 2, which implies that goods are purchased including transport. However, during the project time the shipper has also set up a logistics hub, and much of what goes from the logistics hub to the final destination is then transported using hired transport providers to the final destination (i.e. Type 4).

The case focused on the Type 2 transports' and the shippers' insight in KPIs:

- Regarding cost, the shipper does not know the exact transport cost since the transport costs are included in the price of the products and not presented separately.
- When ordering material, the shipper can choose to have the delivery at a specific time. This is often done for the material deliveries, but less so for indirect materials. The shipper follows up on this in their system when doing the goods receipt.
- The shipper does not receive any data on vehicle utilization (load factor, vehicle time utilization or empty running).
- A requirement is put in the procurement agreements for Euro class and alternative fuel, however, they do not follow up on it.

The shipper has delivery terms that govern how a delivery should be performed. Example of these terms are how the transport providers should be dressed, regarding protective equipment, when they arrive to a construction site. The shipper has a system support to follow up on those terms, however many of the construction sites skip this step in the process. Table 9 shows data access for the Transport Execution Type 2.

Table 9. Data from Case 1 - Measurement and follow up

KPI	Case 1 (Type 2)
Cost	-
Time	r
Load factor	-
Vehicle time utilization	-
Empty running	-
GHG	-
Fuel	r
Euro class	r
Data access	Direct communication with the material suppliers.

Note. r is data that the shipper often requests from the transport provider.

For transport from the logistics hub to the construction site (Type 4), the shipper follows up on delivery precision. The person who receives the transport from the logistics hub sends a handover email, containing information about if the delivery was late or if any other term was not followed, after the shift has ended. The shipper also has information on the truck being full when it leaves the logistics centre.

Data analysis of Case 1 (Type 2): The shipper assembled the data that they had regarding their Type 2 transports, which consisted of data from email communications with the material suppliers. This data helps to understand the logistics systems in terms of volumes in O-D matrices but did not provide any data regarding the KPIs on transport efficiency. Figure 5 gives an example of a geographical illustration that can be made with the data accessed.

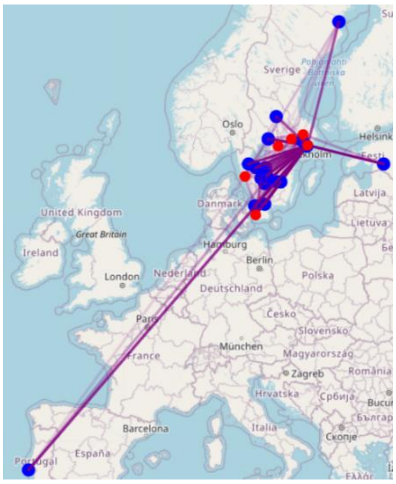

Figure 5. Case 1 – Illustration of material flow [blue dots represent suppliers; red dots represent receivers]

With the limited data that the shipper has access to using Transport Execution Type 2, little analysis can be performed, both on the material flow level and the transport operation level. If the shipper wants to evaluate current performance, improve processes, see what progresses have been made or compare different operations, the data must be requested from the material suppliers, who then has to get access to the data from the transport provider. This makes it difficult to get an overview of KPIs and an understanding of where the largest improvement potential is.

Case 2 (shipper, Transport Execution Type 3 and 4).

Data has been removed and is awaiting approval.

Case 3 (shipper, Transport Execution Type 5). Case description: The shipper is a food retailer in Sweden with three central warehouses that delivers to stores all over Sweden. For the distribution to stores the shipper has chartered transportation (Type 5), in terms of that routes, times, stops etc. is planned inhouse, but the trucks and drivers are sourced from the transportation providers.

Transport efficiency KPIs: With a Type 5, the shipper has access to all data necessary to calculate the transport efficiency KPIs (Table 10). However, for the environmental KPIs they need to get data from the transport providers that owns and operates the trucks.

Table 10. Data from Case 3 - Measurement and follow up

KPI	Case 3 (Type 5)
Cost	a*
Time	a
Load factor	a
Vehicle time utilization	a
Empty running	a
GHG	r
Fuel	r
Euro Class	r
Data access	Own transport planning

Note. a is available data. r is data that the shipper often requests from the transport provider.

**Note. Transport price.*

Data analysis of Case 3 (shipper, Type 5): Within the case, it was chosen to focus on the KPI of load factor to understand how the shipper could find freight from other shippers that could be coloaded on their routes where there was potential in terms of available capacity, in other words finding new partners for horizontal collaboration.

The first part of the case consisted of analysing where there was highest potential to co-load with others, in terms of distances and available capacity. The data used was the route planning data which specifies the stops (i.e. stores) on the routes, times (staring time, stop times and ending time), distances between the different stops, number of pallets delivered to each stop and data about the trucks (for example maximum number of pallets).

With the data an overall potential for co-loading was first calculated. To include both distances and the volumes in the calculation, the measurement of pallets-km (pallets*km) was used. When the trucks leave the warehouses the load factor was always close to 100%. The shipper also picked up return flows from stores, such as packaging material, which implies that when they return to the warehouse in the end of the route, the truck had an average load factor of 50%. In total, on the routes the trucks had freight of 314 million pallets-km/year and roughly 86 million pallets-km/year was available capacity (empty). Regarding the available capacity 21 million pallets-km/year were on the route from the warehouse to the last store and 65 million pallets-km/year from the last store to the warehouse (see Figure 6). This implies that the largest part of the potential is on the distance between the last store and the warehouse.

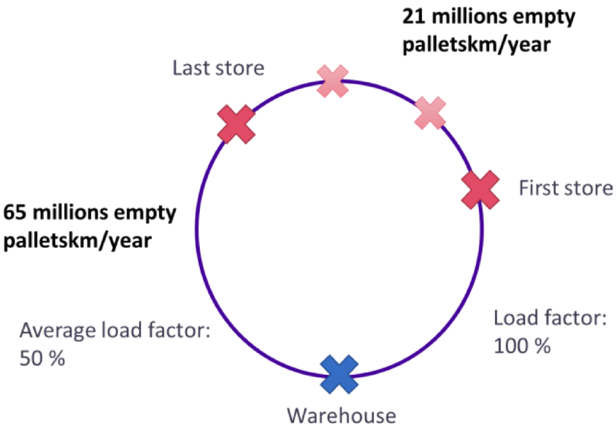

Figure 6. Available capacity on the route

It is however important to understand where the potential is largest geographically, and Figure 7 visualises the distances from the last stores to the warehouses.

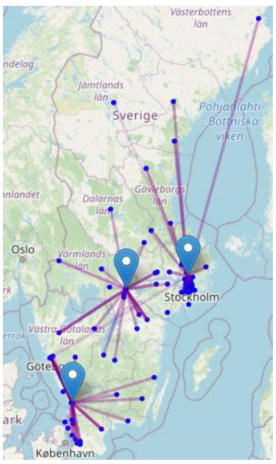

Figure 7. Case 3 – Illustration of executed transports

In overall, with Transport Execution Type 5, the shipper has all the data to understand where the potential is largest for increasing the transport efficiency.

This leads in to the second part of the case, which is finding suitable partners for horizontal collaboration. In the case, three characteristics were identified that are important for enabling these types of horizontal collaboration:

> 1) Regularity over time: To collaborate with other shippers can imply that adjustments must be made to the routes, e.g. in terms of pick up times and total route time. These changes are possible but require investments in time to find solutions as well as time for administration when the routes are up and running. This implies that the shipper wants to have regularity in terms of stability of volumes over time (for example always shipments on Mondays every week) to minimize the administration times around the joint transport planning.
>
> 2) Geographical match: Since the routes are fixed in terms of which stops are made (origin to destination), there must be a geographical match in terms of that the other shipper's origin and destination should be on the route from the last store to the warehouse. The length of possible detours to be able to pick up other freight is dependent on both the total driving time on the route (cannot be too long to comply with laws and regulations) as well as the size of the shipments (the large shipments the easier to economically motivate a detour).
>
> 3) Time-windows match: The last characteristic is linked to that it is only possible to make smaller adjustments to the pickup and delivery times and therefore the other shipper must be flexible and dispatch and receive the shipments so it fits the overall route. In this case, this would imply delivery times are at night or early in the morning.

To find partners for horizontal collaboration the shipper has started with the Swedish producers that are delivering to their warehouses. They have both the characteristics of regularity over time and geographical match (the detour to the origin of the producers can be small since there are routes all over Sweden and the destination is the warehouse). With these two characteristics in place, it is also easy to find time windows matches and work out solutions where the drivers can load the shipments without anyone at the producers' warehouses being present.

To find partners for horizontal collaboration outside of their existing suppliers matching their logistics systems, however, is much more difficult. It is based on that the shipper having contacts with other actors and can identify opportunities of collaboration with these. Here the shipper does not actively seek for collaboration partners among other shippers but are interested if opportunities are identified by others.

3.2.4 Concluding analysis

In WP2, the focus has been to identify what data shippers and transport providers collect about transport efficiency KPIs and how this data is shared with collaboration partners. The analysis has been structured through the analytical framework consisting of three areas: KPIs for measuring transport efficiency, collaboration levels between shippers and transport providers, and transport execution types.

By combining the results from the interview studies and the three cases, the KPIs that are measured and followed up, along with the transport execution type and data access are summarised in Table 11.

Table 11. Concluding Analysis - Data on KPIs and transport execution types

KPIs	**Type 1:** Shippers use own vehicles	**Type 2:** Transport is included with purchased goods	**Type 3:** Shipper purchase LTL	**Type 4:** Shipper purchase FTL	**Type 5:** Shipper does transport planning but sources trucks	**Type 6:** Transport provider
Cost	A	-	a*	a*	a*	A
Time	A	r	r	r	a	A
Load factor	A	-	-	a	a	A
Vehicle time utilization	A	-	-	-	a	A
Empty running	A	-	-	-	a	A
GHG emission	A	-	r	r	r	A
Alternative fuel	A	r	r	r	r	A
Euro class	A	r	r	r	r	A
Data access	Transport planning tools, etc.	Direct communication and invoices	TA-systems**, invoices, Excel files	TA-systems**, invoices, Excel files	Own transport planning	Transport planning tools etc.

Note. a is available data (does however not mean that it is analysed in a structured way). r is data that the shipper often requests from the transport provider.

**Note. Transport price.*

***Note. TA-system = transport administration system.*

The analysis of the data on KPIs that is accessible for different transport execution types is presented in the following.

Shipper using their own vehicles (Transport Execution Type 1) has access to all the data regarding KPIs, however it differs between shippers, and whether they analyse and follow up on the data. It can be time consuming to analyse all the data. For shippers, the core competence is usually in production, sales, customer relations, etc. and therefore, it can be more difficult for the shipper to follow up on the different transport efficiency KPIs compared to transport providers. With this type, horizontal collaboration is possible between shippers. It can however be more difficult for the shipper to find co-loading opportunities with other shippers compared when transport providers act as an intermediary. The main reason for that is because they do not have the same networks as transport providers do.

Transport providers have this as their core business and are usually in daily contact with many shippers, which gives them the opportunity to find suitable matches between different shippers.

When *transport is included with purchased goods* (Transport Execution Type 2*)* there is limited insight into the different KPIs, the shippers usually only get data on the environmental KPIs if they request it. Type 2 is the only transport execution type that does not have any information on either transport cost or price since the transport price is included in the total price of the product they purchase. If transport prices are separated from product prices in the purchase, these are usually standard prices. To know the transport price could be valuable in order to compare if it is more beneficial to purchase their own transport instead. Considering that the shipper in Type 2 is often also the customer, they influence the transport efficiency by, for example, decisions about time windows, frequency, order sizes etc. With no insight in the KPIs for transport efficiency, they do not know how their purchasing demands influence the transport efficiency.

When a *shipper purchases LTL* (Transport Execution Type 3) the data availability is limited to only knowing the transport price, but the shipper often requests data on environmental KPIs and time. When purchasing a less-than-full truck load (LTL), no information on the percentage of their load in relation to the total load is given, and therefore the KPI of load factor cannot be calculated. However, this data could be relevant for the shipper, to understand for which flows they can contribute by adapting for example time requirements or shipment sizes.

When *shipper purchases FTL* (Transport Execution Type 4), the same information as in Type 3 is available with the addition that the load factor is also possible to calculate since they purchase a full truck load (FTL). Data on empty running is not available but this can be useful so that the shipper can assist in finding return loads and improve the transport efficiency. This implies that the shippers take a larger responsibility for the transport efficiency.

The access to data on KPIs for *shippers who do their transport planning, but source trucks* (Transport Execution Type 5) is similar to Type 1. However, they do need to request data on the environmental KPIs since this is coming from the transport providers. Furthermore, they only know the transport price and not the transport costs. With this type, horizontal collaboration is possible between shippers, however here the shippers have the same challenges as is described in Transport Execution Type 1.

The *transport providers* (Transport Execution Type 6) have access to all the data to calculate the transport efficiency KPIs. However, this does not mean that they analyse them all or share them with the shippers. The results from the interview study showed that only a limited number of KPIs were followed up regularly. Transport providers can participate in both vertical collaborations with shippers and horizontal collaborations with other transport providers, and there is a large potential to find ways to share and collaborate around the KPIs.

In the following, three aspects are analysed further, i.e. what KPIs area measured and followed up, whose responsibility it is to share the data, and how data can be collected and analysed more efficiently.

KPIs measured and followed up. When comparing what KPIs are followed up on in most transport execution types, cost and data about environmental KPIs (GHG emission, alternative fuels, Euro class) were most frequently measured and requested. That cost is measured and followed up is not surprising. Regarding environmental KPIs both shippers and transport providers described that the interest in measuring and following up these has increased the recent years. The reason being that many shippers have set goals of improving their environmental footprint, which they want to follow up. However, it was mentioned several times that the shippers request the data on quarterly or even annual basis, which limits the opportunity for shippers to use the data directly as a decision support to understand for what flows, distances, etc. there is large potential to reduce the environmental impact. The transport providers can however still use the data to increase their competitive advantage. There was less focus on the vehicle utilization KPIs which are useful to have to improve transport efficiency (the KPI of GHG emissions per load unit is a result of both the vehicle utilization and used fuel).

Responsibility and collaboration. The analysis of KPIs and transport execution types (see Table 11) shows that for many types shippers can influence the transport efficiency but do not have data about the current performance. There needs to be an understanding of who should have access to what data and who should be responsible for sharing/requesting access to the data. Both shippers and transport providers make decisions that have an influence on transport efficiency, and, therefore, it should be a shared responsibility to jointly improve transport efficiency. Examples of decisions that have effect on transport efficiency are delivery windows, route, and packaging type (Santén & Rogerson, 2018). Increased sharing of data around KPIs could create improvements for both shippers and transport providers.

Transport providers can improve understanding about the current transport efficiency by finding ways to collect and share data with shippers, which can include both reports with quantitative data as well as meetings and workshops to improve the measured KPIs. However, shippers also have a responsibility to be more engaged and a good start is asking their largest suppliers/transport providers for more information and being clear with that the purpose of the increased information sharing is to jointly improve the transport efficiency. For Type 2 it would imply that shippers in a first step need to ask for data from their suppliers that are purchasing the transport and after that involve the transport provider. For Type 3-5, the shippers need to increase information sharing and collaboration with their transport providers.

Making data collection more efficient. Collecting and analysing data and following up on KPIs is necessary to understand what improvements will have the largest impact on transport efficiency. However, collecting and foremost sharing data can be costly and time consuming. To make this more efficient for transport providers and shippers, there is a need for standardised ways of both measuring and sharing data between shippers and transport providers. With recent developments in technical solutions for collecting and sharing information between different companies, especially given the advances in technologies such as GPS, electronic data interchange (EDI), web site data retrieval and assembly, and automated freight-handling services, there are many ways that this can be improved. For example, a lot of data is collected in the trucks, e.g. emissions, driving behaviour, timing, but very few transport providers in the interview study used this data. To find ways for them to efficiently collect data from different sources and automatically calculate KPIs from this data would make it more efficient for transport providers.

In relation to this, it is important to understand with what frequency data about KPIs should be shared. The topic of real time data and time delayed data should also be considered. Having real-time data gives insights right away. Based on this data, it is possible to make decisions, the data allows actors to find the sources of possible problems and identify improvement potentials. Advantages of this technology is that the quality and timeliness of the data is improved so that decision making can be performed more quickly, and there is less of time-consuming paperwork. It can be of more importance to get frequent and real-time data for certain KPIs and for some KPIs it can be possible to share them less frequently such as on quarterly or annual basis. For example, the KPI of euro class can be feasible to follow up less frequently to ensure that the agreements from the purchasing process is fulfilled. For load factors on the other hand, it can be valuable for a shipper to get real-time data, since the shipper could adjust their shipments based on the data they receive.

However, even with technological solutions to automatically calculate KPIs and share this data, there needs to be processes to identify and carry out changes in operations to improve the KPIs. It could be argued that it is mostly valuable to share data with the biggest customers/suppliers. This way, you can improve a large portion of the transport efficiency by only sharing data with a limited number of companies. However, those that are not "the biggest customer/supplier" could in a way also contribute to increased transport efficiency, even though their impact is smaller. Here, it would be interesting to further study how data can be collected and shared automatically, which also includes suggestions on how the shippers can influence the transport efficiency. For example, "if you extend the delivery window, we can fit the assignment on another route and reduce the CO2-emissions with 80%". With this kind of automatic solutions, the data analysis processes will not consume much time for the involved companies.

Receiving data around the transport efficiency KPIs is not enough to improve the transport efficiency. It is important to involve several functions and achieve internal consensus in both the transport providers organisations and the shipper's organisation to succeed with making changes. Examples of important functions that must have a consensus are sales, purchasing, and transport planning. This emphasizes that it is not enough to measure and follow up on KPIs, there must also be processes and behavioural changes that ensure that the information is used to create change.

3.3 WP3 – Development of functionality of a digital tool

In WP3, the aim has been the development of the functionality of a digital tool to make it easier for shippers and transport providers to share data on transport needs and available capacity and thereby find matches for increased transport efficiency.

The user groups for a digital tool are shippers and transport providers. Since increasing load factors has an impact on transport efficiency and in turn on operations and transports costs, both shippers and transport providers are working to find matches. The aim is often to have regular and larger flows which are balanced. When this is not possible, particularly transport providers have "communities" with other transport providers or shippers that are handled by phone, email-lists, or chat groups in social media to find co-load opportunities and return loads. An advantage stressed with these communities is that they are trusted collaboration partners, reducing the risks included with new customers (foremost that the invoice will not be paid). Below, it is investigated how a tool can help to make the information sharing within these communities more efficient as well as to increase the chance of matches by expanding the transport providers current communities to include many more other transport providers and shippers.

The work is presented in six subsections: Applications areas for the tool (3.3.1), cases (3.3.2), challenges and solutions (3.3.3), user needs and onboarding to the tool (3.3.4), tool functionality (3.3.5) and concluding remark (3.3.6).

3.3.1 Application areas for the tool

Five application areas were identified for the tool, three relating to freight characteristics and two linked to actor characteristics (see Figure 8). All application areas are presented in the following.

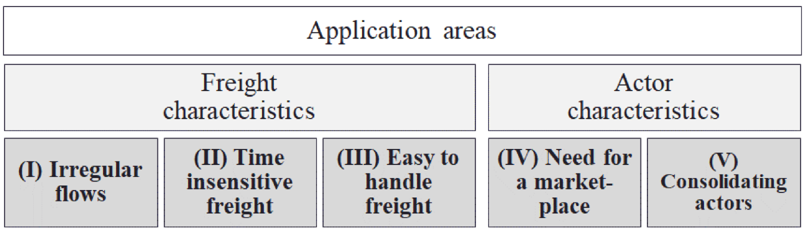

Figure 8. Overview of application areas for the tool

(I) The irregular flows: The interviews in WP2 with transport providers indicated that for many transport providers the 80/20 rule can be applied for the relation between regular flows (the same origin and destination for the same customers) and irregular flows (new destinations for existing customers or completely new customers). For the regular flows, the transport providers often put more effort into increasing the transport efficiency by finding a regular flow for the return as well. However, for the irregular flows they cannot put the same time and effort

into finding return flows. So, for the irregular flows, the tool can help to identify matches that only will occur once with little time and effort.

On the other hand, it can be argued that the tool should be used for regular flows, for there can be unutilized capacity within trucks that are passing by and it is then better to utilize this capacity than to start a new transport assignment. If this would have a positive effect on transport efficiency depends on the usual transport providers flow balances as well as the national flow balances. If transport providers today have a return flow which has to be handled, it will have no impact on the transport efficiency if the freight is picked up by another transport provider passing by since the original transport provider anyway has to pick up the return flow. On a national level, this setup can contribute to increased transport efficiency if there is an occurrence of bidirectional empty running or ER2 above, it can be reduced with the new setup. If, however, it is a structural imbalance or ER1 above, this change of transport provider occurs on the direction with less transport need, it will have no impact on the transport efficiency since it will imply that another truck goes empty instead. Since there are uncertainties regarding the impact on transport efficiency by using a tool for regular flows, it is chosen to focus on the irregular flows in this project.

(II) Time insensitive freight: Previous literature is aligned in that high time demands decrease the transport efficiency. In relation to a tool, it can be argued that freight which is less time sensitive will have a higher chance of being matched in a platform since larger time windows for pickup and delivery can be offered. This implies that time insensitive freight is a suitable application area for a tool. Particularly if it is matched with the characteristic of irregular flows.

But also, as for the irregular flows, it could be argued in the opposite direction. If freight is time sensitive, the shipper may be successful in finding transport opportunity through the platform quickly, especially in urban areas where there is a lot of transport activity. This could enable shippers to find someone in a more quick and efficient way, rather than contacting their network of transport providers. This, however, demands that many companies are connected to the platform (see also “Application Areas V”). Since there are no digital tools with a large number of users today, it is decided to focus on the time insensitive freight in the project.

(III) Easy to handle freight: Freight that can be transported with different types of trucks, either since the load carrier can easily be loaded onto different trucks, or the freight itself is not in risk of being contaminated, does not need cooling, or need certain ways of handling, is more likely to be matched on the platform. Therefore, easy to handle freight is seen as an application area.

(IV) Need for a marketplace: In Sweden, there are roughly 10 000 transport providers[5] and more than 50 000 production companies (in other words shippers)[6]. Even if many companies are restricted to certain geographical areas or types of

[5] https://www.akeri.se/sv/om-akerinaringen
[6] https://tillvaxtverket.se/statistik/foretagande/basfakta-om-foretag.html

freight, there are still many possible matches between shippers and transport providers. Regarding marketplaces for transport providers, one of the core businesses of 3PL providers is to help with matching shippers and transport providers. A digital tool can, however, also contribute to identifying matches for the transport providers that are not linked to a 3PL provider or for transport providers that work for 3PL providers but also have their own sales activities.

Regarding the need for marketplaces for shippers, an important distinction is the resources that shippers have for purchasing transports. Larger shippers often have dedicated resources just for purchasing of transports which implies that they understand the transport market better and it is easier for them to identify potential transport providers compared to small shippers, which might not even have a person working full time with logistics. The functionality of being a marketplace is therefore more important for the smaller shippers compared to the larger ones.

(V) Consolidating actors: Particularly in urban areas, there are a lot of parallel freight flows and companies describe it as a challenge to coordinate these to increase the transport efficiency. A solution that has been discussed, tested, and used for many types of flows is to set up a new type of transport hubs in urban areas. For example, in several municipalities in Sweden, there have been projects to coordinate food deliveries to municipality-controlled units (such as elderly homes and schools) by transport hubs, which enables that the last mile for several suppliers is co-loaded. Another area where transportation hubs are on the agenda is in the construction industry. They are seen to reduce logistics costs and congestion around the construction site and improve productivity and safety (Morel et al., 2020). It is beneficial for urban distribution to have a consolidation point between long regional transports and the shorter delivery transports within the cities. Such consolidation points make it easier to switch to more environmentally friendly vehicles (Johansson, 2020), such as electric vehicles. A disadvantage of city terminals is that they have high operating costs, including costs for rent, salaries for personnel, and electricity bills and other resources (Johansson, 2020). Many decisions need to be made so that the logistics hub can be successful; such as, where should the hub be located and should it be a fixed or a flexible location, what services should be offered, and who should be in charge of the logistics hub (a transport provider, the construction company a machine provider, or someone else).

The tool could potentially aid the organisation in charge of the hub and the transport providers linked to the hub to coordinate their transports and by that increase the transport efficiency. Another alternative is that the tool can replace the fixed hubs and enable coordination of transport through the transport providers own current facilities (this is elaborated on in section 3.3.3)

3.3.2 Cases

From the five application areas identified in 3.3.2, three cases were chosen through which the application of the tool were further investigated: Constructions site, small food producers and waste flows. The link between application areas and cases is presented in Table 12.

Table 12. Link between application areas and cases

Application areas		Cases			
		(1) Construction site	***(2) Small-scale food producers***	***(3) Waste flows***	
			Part1, Part 2	*Part 1*	*Part 2*
Freight characteristics	(I) Irregular freight flows (delivery time, destination, and/or size)	X	(X)	X	X
	(II) Time insensitive freight			X	X
	(III) Easy to handle freight	(X)	(X)	(X)	
Actor characteristics	(IV) Need for a marketplace		X		X
	(V) Con-solidating actors	X	X		

Note. X indicates a strong match, (X) a match for a part of the case.

Case 1 – Construction site. Freight flows to construction sites are characterised by irregular freight flows (Application Area I), need to consolidate actors (Application Area V) and partly by also being "easy to handle" (Application Area III). The reason being is that a construction site is a temporarily delivery address (even if the temporarily time can be years) where the need of products delivered, and waste collected varies throughout the different construction phases. Because of the large variation in need, there are also many companies that are part of the transportation system, in other words, the builder, the suppliers of material, waste collectors and the transport providers. This also implies that there can be companies involved that, in sum, fit all six transport execution types from WP2.

In recent years, many projects have identified and explored the potential to improve efficiency on construction sites as large (Morel et al., 2020). For example, there are projects and tests linked to setting up specific transport hubs for construction in urban areas. Since construction sites fits three of the Application Areas and is an area where development is happening regarding new logistics solutions, it was decided to include it as a case study in WP3.

During interviews and workshops with project partners and other companies working with logistics around construction sites, a model was created according to the flows that could be coordinated with help of a tool. Two different setups for coordination were identified in the model:

1. Coordinate ingoing flows of interior furnishing and building materials with the ingoing and outgoing flows of machines and other equipment.
2. Coordinate ingoing flows, as mentioned in point 1, with the outgoing flows of waste that shall go to material recycling (for example packaging plastic, styrofoam and corrugated boards).

For both these setups, it is crucial that there is a match between the flows in terms of what transportation and load units are used. For example, waste is often collected in waste containers. If these flows should be matched with ingoing flows of materials with covered transport carriers, new load units for the waste must be used, such as big bags to be able to fit into the covered transport units.

Furthermore, it is important that the setups are aligned with the design of the logistics hubs. In the project, two types of logistics hubs were discussed: Fixed logistics hubs and "floating" logistics hubs.

- *Fixed logistics hubs:* A fixed logistics hubs serves the construction site during all the construction phases. The logistics hub could either be a new logistics hub for the construction site or an existing hub, such as hubs for hauliers' centres (sw. lastbilcentraler). Suggestions of operators for these hubs include operators of the hauliers' centres hub, equipment rental agency as well as waste collectors. The operator of the hub, which is going to be the most competent from a transport efficiency perspective, depends on several factors such as the geographical position of material and tools suppliers, the hub operator, and the construction sites as well as the size of the flows.
- *"Floating" logistics hubs:* In the project it was discussed that to increase transport efficiency, it could be suitable that the logistics hub that consolidate and split up flows to construction sites should vary throughout different phases in the project. The hypothesis was that the company with largest flows to the construction site during a certain construction phase would have the logistics hub at their premises during this time. For this to work, more information sharing than at present is needed, and a tool can support with real time data on flows, position of trucks, geo-fencing etc. However, it should be stressed that even if there is potential for increasing the transport efficiency by changing the logistics hubs, there are several other factors that also need to be taken into consideration for the decision between a fixed and non-fixed logistics hub, such as complexity and minimizing delays and mistakes.

One of the findings from the interviews and workshops was that even if many assume that the transport efficiency is low, no studies were identified which studied the load factor at the trucks going to and from the construction sites and what type of trucks were used. Therefore, it was decided to do an observation of trucks on a construction site.

The results from the observation consisted of 27 deliveries and pickups during one week at a construction site in Gothenburg. Only four out of the 27 deliveries were pre-booked with a certain time slot. In sum, 21 out of these 34 shipments were delivered or picked up between 9 am and 12 pm. Most deliveries arrived on pallets; however, the pallets were often packed with odd-sized products and could not be stacked. This led to that pallets were transported only in one layer in the trucks and load factor was measured in the surface of the truck, while the height could not be considered.

When looking at 21 deliveries, the ones where data existed in form of load factor of vehicle, the size of the shipment could be determined (see Figure 9), it became clear that most of the shipments were very small; the delivery of three containers (to be seen in 91-100%) can be disregarded. This finding supports that many deliveries to the site only drop of small amounts (most only between 1-10%) and opens for a discussion around a consolidation hub for construction sites.

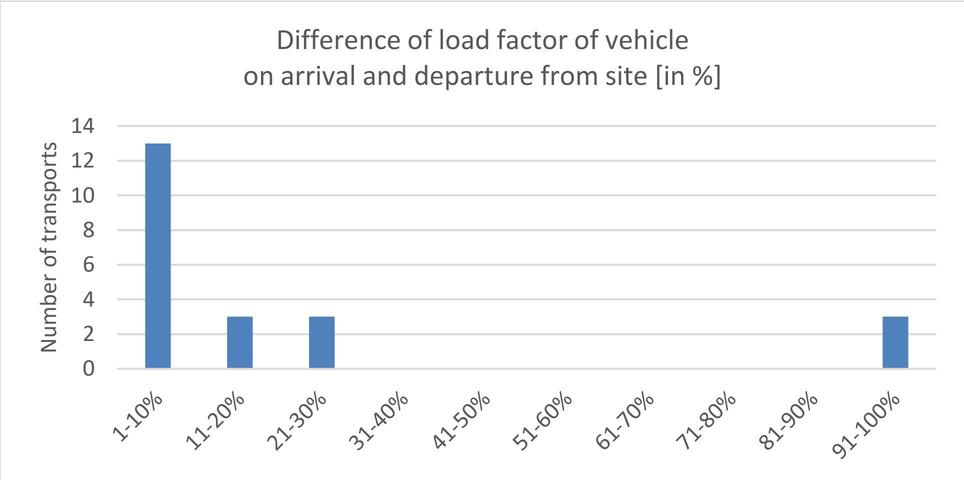

Figure 9. Difference of load factor of vehicle on arrival and departure from site [in %]

Even though most on the small deliveries did not need somebody from the site to receive them, and only a few needed a signature that indicates that they had been received, they generate a high traffic at the site, often unwanted since the site was within a residential area, and lead to many vehicles driving around generating many driven kilometres per shipment. The number of different transport providers was 19 who either transported deliveries, from 16 different suppliers, or picked up shipments.

The observation showed that there is available transport capacity in the transport system to and from the construction site. It also confirmed the application areas of irregular freight flows and to consolidate transport providers, but also stressed that only a limited amount of the freight was “easy to handle”. This implies that a tool can help to improve the transport efficiency, however, since there are many actors involved and development is ongoing relating to logistics hubs, it is important the tool is accepted and used by most actors and it is integrated with the design of the logistics hubs.

Case 2 – Small scale produced food. This case has been conducted in collaboration with the project Lokal Meny. The case consists of small-scale food producers in Region Västra Götaland that regard logistics (particularly the transport) as a barrier for expanding their businesses.

Based on a survey and interviews in the project Lokal Meny, it was identified that the case had four of the application areas for the tool. First, how irregular flows are for the producers vary (Application Area I), some of them have regular customers with regular deliveries, while many have more irregular flows both in terms of customers as well as order sizes. Regarding the possibility to use different type of trucks (Application Area III), the load units most used by the producers were cardboard boxes, followed by plastics trays (survey data). Those load units are possible to transport in most covered transport units, however, since it is food, it often requires temperature-controlled transports (roughly 50% was chilled products and roughly 5 % was frozen products, also survey data) as well as that there are restrictions what can be co-loaded with the food. In relation to difficult to overview companies that are going to the same customers (Application Area 4) as well as a need for a marketplace (Application Area 5), the survey showed that around two thirds of the producers were interested in finding joint transportation solutions with each other. The producers have mostly Transport Execution Type 1 or 3 at the present. Interviews then added the perspective that several producers had little insight in what transport providers would fit their needs in terms of offer, geographical area, and existing routes.

Since four application areas were met, it was decided to do a joint test between USECAP and Lokal Meny to understand how a digital tool could make the producers transports more efficient. The test consisted of two parts: 1) A test where producers used GPS-trackers, in their own vehicles used for deliveries to see if there is a potential for co-loading between producers and with that a need for a digital tool to coordinate this co-loading, and 2) a test where producers used the CS24 platform to be matched with transportation providers they do not work with today. In Part 2, the purpose was to analyse how the tool could aid the producers and make it easier for them identify and collaborate with transport providers.

Part 1 – Producers use own vehicles: Eight producers participated in a test over the period of three and a half month in the summer of 2020. The producers were spread out in Region Västra Götaland, see Figure 10.

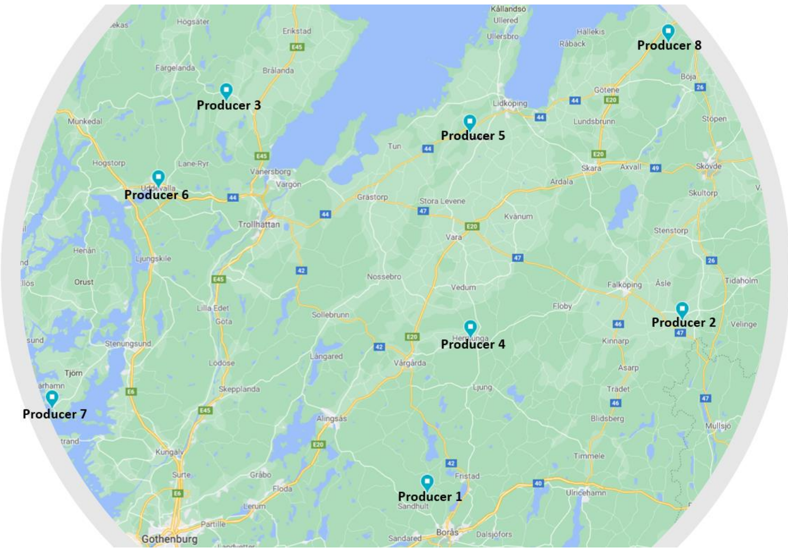

Figure 10. Point of origin for producer 1-8 who participated in the test

During the test period there were 24 matches. Here the term "match" is used for when different producers are in the same city on the same day. It was however rarely that the producers were coming from the same or a similar location. Out of those 24 matches, 13 of them happened in Borås and 17 of them were between the same two producers.

Figure 11 below shows how many days the producers are out driving per month. The variation between the producers is high and the reason for that can either be that some producers choose to use their own transportation more than others, but it could also be that some producers used the GPS equipment less than others.

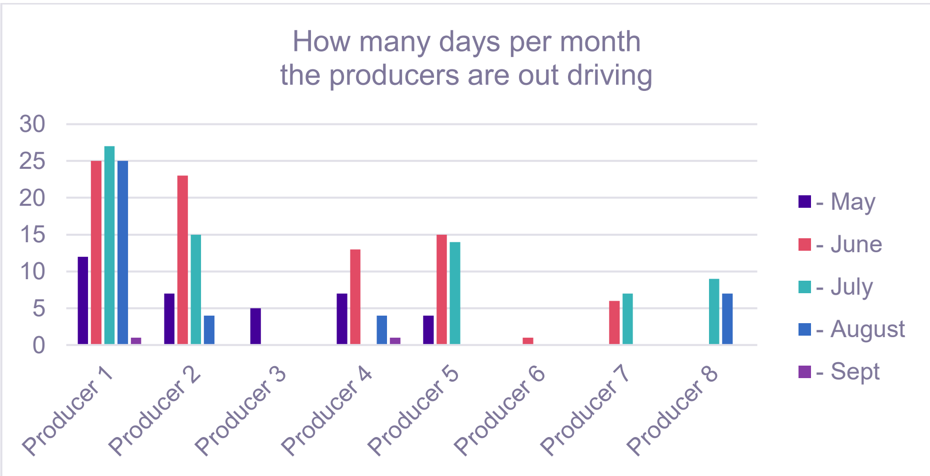

Figure 11. Number of days each producer drove their shipment per month

Part 2 – Producers used the platform: 24 producers signed up for testing the platform. However, when the test started several of them did not use it. The main reason for this was that they realised that they had too small shipments and did not have a need for using transport providers but continued driving themselves. However, one producer used the platform several times and got matches. When there was no match, the producer had a contract with a larger 3PL-provider and used their services, this was also the case if the matches had a higher price than the 3PL-provider offered.

To increase the usage of a tool by producers, it needs to be easily usable even for producers with small shipments. One way to do this, is that the tool not only has to match producers with transport providers but also help producers to match their flows to joint customers/or geographical close customers to increase the shipment sizes. This could for example be achieved by producers adding shipments as soon as they were ordered, so that the transport providers could plan routes with freight from several producers.

The two parts of the test show that there is potential to increase collaboration between shippers and transport providers by using a digital tool and by that increase the transport efficiency. However, there are areas that need to be in place to efficiently use the tool. First, there must be a critical number of users to find good matches. Second, the tool must be user friendly to enable the onboarding, which will be elaborated on in sections 3.3.4 and 3.3.5.

Case 3 – Waste flows. There are several waste flows in Sweden, and they differ depending on what waste it is.

Regarding time demands, the receivers of the waste rarely have demands on deliveries in terms of fast deliveries or tight time windows (JIT). However, the companies or organisations wanting to dispose the waste can be less flexible and have requirements on fast pick-ups. This is, however, different depending on who the waste disposer is.

Regarding being irregular or regular, there are large differences. One example of regular flows is for households, where there are fixed dates for picking up the waste and the volumes are rather predictable. On the other side of the spectrum is, for example, constructions sites, for which waste flows are more irregular since constructions sites are non-permanent and the type of waste and volumes varies throughout the construction phases.

Regarding if the waste can be transported in different units, this also varies for different kind of waste. In general, it can be said that the more mixed a waste fraction or the higher the “moist content” is, the more limited the number of possible load units are. In the project, suitable fractions that have been discussed to have the potential to utilize return flows for other type of freight is “clean” waste flows (both in terms of not being dirty as well as only consisting of one material type such as plastics) or that a truck is used where the “waste bin” can be transported as a whole (for example a container put on a demountable truck).

Another limitation is that to be allowed to transport waste in Sweden as a business, there is a requirement to have a permission for this. Today, there are around 4 500 Swedish companies[7] that have this permission, implying that around half of the total number of transport providers have this permit.

[7] https://www.kontrolleraavfallstransportorer.se/Search

In this project, two subcases were identified, together with project partners, focusing on specific waste flows that fitted the application areas; Part 1) Container with waste, and Part 2) old boats that are collected for recycling.

Part 1 – Containers with waste: The case company is a large waste collector in Sweden, mainly collecting waste from businesses. For the transport setup, they have both their own fleet (Transport Execution Type 1) and purchases FTL shipments from transport providers (Transport Execution Type 4).

During meetings, it was identified that the tool could be interesting to use for containers that are placed at the customers facilities and then picked up when customers ask for a pickup. The company wants to deliver the containers to the customers themselves to ensure high service quality. However, for the pickup of containers, transport providers can pick them up as well. Within the contracts with the customers, the company often has three days to pick up the container from the day that the customer orders the pickup. Commonly, the company handle the pickup transport as a regular transport on the first day, either by own transport resources or by the transport providers they collaborate with. This implied that they tried to balance flows with delivering empty containers and picking up full ones, but if this was not possible, they sent out an empty truck to pick up the container.

With a tool the case company see a potential to use overcapacity in the vicinity instead of using transport resources that go empty to the pickup of the container the first day. This will be done by using the whole time of three days to find a transport that is already in the vicinity and has overcapacity with the following setup:

- Day 1: Directly when a customer orders a pickup, the company puts up the transport request in the tool (as a shipper having something they want to have transported) with a suggested price that implies that only if a transport provider will be passing by both the pickup point and the facilities empty with a suitable truck (demountable) on their planned route will they be interested in the task.
- Day 2: If no match was made during Day 1, the price is increased on Day 2 implying that transport providers can take a smaller detour from their planned route to handle the transport assignment.
- Day 3: If there is no match on Day 2 either, the company handles the transport as a regular transport as they would do today.

The company identified three enablers that would make it easier for them to use the tool:

- *Integration with the existing transport planning software:* It must be easy for the transport planners to use this setup and the company suggests that it is done with a direct integration between the tool and their transport planning software.

- *Payment:* The company wants that the tool includes the functionality of payment, implying that they do not have to handle invoices from all new transport providers that they will collaborate with through the tool, but instead only the with tool provider.
- *Geo-fencing and predictions:* Geo-fencing and predictions within the tool could make it easier for transport providers that handle the transport planning from the truck to identify suitable transport assignments for them.

Part 2 – Old boats to recycling: The case company is an organisation helping boat owners that have boats that are no longer possible to use to ensure that they are material recycled. Previously in Sweden, many boats that were no longer possible to use were rarely recycled since this was linked to high costs and there were no regulations demanding this. However, now the Swedish government gives out grants to cover costs for the material recycling. The case company helps boat owners to find a transport to pre-processing plants for material recycling.

The case is interesting since it aligns well with the Application Area II of "Time insensitive freight". Many of the boats had already been stored at personnel sites or boat clubs for years implying that waiting a few more months or even a year to have the boat removed is no problem. The authors of this report have never heard of any freight with less time restrictions.

The flows are irregular (Application Area I) and there is a need for a marketplace since the shippers have little experience in purchasing transports (Application Area IV). On the other hand, the boats are often large and have impractical shapes, implying that the number of trucks that can be used is limited (lack of Application Area III).

Two enablers linked to the tool were identified in the case:

- *Identifying possible trucks:* The boats can have shapes that limits the number of possible trucks. In the tool, it is important that it is easy to identify which types of trucks and units that can be matched with the boats. In this case, it was for example suggested that timber trucks could be used for transporting the boats, which would increase the number of possible trucks that can be used. If the digital tool could provide suggestions on possible trucks based on previous matches, that could increase the chance of matches.
- *Marketplace:* A marketplace where the case company, which is not used to purchasing transports, can find transport providers that has overcapacity on the routes from the boat owners to the pre-processing plants.

3.3.3 Challenges and solutions

From the cases, workshops, and interviews challenges for using the tool as well as solutions to overcome the challenges were identified. In a digital tool, the purpose is to generate matches between shippers and transport providers. Two concerns, that become challenges, in relation to this was based on that "no matches made" or that the "wrong type of match" is made. These concerns are described in the following tables and texts and include potential enablers and solutions to overcome these concerns.

"No matches made". For shippers that have been interviewed or participated in workshops, one commonly mentioned concern is that when using the platform, matches will not be made and the shipments they need transported, are not carried out. The more time sensitive the freight is the larger the concern is. Table 14 summarizes solutions and enablers linked to the challenge area.

Table 13. "No matches made" – Solutions and enablers.

Challenge area	Solutions	Enablers
"No matches made"	1. Longer time on the platform	Post immediately when shipment is scheduled (Interviews)
		Change working methods for shippers (Interviews)
	2. Larger delivery windows	More dialogue around delivery windows (Case 1 –construction site and interviews)
		Change working methods for shippers (Case 1 –construction site and interviews)
	3. Backup plan	Have a solution that can be used quickly in case no match is made (Case 3 – Waste flow, Part 1)
	4. Critical mass of users	Start with existing communities that can be expanded (Interviews and workshops)

Previous literature often describes high demands on time, either as short lead time or tight delivery windows, as an important constraint for increasing transport efficiency. It is the same for using a tool, and therefore the first two enablers are linked to changing time demands:

Solution 1: *Longer times on the platform:* The longer before a shipment needs to be picked up it is added to the platform, the larger chance for a match. So, the first solution is to prolong the time it is on the platform. The interview study described that transport providers often get information about a transport close to the pick-up time even if the shippers knew about it much earlier. So, a first enabler is that as soon as a shipment is confirmed with the receiver, it is also added to the platform. This implies little change in the operations for the shippers. A second approach is that the shippers overview their purchasing and sales processes together with suppliers and customers to identify how changed operations and collaborations can increase the time between the confirmed order and the pickup time. This will demand much more of the shipper as well as its suppliers and customers in terms of changed operations.

Solution 2: Larger delivery windows: If the shipper can increase the pickup and delivery time windows, this also increases the chances of a match since it will be easier to include it on existing routes for transport providers. In the interview study, it was described by transport providers mainly working in the construction industry, that it happened that the shippers gave a tight delivery window, but when they delivered the shipment, it was apparent that it was not as urgent as described and the need for a prompt delivery within a small window was unnecessary. Hence, a first enabler is that shippers extend the delivery window as much as possible within current agreements with suppliers and customers. And as for the first solution, the second enabler is that trying to change current operations to widen the possible delivery windows.

Solution 3: Back-up plans: The third solution implies that there is a back-up plan in terms of an "emergency transport" for the shipment if no matches are made for transports in the platform that can fit it onto existing routes. How this can be executed was described in Case 3 and used by a shipper in Case 2.

Solution 4: A critical mass: An important aspect of the tool is that the more users there are, the larger is the chance for a match. For tool developers, this will be a challenge since it will be difficult to get the first users on board when there is little activity within the tool. An enabler here would be to start with the existing communities that transport providers have today. If a whole community joins at once, they can make their current information sharing more efficient and therefore have a benefit from the beginning. Then the community can gradually grow and integrate with other communities to gain the "large scale effects".

"Wrong type of match". A concern raised by both shipper and transport providers is that they are being matched with companies they do not want to do business with. Table 14 summarizes the challenge areas and solutions.

Table 14. "Wrong type of match" – Challenge more specific and solutions

Challenge area	**Challenge more specific**	**Solutions**
"Wrong type of match"	Transport is performed with poor environmental performance and does not meet social legal requirements	5. Certification (e.g. ISO and Fair Transport) (Interviews and workshops)
	Transport provider risks non-payment	6. The platform includes payment features (Interviews and workshops)
		7. Charge for transport in advance (Case 3 – Waste flow, Part 1)
	Wants to work with established partners	8. Closed communities within the platform (Interviews and workshops)
	Afraid of price pressure	9. Transport planning functionalities (Interviews and workshops)

Solution 5: Certification: Shippers are mainly concerned that they will be matched with transport providers not fulfilling sustainability requirements, mainly specified as ensuring that trucks with a certain environmental standard are used (e.g. euro classes or certain type of fuel) and regulations regarding working conditions are met (e.g. guaranteed that cabotage is not happening). To ensure that shippers can feel safe with using new transport providers the platform can show what certifications certain transport providers have. For example, the industry organisation Sveriges Åkerier has the certification "Fair Transport" that ensures that the transport provider follows regulations regarding traffic safety, emissions and working conditions. Another certification that are used by transport providers is ISO.

Solution 6: The platform includes payment features and *Solution 7: Charge for transport in advance:* Transport providers were concerned about being matched with shippers that will not pay the invoices after the transport is handled. Adding a new customer is for many transport providers a process that takes some time in terms of getting all the information and carrying through credit checks. In addition, the correct insurance agreements need to be in place for each shipment. These processes make many transport providers hesitant to take on one-term jobs. To reduce the economic risks for transport providers, two solutions are proposed. First, since many transport providers have suggested that a platform also should include the financial services of invoicing the shipper, the tool owner could bear the financial risk instead of the transport providers. This can also be extended to other "middleman" services, such as insurances. The second alternative could be to charge for the transport when it is ordered, instead of after.

Solution 8: Closed communities within the platform: Since many transport providers have communities with trusted collaboration partners (both other transport providers and shippers) where communication is done by phone, email, and/or social media, a solution is to use closed communities within the tool. To use a tool with maps and GPS-positioning can make the communities information sharing more efficient. It can also be an efficient way to expand communities with trusted collaboration partners from different current members.

Solution 9: Transport planning functionalities: The interviewed transport providers expressed that many tools that are available today to provide marketplaces for transportation creates a competitive situation where prices are pressed below the costs for executing the transport. To avoid this, a solution is to extend the functionality of the platform to also include transport planning functionalities and to stress that a tool has more advantages than reducing transport prices, and that the economic gains of increased transport efficiency should be shared between transport providers and shippers.

3.3.4 User behaviour

The mobile ethnography study showed that technology adaptation in this sector is slower than average. The first user (subgroup a) in the study managed the operative planning on paper, either printed and kept on a clipboard or written down in a calendar. New assignments and changes were handled with phone calls.

Doing this by phone was important since he spends his day on the road, and thus is unable to look at text in written form whilst driving. And when there are stops for pickup or delivery and they often “work against the clock”, there is no time to check an app or a website for potential updates. For the second user (subgroup b), which was a haulier centre, the transport administrator worked by the computer and received assignment requests via email. These were then printed and assigned to the various drivers. They are one year in of implementing a digital assignment system, but the adaptation with the drivers is still slow. The digital system was perceived as cumbersome and not reliable, so printed assignments were still the norm.

To create a sustained change in behaviour it is important to look at the factors behind a behaviour change. According to Fogg (2009), “behaviour is a product of three factors: motivation, ability, and triggers.” These three factors must occur at the same moment, or the behaviour will not happen. In the following section the factors motivation, ability, and triggers are discussed.

Motivation. From the transport providers perspective, the added value of ad-hoc transportation must counterbalance the uncertainties of a new pick-up location, new receiver, new shipper and all the information required to decide if it is even possible to access both locations with their current vehicle, as well as cover the cost of time, mileage, and effort. With constant pressure for cost reductions in the business in general, there is an anticipation from the shipper that these transports should be cheaper than usual since the transport providers are “passing by anyway” and otherwise must go empty. However, the time for changing route or uncertainties are the costs that also need to be accounted for. For haulier centres (subgroup (b)), these uncertainties are perceived as somewhat reduced since transport planners can gather the needed information. For hauliers (subgroup (a)) to gather the needed information can, however, be an extra work task for the driver. On the other hand, haulier centres could find putting resources into finding ad-hoc/single instant shipments unnecessary, since they primarily focus on increasing load factors with long-term deals and repetitive shipments.

Ability. From a design perspective, ability is the factor that is easiest to incorporate in product design decisions to provide an impact to create a wanted behaviour change. In the following, factors of user friendliness are presented and discussed in the relation to the tool.

(1) Accessing information: The basic rule for interface design is to ensure it is easy for everyone to access the information, be it on a central fixed display or distributed to phones or tablets. Layover times during transportation are short and filled with activities where checking updates in an app/platform is both distracting and time-consuming. The use of notifications/custom tailored push messages can help the user and trigger usage. Alternatively having a voice operated service that can be accessed whilst driving, if that is allowed by the employer, would be an advantage. Instead of the user having to search for a match, the system could find the user by receiving notifications about

shipments that fit the specific criteria of the available vehicle (size, loading possibility etc).

(2) Automation: The aim should be to automate as much information as possible throughout the service chain. For example, by using augmented reality technology to scan parcels to get correct measurements, or GPS/position data to determine driving time for an assignment. The tool should allow for easy and continuous updates on the assignment, so that it can be entered as soon as possible in the system, and work with default settings so that the user does not have to choose.

(3) Communication: Ad-hoc communication is done primarily as synchronous communication, that is through phone calls today. This is a richer means of communication that can provide companionship on the road and helps build familiarity and trust between parties. However, most technologies and platforms today rely primarily on asynchronous communication. In theory, this should work well in this setting given the varying workday where possibilities to check for new assignments or answer a call is different from day to day and individual to individual, but the mode of communication (voice or text) have to be carefully considered to suite the context. One alternative can for example be that it is possible to listen to new assignments while driving.

Trigger. Change takes time and continuous effort and to encourage change the use of triggers is essential. Triggers tell a person to do something and must be presented once motivation and ability have reached sufficiently high levels for the person to engage in a new behaviour. Triggers that could be used here are, for example, promotions such as using the system for free during a trial period. Another trigger is to highlight how many people have seen a specific assignment, to both create trust as well as trigger demand through competition. In areas like this where tech-adoption is slower, it is crucial that the first attempt is successful, otherwise the reputation can quickly go bad and trust deteriorate. It is vital that the solution has been adequately tested and that the users have been involved in various capacity throughout the development process.

3.3.5 Tool functionality

In this section, functionality is identified for a tool to make it easier for shippers and transport providers to share data on transport needs and available capacity and find matches for increased transport efficiency. The identified functionality falls into six categories, marketplace, transport planning, user friendliness, sustainability information, collaboration, and financial information:

Marketplace. A marketplace where information about shipments that need a transport is described can be as seen as the basic functionality of the tool (for an example, see Figure 12).
For example, in the tool of CS24, when registering a new shipment, information is required such as pickup and delivery address, company name, pickup and delivery time, cargo type, package description, quantity, weight, length, width, height, and volume. Buyer can put in optional requirements such as temperature-controlled transport, opening side, or specific engine type and price. Transport providers can

also add shipments if they have too much freight and need someone else to handle parts of it. With this information about shipments, transport providers can identify if there are any suitable matches for them. This can either be done by a separate tool, or by integration with transport planning tools, as discussed in the subsection of user friendliness.

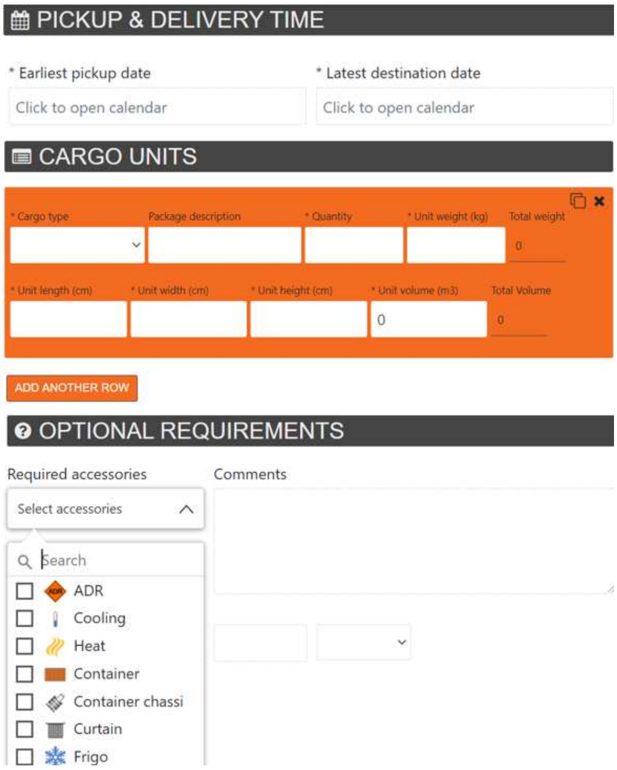

Figure 12. View when adding a new shipment in the CS24 platform

Transport planning. To have functionalities enabling more efficient transport planning was addressed in both cases, interviews, and the mobile ethnography study. In the tool of CS24 the information required from transport providers to enable transport planning functionalities is that vehicles are registered in the tool with information such as registration number, vehicle name, length, height, width, maximum load weight, vehicle type, engine type, GPS provider, IMEI/GPS ID, vehicle accessories (such as temperature-controlled transport and tailgate lift) and home address. This data enables three types of transport planning functionalities:

- *Ability to track shipments and provide delivery status updates:* For both the shippers and transport providers, that the trucks are connected to the tool with GPS providers enables to track shipments in real time on maps as well as providing delivery status updates via for example text messages and emails.
- *Geofencing:* With both location of possible shipments and the position of trucks, it is possible to use the functionality of geofencing for notifying transport providers when they are in the vicinity of possible matches.

- *Predictions:* When the trucks have specified their home address, it is also possible to have the functionality of predictions. This implies that recommendations for matches are made based on the truck's current position and its' home address, so shipments for the return transport are identified. If it is possible to also provide information about planned routes through integration with their transport planning tools, predictions can be used for shipments suitable along the routes. Both geofencing and predictions will ensure that less matches are missed and reduces the time and effort by people actively checking for matches.

Figure 13 shows an example of the interface of the transporter access.

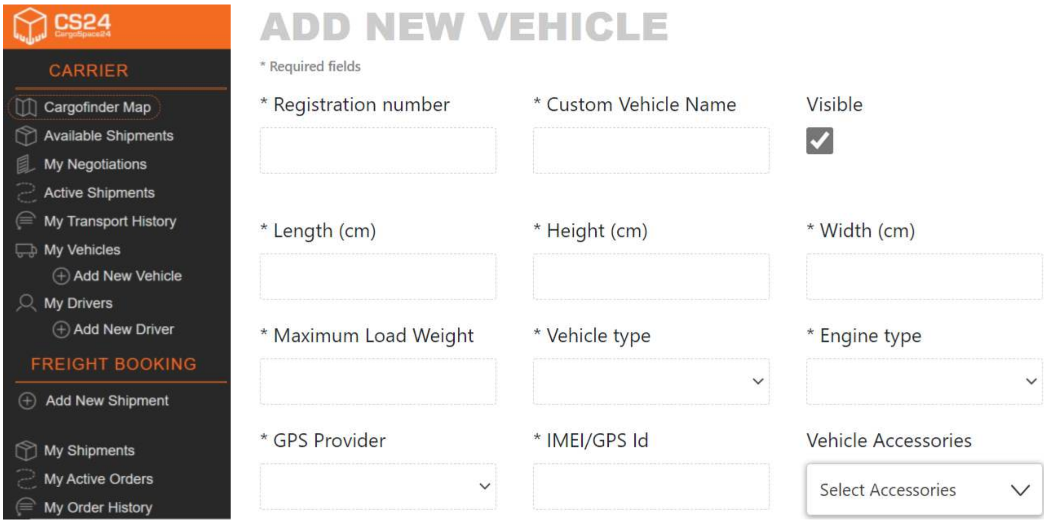

Figure 13. View when adding new vehicle in CS24

User friendliness. To create a sustained change in behaviour it is important to have a responsive interface that adapts to the device that the user is using, and language and terminology that is familiar to the user. Placement of buttons and actions should be in line with the device's operating systems conventions, so that patterns are recognizable for the user. Lastly, it is advantageous that as much as possible is automated to make the interaction with the system feel smooth.

Four functionalities to enable this were identified:

- *First interaction with the system:* When acquiring knowledge and skills necessary for the system it is essential to get a simple explanation of the usage during the first interaction with the system. The so-called onboarding system should have different versions for those who want to send something and those that will pick up and deliver something.

- *Push notifications:* Push notifications should help the users to identify matches and these notifications should be relevant for the users and easy to answer.

- *Voice controlled system:* Such a functionality could enable for users that spend a lot of time driving trucks to use the system, this, however, this needs to be further investigated to ensure that it really creates a value for the users.

- *Integration with existing transport planning systems:* To integrate with the transport planning makes it easier for transport providers to work with the tool and by that using it regularly in their daily work. To include transport planning functionalities will also separate tools from the current digital marketplaces on which price is pressed.

Sustainability information. To ensure that shippers are matched with transport providers that fulfil their requirements regarding sustainability the tool can provide information regarding these measurements, two areas were identified:

- *Certifications such as ISO and Fair Transport*: This information is the same for all transport activities handled by a transport provider and the transport provider should only have to add this data once for their profile in a tool.

- *Environmental data on vehicles used*: Shippers can have specific requirements on the vehicles that will be used for their systems. This implies that if a transport provider has trucks that both fulfil and not fulfil these requirements, the shipments should only be matched with trucks that fulfil the requirements. That trucks are added individually in the tool enables this.

Collaboration. The empirical data showed that several transport providers today have communities in which they more manually identify the matches that a tool could enable. Since many transport providers and shippers do not want to this on an open marketplace from the beginning, a functionality that the tool can have is the possibility to have closed groups in the tool, so that all functionality is available, but the marketplace is limited to approved users.

Financial information. The tool will imply, for both shippers and transport providers, that they can be matched with new customers that require a financial transaction (if not only strictly closed groups are used). Today, transports are mostly paid after they are executed, which implies a risk for the transport provider when working with new customers. To reduce this risk, two functionalities have been proposed which also implies new business models for everyone involved:

- *Advanced payments:* If payments are made in advance, it reduces the risks for the transport providers and/or reduces the time it takes to perform credit checks. This, however, would imply a new setup for several transport providers, where a transport price must be estimated in advance.

- *Payment functions in the platform:* This implies that the platform operator take a larger role and offer financial services in terms of payments from the shippers and pay outs to the transport provider. This can also be extended to other "middleman" services, such as insurances. With this setup, it would be possible for the shipper to pay in advance, but the transport provider would not be paid until after the transport is executed. An established system for payment functions could be integrated into the platform to handle all the payments, so that the tool owner does not need to be involved in the transaction.

3.3.6 Concluding remark

The results from all three work packages indicate that there is a potential to increase transport efficiency with a digital tool that makes it easier for shippers and transport providers to share data on transport needs and available capacity and find matches for increased transport efficiency. However, to use the full potential of a tool, there are many areas that require changes. First, there need to be *technical solutions* for functionality such as geo-fencing and predictions. Second, it requires *adaptations of existing business models* in terms of monetary flow by deciding who will charge who (the transport provider charging the customer, or the tool provider charging the customer that in turn pays the transport provider) and at what time the payment shall take place (when the match is made or after the transport is executed). The third area requiring changes is *collaboration models*, in terms of that both transport providers and shippers possibly will increase the number of collaborations partners and this transition must be supported with easily accessible and trustworthy information about new collaboration partners, such as certifications. The fourth and last area, requiring *changes is the daily operations* of the people that will use the tool. It will require new ways of working and enablers here are integration with current transportation planning tools as well as features such as push notifications.

4 Discussion and conclusion

In the project "Utilizing the existing overcapacity in the transportation system for increased energy efficiency (USECAP)", the focus has been set on identifying and reducing underutilized capacity in the transportation system and was divided into three steps. First, to understand this improvement potential, the availability of transport data on the national level and how this data can be used to increase transport efficiency, was studied. Second, data on company level was collected. Third, it explored how to make it easier for shippers and transport providers to share data on transport needs and available capacity and thereby finding matches for their freight flows which in turn increases transport efficiency. For this, the functionality of a digital tool was investigated, and its needs illustrated. In the following the three steps are discussed in more detail.

First, regarding the data on national level, the Swedish National Freight Transport Model Samgods was used to illustrate the capacity utilization of Sweden's freight flows and so to present realizable efficiency improvement potential. However, Samgods is a modelling tool and thus does not purely reflect reality; freight flows are divided in 28 commodity types and those cannot share the same transport resources according to Samgods. Furthermore, data is often aggregated on a higher level, such as on a county level, and a detailed reliable view on individual flows is not possible. The results indicate that there are substantial levels of structural imbalances in the geographical distribution of interregional (at country level or NUTS3) transport demand for different commodity types. Maximum achievable efficiency potential of the network indicates that empty runs of around 30-40% should be expected. In other words, a network with these properties, if operated at maximum efficiency can achieve a utilization rate of 60-70%. However, there are significant validity issues related to the data employed which necessitates further study of this phenomenon with new empirical data that is today not readily available. The principal point that empty running in and of itself is not a very good indicator of realizable efficiency improvement potential is strengthened based on these results even though the exact numerical values cannot be empirically validated here. In sum, it could be shown that, given the substantial expected empty runs due to structural imbalances, that the available realisable efficiency improvement potential of the Swedish road freight transport system is probably significantly lower than the underutilized capacity alone indicates. However, to use this data to understand where there is realizable efficiency potential is not possible. This implies that this data cannot act as guidance for transport providers and shippers to identify on which flows, they should put more focus in finding for example return flows. This highlights the need for developing new methods for empirical data collection on national level to enable reliable analyses of these issues. It stands as evident that existing sources of official statistics are not up to the task.

Second, regarding data availability and its analysis on a company level, the results showed that only a few transport providers measure KPIs regularly and even if they collected the information, it is even more unusual for them to share the data with the shippers (i.e. the transport providers' customers). From the perspective of shippers, it became apparent that shippers do not have the overview of how their transport could be made more efficient and that transport efficiency KPIs are not regularly measured, followed up and shared. In recent years, there has been an increased interest in getting data on environmental KPIs, but the data requested is aggregated for several flows and over large time intervals (normally quarterly to yearly). Furthermore, once the data is received, it is reported in annual environment reports but not processed further to make a transport efficiency improvement. The work builds on previous research by for example Björklund et al. (2012) who presented advantages of measuring the transport performance and the extension of the categories of transport efficiency as suggested by McKinnon et al. (2003); i.e. cost, time, load factor vehicle time utilization, empty running, GHG emission, alternative fuel, and Euro class. The contribution of this project lies in showing what and how KPIs are measured and followed up in Sweden both among transport providers and shippers.

The reasons why transport providers and shippers do not measure, share, and follow up on their transport data in a more structured way was mainly due to (1) lack of tools for efficient measurement and follow-up and (2) lack of processes for sharing these between transport providers and shippers. This calls for further research to overcome the lack of tools for efficient measurement and follow-up. For this, tools are needed that enable a structured way to collect data, as well as showing results and analyses in ways that support decision making for increasing transport efficiency. Regarding the lack of processes for sharing these between transport providers and shippers, further research is necessary, such as research around developing processes and tools, so that transport providers and shippers can gain a better understanding of key figures for transport efficiency and be able to jointly improve these. To be able to succeed with this, it is believed that a multidisciplinary approach is necessary including researchers from the disciplines of logistics and transport, business, IT-development, communication, and behavioural scientists.

Third, the functionality of a digital tool to share overcapacity in the transport system was studied and illustrated. Regarding the development of functionality of a digital tool, it was identified that the tool needs to span over six functionality categories: Marketplace, transport planning, user friendliness, sustainability information, collaboration, and financial information. However, at the same time, the results also show that it is not simple to develop a tool with this wide range of functionalities. In relation to theory, the results taken up in the project, built on the findings from example Jacobsson et al. (2019) on the need for better data access and real time exchange of information through providing application areas (i.e. (I) irregular freight flows, (II) time insensitive freight, (III) easy to handle freight, (IV) need for a marketplace and (V) consolidation of actors) of such a tool and by studying the user needs and how users could be boarded on the tool.

To be able to use the tool, transport providers and shippers must make adaptations in relation to their existing collaboration and business models as well as adaption in their daily operations. This also calls for further research focusing on how the shippers and transport providers jointly can make necessary adaptions of their transport systems to be able to improve transport efficiency with support of the functionalities in the tool.

Calculation models are generally applicable, however, the necessary data used in WP1 was context dependent and data needs to be collected specifically for the analyses of any network. The data from WP2 (i.e. from interviews, case studies, workshops) has been collected in Sweden, where the need for collaboration of different logistics actors became apparent. However, it can be assumed, that the project's results, also in regard to the need of a digital logistics tool (WP3) could be useful in many other countries as well; especially because freight transport chains often go beyond country boarders and foreign transport providers come into Sweden. Hence, for the development of a tool it is crucial that it has the right functionality to fit the requirements and needs of both shippers and transport providers.

Concluding, the results of the three different workspaces (WP1-3) showed that there is a lack of data at aggregated national level and at company level. Improved collection, follow up and sharing of transport data will improve transport efficiency and by that contribute to a fossil-free transport system in Sweden. The concluding take-aways of the project are summarised in a managerial summary in Table 15.

Table 15. Managerial summary

USECAP Three focus areas of the project USECAP: (WP1) Estimating the proportion of underutilized capacity that constitutes a realizable efficiency improvement potential at the national level, (WP2) analysing how shippers and transport providers measure and follow up transport efficiency Key Performance Indicators (KPIs) in order to realize the efficiency potential, and (WP3) developing a conceptual model for a digital tool containing functionalities that enable shippers and transport providers to better match demand and supply and thereby utilize overcapacity.
Realisable efficiency improvement potential Challenges of realising the efficiency improvement potential: 1. Lack of empirical data at national level 2. Lack of empirical data at company level 2.1. Lack of tools for efficient measurement and follow-up 2.2. Lack of processes for sharing these between transport providers and shippers.
Transport efficiency Three buildings blocks for measuring, sharing and follow up on transport data: • Transport efficiency KPIs (1) Cost (2) Time (3) Vehicle utilization (3.1) Load factor (3.2) Vehicle time utilization (3.3) Empty running (4) Emission (4.1) GHG emission (4.2) Alternative fuel (4.3) Euro class • Transport execution types Type 1: Shipper uses own vehicle for transport Type 2: Transport is included in the purchase of goods Type 3: Shipper purchases LTL Type 4: Shipper purchases FTL Type 5: Shipper does transport planning but sources trucks and drivers Type 6: Transport provider’s role in Type 2-5 • Collaboration levels – Vertical collaboration – Horizontal collaboration

Enablers for improvement of transport efficiency:

- KPIs measured and followed up
- Responsibility and collaboration
- Making data collection more efficient

Development of functionality of a digital tool

Applications areas for the tool:

I. Irregular freight flows
II. Time insensitive freight
III. Easy to handle freight
IV. Need for a marketplace
V. Consolidation of actors

Digital tool as a solution

Solution 1: Longer times on the platform
Solution 2: Larger delivery windows
Solution 3: Back-up plans
Solution 4: A critical mass
Solution 5: Certification
Solution 6: The platform includes payment features
Solution 7: Charge for transport in advance
Solution 8: Closed communities within the platform
Solution 9: Transport planning functionalities

Tool functionality:

- Marketplace
- Transport planning
  - Ability to track shipments and provide delivery status update
  - Geofencing
  - Predictions
- User friendliness
  - Onboarding
  - Push notification
  - Voice controlled system
  - Integration with existing transport planning systems
- Sustainability information
  - Certifications such as ISO and Fair Transport
  - Environmental data on vehicles used
- Collaboration
- Financial information
  - Advanced payments
  - Payment functions in the platform

5 List of publications

Jónsdóttir, H., Liljestrand, K., Wehner, J., Kalantari, J., van Loon, P. (2020), "Measuring and sharing data on KPIs for transport efficiency: an interview study of shippers and transport providers ". Submitted to conference: 32nd Annual Nordic Logistics Research Network (NOFOMA 2020), 17-18 Sept 2020 in Reykjavik, Iceland [moved to an online conference because of the pandemic]. (See Appendix III for the academic article.)

> *Summary of article:* To reach the goal of a fossil-free transport, large changes are necessary, and to lay a foundation for this a first step is to measure the current performance. The purpose of the paper is, therefore, to identify what Key Performance Indicators (KPIs) transport providers measure, follow up and how they share these with their customers (i.e. shippers) to improve transport efficiency. To do so, data has been collected through 23 semi-structured interviews, with 10 shippers and 13 transport providers in Sweden. The results show what KPIs are measured by transport providers and shared with shippers. The collection of emission-related KPIs was high, while surprisingly few follow up on time and vehicle utilization KPIs. Measurements and follow-up were constrained through (1) a lack of tools for efficient measuring and follow-up, and (2) a lack of demand for certain KPIs and processes for sharing these between shippers and transport providers. What is more, the results show that a more standardised way of measuring and sharing of all types of KPIs is needed, at a minimum nationwide. The results can be used by transport providers and shippers to understand how they jointly can improve transport efficiency by measuring and sharing data on KPIs. The academic contribution lies in describing what KPIs are measured by transport providers and shared with shippers. The study builds on previous literature on KPIs for transport efficiency and collaboration between shippers and transport providers and adds to the field by identifying what KPIs are currently applied in practice and how collaboration can be improved by increased sharing of KPIs.

Lundgren, E. och Freij, H. (2020), "Vägen mot ökad transporteffektivitet – En studie om hur ökad transporteffektivitet kan möjliggöra för transportköpare inom byggsektorn att minska sin miljöpåverkan", Bachelor thesis, Gothenburg University, Gothenburg, Sweden.

> *Summary of bachelor thesis:* Emissions from trucks from road transports contribute to global warming. One way to reduce the negative environmental impact of transport is to increase transport efficiency. The construction sector is resource-intensive and accounts for almost one fifth of Sweden's total greenhouse gas emissions. The purpose of the thesis is to investigate how KPIs and digital tools can act as tools to increase transport efficiency within the construction industry with the aim of reducing the industry's environmental impact. Data was collected through interviews with transport buyers from some of the largest construction and civil engineering companies in Sweden.
>
> The analysis of the interviews against literature showed that potential cost savings were possible if the transport buyer increased their transport efficiency, which also contributed to a reduced environmental impact. Moreover, there was a trade-off between improved environmental work and maintained competitiveness, and that it showed that adequate knowledge of what the transport's environmental impact was, was often lacking. The

analysis pointed out that the KPIs were not sufficiently anchored in the various companies to contribute to an increased transport efficiency. There was a lack of reliable and accurate data but without relevant data, performance measurement and thus efficiency is not possible to improve. The level of digitization combined with the requirements of the end customer was an obstacle to choosing and following up KPIs. Companies often let the end customer choose KPIs, which affected their ability to reduce their environmental impact themselves. It turned out that the largest companies in terms of turnover size were the most digitized and that the digitization rate decreased the smaller the companies were in terms of turnover size. The digital tools were of the utmost importance as they enable information sharing that can be used to increase transport efficiency.

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7 Appendices

I. **Analysis of interview data from the transport provider on KPIs**

II. **Dissemination list**

III. **Academic article (NOFOMA Article) [in a separate attachment to the report]**

IV. **Administrativa attachement/Administrativ bilaga (OBLIGATORISK) [in a separate attachment to the report]**

Energimyndigheten

Appendix I. Analysis of interview data on KPIs (Part A and B merged)

No.		Cost	Time	Vehicle utilization			Emission		
				Load factor	Vehicle time utilization	Empty running	GHG emission	Alternative fuel	Euro class
H1	Measurement	Cost/truck and hour	On-time	Weight/truck (%)	-	-	Fuel-consumption/car	% fossil free	% different classes
	Coordination with customer	-	Reports	-	-	-	Reports	-	Reports
H2	Measurement	Total costs/month	-	-	-	-	-	-	% different classes
	Coordination with customer	-	If a problem	-	-	-	-	-	-
H3	Measurement	Total cost	On-time	-	-	-	CO2-emissions	% fossil free	% different classes
	Coordination with customer	-	-	-	-	-	Reports at request	Reports at request	Reports at request
H4	Measurement	Cost of staff and fuel/turnover	On-time	-	-	-	Emissions/tonkm	% fossil free	% different classes
	Coordination with customer	-	-	-	-	-	Reports	Reports	Reports at request
H5	Measurement	Cost/vehicle	-	Weight/container (%)	-	-	Emissions/tonkm	% fossil free	% different classes
	Coordination with customer	-	If a problem	-	-	-	If requested	If requested	If requested
H6	Measurement	Cost/truck, number of executed orders/truck	On-time	Weigth/truck (%)	Utilization/truck	-	-	% fossil free	-
	Coordination with customer	-	-	-	-	-	-	-	Sometimes in contracts
H7	Measurement	Cost/transport	On-time	Weight/truck (%)	-	Through tonkm calculations	Fuel/tonkm	% fossil free	% of Euro class 5 and 6
	Coordination with customer	Reports and meetings	Reports and meetings	Reports and meetings	-	Reports and meetings	Reports and meetings	Reports and meetings	Reports and meetings

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HC1	**Measurement**	Cost/vehicle	On-time	Ton/truck or volume/truck	Utilization/truck	Identification of "empty distances"	Emissions/tonkm	% fossil free	% different classes
	Coordination with customer	Reports and meetings	Reports from customers	Reports and meetings	Reports and meetings	Reports and meetings	Reports	Reports	Reports
HC2	**Measurement**	Cost/ton	-	Weight/truck (%)	-	-	Emissions/tonkm	% fossil free	% different classes
	Coordination with customer	-	-	-	-	-	Reports	Reports	Reports
HC3	**Measurement**	Cost/day, cost/hour, cost/kms (varies by tasks)	-	-	-	-	Emissions/tonkm	% fossil free	% different classes
	Coordination with customer	-	If a problem	-	-	-	Reports at request	Reports at request	Contracts
HC4	**Measurement**	E.g. cost/ton, cost/load unit, cost/truck	On-time	Weight/truck (%)	-	Kms empty running	Emissions/tonkm, CO2-reduction between years	% fossil free	% different classes
	Coordination with customer	Reports and meetings	Reports and meetings	Reports and meetings	-	Reports and meetings	Reports and meetings	Reports and meetings	Reports and meetings
LSP1	**Measurement**	Cost/kg	On-time	Pallets/truck (%)	-	-	CO2-emissions	% fossil free	% different classes
	Coordination with customer	-	If a problem	-	-	-	Reports at request	Reports at request	Reports at request
LSP2	**Measurement**	Cost/pick up and cost/delivery (average)	On-time	Weight and volume/truck (%)	-	-	Emissions/tonkm	% fossil free	% different classes
	Coordination with customer	-	Reports	-	-	-	Reports	Reports	Reports at request
S11	**Measurement**	Cost/tonkm	-	Used as KPI	-	Used as KPI	Used as KPI, information from transport provider	Defined in procurement specification	Defined in procurement specification
S12	**Measurement**	Total cost	Delivery security	-	-	Efficiency	Predefined, on demand	Defined in procurement specification	Defined in procurement specification

S13	**Measurement**	Per transport	Delivery security	Used as KPI	Used as KPI	Used as KPI	Transport provider is supposed to follow up	Defined in procurement specification	Amount of Euro class
S14	**Measurement**	Total costs on project level	Only monitoring deviation	-	-	Used as KPI	Predefined	Defined in procurement specification	Defined in procurement specification
S15	**Measurement**	Predefined	Delivery security	-	-	-	Predefined	Defined in procurement specification	Defined in procurement specification
S16	**Measurement**	Total transport/ number of transports	Only monitoring deviation	-	-	-	-	Defined in procurement specification	Defined in procurement specification
S17	**Measurement**	Total costs		Used as KPI	Used as KPI	Used as KPI	Transport provider is supposed to follow up	Transport provider is supposed to follow up	Defined in procurement specification
S18	**Measurement**	Cost/hour or cost/ton	When transporter gets paid per hour	Weight	-	-	-	-	-
S19	**Measurement**	Total cost	-	-	-	Used as KPI	Defined in requirement specification	Defined in procurement specification	Defined in procurement specification
S20	**Measurement**	Cost/transport and total costs	-	-	Used as KPI	Used as KPI	Total consumed diesel/ number of transports	Amount of filled up HVO100	Percentage of increased Euro class
S21	**Measurement**	-	-	-	-	-	-	-	-

Energimyndigheten

Appendix II. Dissemination of results

- Trafikverket's presentation of results at a seminar on the government assignment "Horisontella samarbeten och öppen data" (Online), 2020-11-30, presentation by Joakim Kalantari, VTI.
- Lecturing at Yrkeshögskolan Programme "Transportledare - Grön Logistik 400 YHP" at Teknikhögskolan, 2020-11-17, lecture held by Kristina Liljestrand and Jessica Wehner, CIT.
- The Swedish Energy Agency's "Programkonferens för Energieffektiviseting inom transportsektorn" (Online), 2020-10-27, Kristina Liljestrand and Jessica Wehner, CIT.
- Guest lecture at Borås University, 2020-10-13. "Transporteffektivitet och e-handel", lecture held by Joakim Kalantari, VTI.
- Popular article on Linkedin. Amanda Borneke (2020-09-12): " Bästa med Byggforum - och sämsta", online: https://www.linkedin.com/pulse/bästa-med-byggforum-och-sämsta-amanda/.
- Byggforum in the fall 2020 – presentation held by Kristina Liljestrand (CIT) and Linea Kjellsdotter (VTI)
- 32nd Annual Nordic Logistics Research Network conference (NOFOMA 2020), in fall 2020 in Reykjavik, Iceland [*conference was delayed from June 2020 to fall because of Corona*]. Presentation by Hafdis Jonsdottir, Chalmers Industriteknik: "Measuring and sharing data on KPIs for transport efficiency: an interview study of shippers and transport providers".
- Bachelor thesis project with two students, Ebba Lundgren och Heléne Freij, from Gothenburg University that worked on a thesis with the title "Vägen mot ökad transporteffektivitet – En studie om hur ökad transporteffektivitet kan möjliggöra för transportköpare inom byggsektorn att minska sin miljöpåverkan", spring term 2020 and presented their work June 5th, 2020. Students were supervised by Jessica Wehner, Chalmers Industriteknik
- Presentation at Triple F:s result conference, 2019-11-14, Linea Kjellsdotter Ivert, VTI.
- The Swedish Energy Agency's "Programkonferens för Energieffektivisering inom transportsektorn" in Stockholm, 2019-10-30 to 31. Presentation and round table discussion by Joakim Kalantari, VTI: "Utnyttja befintlig överkapacitet i transportsystem för ökad energieffektivitet".
- Workshop with all project members and interested organisations in Gothenburg, 2019-08-27.
- Presentation of preliminary results at Cramo in Stockholm, 2019-06-04, Joakim Kalantari, VTI.
- Online workshop with project members in Gothenburg, 2019-05-09.
- Klimatneutrala godstransporter på väg (KNEG) workshop "Klimatpåverkan från livsmedeltransporter" in Stockholm, 2019-04-23. Presentation by Kristina Liljestrand, Chalmers Industriteknik: "Effektiviseringspotentialen inom livsmedelstransporter".

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- The Swedish Energy Agency's "Energirelaterad fordonsforskning 2019" in Gothenburg, 2019-04-01 to 02. Presentation by Kristina Liljestrand, Chalmers Industriteknik: "Utnyttja befintlig överkapacitet i transportsystem för ökad energieffekt".
- Trafikverket's workshop in Stockholm, 2019-02-04. ”Regeringsuppdrag om horisontella samarbeten och öppen data”, Joakim Kalantari, VTI.
- Blogpost "Varför rullar det tomma lastbilar på svenska vägar?" written by Vibeke Specht, Logtrade 2018-09-11, online at: https://blog.logtrade.se/tomma-lastbilar-pa-svenska-vagar.