Ring road logistics - efficient use of infrastructure

Public report

Project within Efficient and connected transport systems

Authors:

Hannes Lindkvist	CLOSER/Lindholmen Science Park AB
Emelie Klasson	DB Schenker Consulting
Sönke Behrends	Chalmers Tekniska Högskola
Ivan Sanchez-Diaz	Chalmers Tekniska Högskola
Xiaoliang Ma	KTH
Junchen Jin	KTH
Maria Börjesson	VTI
Catrin Wallinder	Trafikverket

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FFI Fordonsstrategisk Forskning och Innovation

Content

FFI in short

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Currently there are five collaboration programs**:** Electronics, Software and Communication, Energy and Environment, Traffic Safety and Automated Vehicles, Sustainable Production, Efficient and Connected Transport systems.

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1 Summary

High mobility and accessibility is essential for a favourable social and economic development in metropolitan areas. However, over the coming decades, the population growth in the Swedish metropolitan areas will continue to increase, implying higher passenger and freight traffic volumes. Improving the efficiency of the use of the existing infrastructure to mitigate congestion is therefore essential in the coming years.

The purpose of this project is to investigate the effect of dynamic priority lanes for freight (DPLF), in terms of the efficiency on existing infrastructure, and to prepare for a full-scale demonstration. The hypothesis of this project is that social benefits can be achieved by giving freight vehicles priority during certain conditions. By simulating a road stretch in Gothenburg and studying both literature and legal conditions regarding the concept of dynamic priority lane for freight, it has been possible to evaluate different scenarios of implementation and determine how it can be used for more sustainable freight traffic.

The conclusion states that dynamic priority for freight would increase the social value when comparing to the current traffic system layout in the specific case study performed. It is possible to assume that the more locations dynamic priority lane for freight is implemented in, the higher social value will be achieved. To give certain freight transports priority on ring roads could also work as incentives for more sustainable freight movements and increase goal achievement on both local, regional and national policy objectives related to transport, environment and business development.

In order to only give access to a priority system for freight vehicles which fulfill pre-set requirements that increase overall goal achievement for more sustainable transports there need to be a supporting technical and service system for access control. However, there are some barriers to be able to implement dynamic priority lane for freight where the main barriers lie within the legal, organizational and political framework.

It would be beneficial to test and demonstrate a potential technical system for DPLF and further investigate effects on the system after implementation and evaluate business models and possible changes in the legal framework for implementation. The suggestion is thus to continue with two separate projects that could run parallel with the following agendas:

1. Test of technical system that enable DPLF
2. Broader system analysis of DPLF

2 Sammanfattning på svenska

Hög framkomlighet och tillgänglighet är nödvändigt för en gynnsam social och samhällsekonomisk utveckling i storstäder. De kommande decennierna förväntas befolkningen i de svenska storstadsregionerna fortsätta öka vilket kommer leda till större trafikvolymer för både gods- och persontrafik vilket kan påverka framkomligheten negativt. För att undvika dyra infrastruktursatsningar bör istället alternativa sätt att effektivt utnyttja befintlig infrastruktur undersökas.

Syftet med projektet är att undersöka effekterna av dynamisk körfältsprioritering för gods, i relation till effektivt utnyttjande av befintlig infrastruktur, och för att förbereda för en fullskalig demonstration. Hypotesen för projektet är att samhällsekonomiska fördelar kan nås genom att ge tillträde för godstrafik i prioriterade körfält under vissa förhållanden. Genom att simulera en vägsträcka i Göteborg samt studera både litteratur och legala förutsättningar för dynamisk körfältsprioritering för godstransporter har det varit möjligt att utvärdera olika scenarier för implementering och fastställa hur konceptet skulle kunna användas för att skapa incitament för mer hållbara godstransporter.

Slutsatsen är att implementering av dynamisk körfältsprioritering för gods skulle ha samhällsekonomisk nytta på den specifika sträckan där simuleringen genomförts. Att ge viss godstrafik prioritet på kringfartsleder kan också skapa incitament för mer hållbara godstransporter och bidra till uppfyllnad av transport-, miljö-, och näringspolitiska mål på både på lokal, regional och nationell nivå.

För att enbart ge tillträde till godstransporter som uppfyller vissa förutbestämda krav som bidrar till övergripande måluppfyllnad för hållbara transporter krävs dock en teknisk lösning som stödjer detta med tillhörande efterlevnadskontroll. Teknisk utveckling är dock inte det största hindret för implementering, utan de främsta hindren är av organisatorisk, juridisk och politisk karaktär.

Det vore dock fördelaktigt att genomföra en demonstration av ett tekniskt system för att påvisa ett funktionellt system som möjliggör dynamisk körfältsprioritering för samhällsnyttig godstrafik. Parallellt bör effekterna av konceptet utvärderas vidare med förslag på möjliga affärsmodeller samt hur hinder i det legala ramverket ska kunna överbryggas för att möjliggöra implementering. Förslaget för nästa steg delas upp i två projektförslag som kan drivas parallellt med följande huvudsyften:

1. Test av teknisk lösning som möjliggör dynamisk körfältsprioritering av godstrafik
2. Bredare systemanalys av dynamisk filprioritering av godstrafik

3 Background

High mobility and accessibility is essential for a favourable social and economic development in metropolitan areas. However, over the coming decades, the population growth in the Swedish metropolitan areas will continue to increase, implying higher passenger and freight/delivery traffic volumes. This in turn increases the risk of declining accessibility due to more congestion which lead to both negative environmental and economic effects. Improving the efficiency of the use of the existing infrastructure to mitigate congestion is therefore essential in the coming years. This project explores one measure aiming at increasing the efficiency of the use of road infrastructure, namely dynamically prioritizing freight vehicles.

During 2015 and 2016 the FFI-financed pre-study ‘Kringfartslogistik – effektivt utnyttjande av infrastrukturen’[1] was conducted, the predecessor of this project. The project concluded that more efficient use of existing infrastructure could be managed by dynamically prioritizing freight vehicles on ring roads in the Swedish metropolitan areas of Stockholm and Gothenburg where congestion is high. Dynamically prioritizing freight vehicles could be used as incentives for more sustainable freight transport when freight transports with high social value are given priority in congested traffic conditions. Further the pre-study concluded that dynamic priority for freight could during certain traffic conditions increase the traffic-flow and create win-win situations for several traffic users with both economic and environmental profits as a result. There are today technical solutions that support the concept of dynamic priority for freight on ring roads by use of connected and cooperative vehicles and infrastructure. The results from the pre-study resulted in the current feasibility study which expects to further explore the possibilities with dynamic prioritizing, what technical developments are required, what social values are created and how and where the concept of dynamic prioritization of freight vehicles can be demonstrated in real environment.

The term of ring road logistics is in this project defined as the interface between the urban and interurban traffic system, or the interface between the municipal and state-owned road network that serve local as well as inter-city traffic, sometimes called urban motorways. Ring roads in Stockholm and Gothenburg are visualized in figure 1 and 2. Ring roads serve freight transports in and out of the city as well as passing transports of both national and international type and transports to important nodes, such as harbors and other terminals. In order to develop effective transport corridors there is an expressed need to focus more on these road segments and increase mobility. Traditionally municipalities focus more on short-range, urban transport as they do not have responsibility for planning of ring roads as these roads usually are state-owned road networks, while the government authorities traditionally focus on longer-distance transport.

[1] Vinnova reference number 2014-06250, report available at https://closer.lindholmen.se/projekt-closer/kringfartslogistik-forstudie

Figure 1. Ring roads in Stockholm

Figure 2. Ring roads in Gothenburg

4 Purpose, research questions and method

The purpose of this project is to investigate the effect of dynamic priority lanes for freight (DPLF), in terms of the efficiency of the use of existing infrastructure, and to prepare for a full-scale demonstration. The hypothesis of this project is that both economic and environmental benefits can be achieved by giving freight vehicles priority during certain traffic conditions. We conduct a cost-benefit analysis on a case including dynamic priority lane for freight, but also investigate the incentives, technical aspects and regulatory elements to consider for demonstration and long-term implementation.

4.1 Research questions

Based on the results and analysis of the pre-study a set of research questions were formulated, which we aim at answering in this project. The research questions and results are categorized in three sub-categories, *Criteria for prioritizing freight traffic*, *Modelling and evaluation of dynamic priority lane for freight (DPLF)* and *Factors for implementation of DPLF*. The research questions define the purpose and objective of the project.

Criteria for prioritizing freight traffic

- How should travel time and reliability for freight transport be valued?
- What sustainability criteria are relevant for prioritizing freight transports?

Modelling and evaluation of DPLF

- How does the prioritization of freight transport impact different types of transport and travelers (buses, trucks, passenger cars), in the current traffic conditions and in the expected increased future traffic demand?
- What are the social effects of dynamic priority lane for freight transport?

Factors for implementation of DPLF

- Can DPLF create market incentives for better environmental qualification of freight vehicles?
- What policy and regulations enable or prohibit dynamic priority lane for freight on ring roads on national, regional and municipality roads?
- How could a system architecture for authorization procedures, access control and compliance, be designed based on current and future technology?
- What is required for a demonstration and later implementation of DPLF? What barriers exist?
- What stretches would be most suitable for a demonstration of DPLF and are there relevant projects from which experience exchange can be valuable?

4.2 Method

The feasibility study has been a collaboration among DB Schenker, Trafikverket, Chalmers, KTH and CLOSER at Lindholmen Science Park. VTI has contributed to the project on behalf of KTH. All partners have been responsible for seven different work packages that each study different aspects of DPLF. Figure 3 show how the work packages interrelate where WP1 is project coordination:

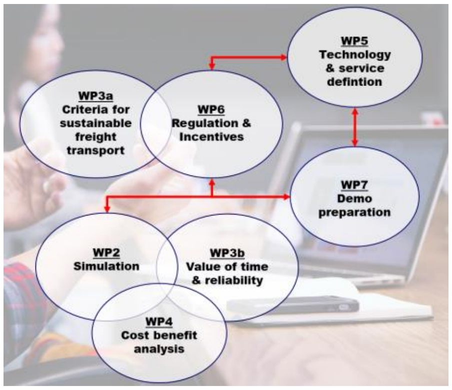

Figure 3. Interrelation of work packages

The method in each work package is designed to answer the research questions and contribute to the overall aim of the project. The method of each work package is described in more detail in the appendices to this report, but an overview is presented in table 1.

WP	Method/activities
1. Project coordination	Regular project meetings and dissemination
2. Simulation	Implemented the DPFL scheme on a real stretch in Gothenburg. The simulation has used the microscopic modelling tool, SUMO and traffic data has been available through the sensors of the Motorway Control Systems along the stretch. The simulation can be used to estimate travel time, speed, flow and other performance measures.

3. Time evaluation of freight transport Consists of two parts: a) Criteria for sustainable freight transport b) Value of time and reliability	a) - Literature review on existing definitions, framework, concepts and best practice - Workshops with freight transport stakeholders has been used to determine factors for sustainability performance of freight transport. b) - Literature review on value of time for freight - A stated preference study and interviews to determine value of time and reliability for freight
4. Cost-benefit analysis	Using results from WP2 and WP3 as well as figures from ASEK in order to estimate the social benefits of implementing DPLF
5. Technology and service development	Workshops and interviews with OEM- and telecom companies and other relevant stakeholders such as road authorities, complemented with studies of recently finished reports within technology field
6. Regulation & incentives	- Literature study to gather information on transport goals related to transport, environment, safety, transport policies and previous work on incentives done by SKL and the Swedish transport administration for improving mobility. - Workshops and dialogue with WP3 have been the basis for preparation of the criteria list for sustainable freight transport. - Literature study and a dialogue with the Swedish Transport Agency have been conducted to gather information on rules affecting the possibility of developing priority lanes.
7. Demonstration preparation	- Dialogues with relevant stakeholders, such as public transport operators and traffic management operators, and several workshops to define possible scenarios and identify potential stretches for demonstration - International outlook for inspiration and knowledge exchange with similar projects - Workshop with K2, the national knowledge centre for public transport, to identify possible synergies with other traffic users for increased mobility on ring roads

Table 1. Methodology in the different work packages

4.3 Limitations

There are many ongoing projects and initiatives that aim to steer away traffic during peak hours to reduce congestion on ring roads. This project is however limited to analyzing freight transports using ring roads during peak hours. Thereby the focus is not on actions such as

- Inducing a shift of freight traffic to off-peak hours (i.e, night-time or early morning deliveries) via traffic access restrictions, pricing, or freight demand management
- Inducing a shift of road freight traffic to other transport modes, e.g. rail or water ways
- Redirection of passenger vehicles on ring roads in order to increase accessibility for freight transport

The project uses a microscopic traffic model that simulates the traffic in the corridor selected as a case study, therefore the project does not consider traffic impacts of DPLF on other parts of the network. The study has also focused on urban areas with most substantial problem with mobility on ring roads due to congestion.

5 Objective

The overall objective is to highlight the social value, including parameters of economic benefits for transport companies, industry and society, of dynamically prioritizing freight vehicles on ring roads in the big city regions. This would stimulate a more efficient use of the existing infrastructure which in the long term is expected to result in higher transport efficiency and lower external costs.

One initial objective was to include analysis of environmental benefits of DPLF. This has however not been possible due to uncertainty in environmental related data, such as what fuels are used or the emission standard of the vehicles, and as it is not possible to model if and, in that case how, the traffic volumes would change with DPLF. However, it cannot be excluded that implementation of DPLF could impact emissions. If, for instance, accessibility for freight traffic increase, it is possible that the volumes increase inducing more emissions. However, if only cleaner vehicles are prioritized, this could have a positive effect on the transitions to cleaner vehicles used for freight. For this to happen, however, the measure must be widely used in many cities and on most arterials and ring-roads. If not, they have little incentives to invest in cleaner vehicles. Still, the lion's share of the benefit of prioritizing freight vehicles is accessibility, and so neglecting the environmental effect will not have any significant impact on the cost-benefit analysis.

6 Results and deliverables

This chapter describes the projects contribution to the overarching FFI-objectives and its relation to the sub-program Efficient and Connected Transport Systems. Further the chapter goes into the results and deliverables from the activities mentioned above, including criteria for prioritizing freight traffic, modelling and evaluation of dynamic priority lane for freight (DPLF) for the case study used in this project. Lastly this chapter with the factors needed for implementation of DPLF, including key factors needed to enable the technique for DPLF, and discussion on how the legal framework affects implementation.

6.1 Contribution to FFI-objectives

This project contributes to several objectives in the *Roadmap for efficient and connected transport system* by analyzing mobility issues related to freight. In addition, the project addresses alternative solutions that could mitigate environmental impacts of freight transports, create new business opportunities and increase knowledge on traffic relations on ring roads.

The project addresses the following areas linked to FFI objectives:

- Lanes and vehicles for specific purposes and applications

- Technologies for communication between infrastructure and vehicles
- Effects of interaction between vehicles and infrastructure

This project contributes to a better understanding of how to fulfill the following overarching FFI-objectives:

- To reduce the environmental impact of road transports
- To strengthen international competitiveness

6.2 Criteria for prioritizing freight traffic

The hypothesis of this project is that both economic and environmental benefits for society can be achieved by giving freight vehicles priority during certain traffic conditions. Maximizing these benefits requires a careful selection of the vehicles to be prioritized. This chapter summarises the work on the development of criteria for such a prioritization. It is divided into two sub-sections, where the first part focuses on the economic impact of congestion, including studies of the two concepts "value of time" and "value of travel time reliability". The second part describes the possibilities to support wider policy goals of transport policy by defining criteria for sustainable freight transport.[2]

6.2.1 Time factors for prioritizing

This section addresses the concept "value of time" for freight traffic (the "value of time" is sometimes referred to as "the value of travel time (VTT)", and the concept of "value of reliability of freight arrival time (VoR)". The value of travel time (VTT) for freight traffic is defined as "*the benefit that derives from a unit reduction on the time necessary to move a particular quantity of goods from the origin to the destination*" (Zamparini, L. and A. Reggiani, 2007). Meanwhile, the value of reliability (VoR) is defined as "*the percentage of travels that can be successfully finished within a specified time interval*" (Nicholson, 2003).

The VTT for freight traffic can be assessed using different approaches (i.e., factor cost method, assessment of willingness to pay, and hedonic price theory) and variables. The choice of the approach depends on the purpose of the study. The most common variables used are shipment size, type of commodity, vehicle size and type of company. As different approaches could lead to different assessments of VTT, it is important to ensure that the data and methods applied are in line with the purpose of the project.

Identifying the VTT is essential for this project because it allows to convert the travel time savings when implementing DPLF in the microsimulation into a monetary value, used as an input for the CBA. To define VTT for freight this project has adopted the ASEK-

[2] We use the term 'sustainable freight' instead of 'high social value', their meanings are the same. Sustainability here is not limited to environmental goals but include the three dimensions of environmental, economic and social goals.

definition and values, which are based on method from the SAMGOODS model (Trafikverket, 2016a). According to ASEK, the VTT depends on transport costs (i.e., operational costs) and capital costs of the goods during the transit. See appendix 2 which shows a distribution of VTT based on the numbers provided by ASEK (in SEK per hour, vehicle class and commodity type). As information of the goods being transported by each truck in the case study is not available for the CBA, data from Trafikerket (2016) about the share of different commodities at the national level is used to estimate the probability that each type of good is transported.

The VoR can be defined as the monetary value that users are willing to pay to reduce travel time variability. There are different factors that impact the travel time reliability (i.e., expected risks, contingencies, system killers, catastrophic events). Based on a set of interviews with transport companies (i.e., goods owners and transport operators) in Sweden, the main sources of lack of reliability identified were accidents, delays at (un)loading and other facilities, availability of real time traffic information, weather conditions, consistency in travel times, and drivers unable to find destination.

For this project a master thesis was conducted which has estimated the willingness to pay for travel time savings for freight transports by collecting stated preference data from a number of transport operators (and shippers with their own transport) and estimate a set of discrete choice models. The VTT was assessed using the willingness to pay for a reduction in the mean travel time (ranging between 40 mins and 75 mins) for a hypothetical corridor; while the value of travel reliability was assessed as the willingness to pay for a reduction in the variability in travel time (ranging between 20% and 50% of the mean travel time). From the estimated models it was possible to derive the willingness to pay for both travel time savings (see table 2) and for travel time reliability (see table 3) by using the random utility theory (McFadden, 1973).

Industry sector	**Vehicle size**				
	1-tonne vehicle	3-tonne vehicle	14-tonne vehicle	24-tonne vehicle	40- tonne vehicle
Automotive	148.3	154.9	204.7	289.2	928.2
Electronics	114.9	118.8	146.0	184.5	317.3
Transport	101.1	104.1	124.5	157.2	231.6
Commercial	71.6	73.0	82.5	93.5	118.9
Pharmaceutical	63.5	64.6	72.0	80.2	98.2
Manufacture	44.4	45.0	48.5	52.1	59.1
Textile	18.3	18.4	19.0	19.5	20.4

Table 2. Willingness to pay for an hour of travel time saved (in SEK).
Source: Conesa Gago, N. and J. Juanmarti Arimany, 2018

The study shows that the value for one hour of travel time saved range between 18.3 SEK (for a small vehicle in the textile sector) and 928.22 SEK (for a heavy-duty vehicle in the automotive sector), meanwhile the VoR ranges from 1.0 SEK (for a small vehicle in the textile sector) to 46.8 SEK (for a heavy-duty vehicle in the automotive sector) for 10 minutes reduction in the variability of the travel time.

Industry sector	Vehicle size				
	1-tonne vehicle	3-tonne vehicle	14-tonne vehicle	24-tonne vehicle	40- tonne vehicle
Automotive	8.1	8.5	11.2	15.9	46.8
Electronics	6.3	6.5	8.0	10.1	17.5
Transport	5.6	5.7	6.8	8.3	12.7
Commercial	3.9	4.0	4.5	5.1	6.5
Pharmaceutical	3.5	3.5	4.0	4.4	5.4
Manufacture	2.4	2.5	2.7	2.9	3.2
Textile	1.0	1.0	1.0	1.1	1.1

Table 3. Willingness to pay for 10-mins reduction in travel time reliability (in SEK). Source: Conesa Gago, N. and J. Juanmarti Arimany, 2018

The sectors with the highest value of time and VoR are the automotive and electronics sectors.

The studies on value of travel time and reliability reveals a number of implications for the social value of DPLF:

1. Large vehicles have potential for higher VTT:
    - Highest transport cost and higher capacity allows larger shipments sizes
    - However, they also require control over load factor to avoid higher externality/tonne.km
2. Some commodities have higher VTT: Goods for the automotive industry, electronics, clothes and other manufactured items, pharmaceutical goods, machinery and transport equipment, and food
3. Long distance shipments usually have less strict time windows and thus tend to have lower VTT.
4. Using willingness to pay leads to lower values than using the cost factor method from ASEK.
5. The willingness to pay for travel time savings and higher reliability are not linear, i.e., decreasing travel time from 0-5 mins is not as valuable as decreasing travel time from 30-40 mins.
6. There is no consensus in the literature to determine if there is a higher VTT for companies doing their own transport or for-hire transportation

The methods presented provide estimates of VTT and VoR depending on vehicle class, payload and commodity transported (or industry sector). The main limitation when applying these models to traffic data is the lack of information about the commodity being carried inside the vehicles and the payload which, as shown in the tables above, can make the difference between having a VTT of 20 SEK/hour or 930 SEK/hour.

6.2.2 Sustainability factors for prioritizing

This section defines different determinants for sustainable freight, resulting in a list of criteria that could be used to determine which freight vehicles should be prioritized, and thus create incentives for more sustainable freight transports.

6.2.2.1 Determinants of sustainable freight transport

Freight transport generates several impacts on the environment and society, including impacts on public health and ecosystems from air pollution, climate change, noise and accidents. These impacts are the outcome of interactions of economic activities, logistics structures, transport systems, vehicle and energy sector, and the urban form. Criteria for sustainable freight transport have to take into account these interactions and include the driving factors from the different sectors.

Consequently, a reduction of the unsustainable impacts of the transport sector can be achieved in two ways (assuming that economic growth is desirable): either by reducing traffic intensity of the economy; or by reducing the impact per unit of traffic[3] (i.e. by improving the environmental performance of the vehicles). To identify the components driving to the unsustainable impacts, the traffic intensity of the economy and the impact intensity of the traffic system are decomposed into their contributing factors.

The **traffic intensity of the economy** can be defined as the product of inversed value density of the economy, transport intensity of the logistics system and traffic intensity of the transport system, where the factors are defined as follows:

- *Value density of the economy* [monetary unit/ton]: the amount of goods in tons needed to generate an economic value.
- *Transport intensity of the logistics system* [ton km/ton]: the average distance a product is transported. It converts the weight of the goods produced/consumed into ton-km.
- *Traffic intensity of the transport system* [vehicle km/ton km]: the amount of traffic (vehicle km) required to move a certain transport demand (ton km).

The **impact intensity of the traffic system** is defined as the damage (in monetary units) on human health, economy and ecosystems, often also referred to as external costs, per unit of traffic (in vehicle km). In the transport sector, different impact types are normally considered, including congestion, accidents, air pollution, noise and climate change (Ricardo AEA, 2014). The contributing factors to the impact intensity are:

- *Energy intensity of the traffic system* [energy/vehicle km]: the amount of energy needed to move the vehicles.

[3] In recent years, there have been substantial improvements on the vehicle level, e.g. efficiency improvements reducing CO2 emissions and the EURO emission limits reducing the emissions of local pollutants, reducing the impact intensity of vehicle movements. However, increasing traffic volumes have overcompensated these improvements on the vehicle level, resulting in a situation where the absolute impacts are nonetheless rising. It is therefore key to address the increasing traffic volumes, if a sustainable transport sector is to be achieved.

- *Emission intensity of the fuel/vehicle system* [emissions/energy]: the amount of emissions generated when using energy for moving a vehicle.
- *Emission sensitivity of the environment*: [monetary unit/emission]: the economic impact the emissions generate on the environment.
- *Impact intensity of the traffic system* [impact factor/vehicle km]: the amount of impact generated from the vehicle, i.e. the amount of noise, accidents and congestion.
- *Impact sensitivity of the environment*: [monetary unit/impact]: the economic damage of the impacts on the environment.
- *Social impacts*: Not all impacts of transport are related to traffic activities and emissions having negative impact on the general public. Transport companies are economic corporations which are part of the society, hence they have social responsibility.

6.2.2.2 Criteria for sustainable freight transport

Reducing the unsustainable impacts from the transport sector requires reducing one or more of the factors above. As the value density cannot be directly influenced by transport policy, the focus needs to be placed on the transport intensity, the traffic intensity, the energy intensity, the emission and impact intensity, as well as emission and impact sensitivity. Accordingly, criteria for sustainable freight transport can be derived from these factors.

The resulting criteria are listed in table 4[4]. This is an initial criteria list covering all determinants.

KEY RATIO	DETERMINANT	SHIPPER/RECEIVER	TRANSPORT	VEHICLE
TRANSPORT INTENSITY	Length of supply chain links	Local sourcing		
	Location of logistics facilities		Centrally located terminal	
TRAFFIC INTENSITY	Payload on vehicle trips	Large shipment sizes	Transports to rail/sea terminals	
		Lead time flexibility	Transports to microterminals	
		Packaging enabling consolidation	Open network	
	Vehicle routing		Efficient routing (shortest)	
ENERGY INTENSITY	Driveline			Energy efficient drivelines
	Operations		Eco driving	
			Efficient routing (congestion)	

[4] More information on definition of sustainable freight transport is available in the PM for WP3 on https://closer.lindholmen.se/projekt-closer/kringfartslogistik

EMISSION INTENSITY	Driveline/fuel			Low-emission driveline/fuel
				Renewable fuels
IMPACT INTENSITY	Vehicle design			Surrounding visibility
				Low-noise equipment
	Driveline			Low-noise driveline/fuel combinations
	Operations		Low-noise operations	
EMISSION/ IMPACT SENSITIVITY	Location of logistics facilities		Terminal in low-density areas	
	Timing of transports	Flexible delivery time windows		
IMPACT SENSITIVITY	Location of logistics facilities		Terminal in low density areas	
SOCIAL SUSTAINABILITY	Social responsibility		Comply with laws	
			Sharing data	

Table 4. Criteria for sustainable freight transport

The concept of DPLF is a new way of thinking by prioritizing freight transport with high social value and can thus be used as incentives for more sustainable freight transport. Incentives are an important aspect in reaching goals and objectives related to transport efficiency and decreasing environmental impact of freight transport (Trafikverket, 2014).

The criteria list for sustainable freight transport could be used as a measure to reach local, regional and national objectives, visions, strategies and governing documents, such as Agenda 2030, the Paris Agreement, Sweden's new climate act[5], new national strategy for freight[6], EU White Paper, and Roadmap for citylogistics[7]. Other relevant guiding documents that correlates with the criteria list and also the fundamental idea of increasing movability for freight transport are the *Urban mobility strategy*[8] in Stockholm, the *Transport strategy*[9] in Gothenburg and the *freight strategy* in Region Västra Götaland. The four-step principle[10] used by the Swedish transport administration is also important to apply when it comes to choosing actions and incentives to achieve goals.

[5] http://www.regeringen.se/artiklar/2017/06/det-klimatpolitiska-ramverket/
[6] Expected during the spring 2018
[7] Available in Swedish at https://www.transportinnovation.se/sv/forums-fardplaner
[8] Available at http://www.stockholm.se/TrafikStadsplanering/Trafik-och-resor/framkomlighetsstrategin/Framkomlighetsstrategi
[9] Available at http://goteborg.se
[10] 1. Think new, 2. Optimize, 3. Rebuild, 4. Build new

The open criteria list is intended as proposals for requirement areas for companies and their vehicles to gain access to priority lanes. These relates both to determinants for sustainable freight transports, but also to existing guiding documents and objectives that encourage increased movability and decreased environmental impact of freight transports. The requirements and the level of requirements are adapted to the most important objectives, type of area referred to and the type of truck transport referred to. What criteria to apply for the prioritization obviously depends on data availability and the regulatory framework. Furthermore, it should be decided based on the context of the case and the local conditions, i.e. it should be decided what criteria from the initial criteria list, how many of them, and in what combination need to be fulfilled. The outside world is also developing very fast with new technology and new requirements, which creates the need for flexibility.

6.3 Modelling and evaluation of DPLF

To increase the understanding of the impacts of DPLF on different types of traffic and the net benefit for the society as a whole, a traffic simulation and cost-benefit analysis (CBA) has been conducted in a case study. The case study is defined as the introduction of DPLF for an arterial leading into Gothenburg and is described in this section.

6.3.1 Simulation study of DPLF

To create a case study as realistic as possible for DPLF we apply close-to-reality data as input to the simulation. One way to do so is to use data from a road section where priority lanes exist and where there is some free capacity which could be used by congested vehicles. In this case study we have used the three-lane urban motorway E6 in Gothenburg, shown in figure 6 (See appendix 1 for a detailed lane setting along the road stretch) with a priority lane for public transport on the far-right side.

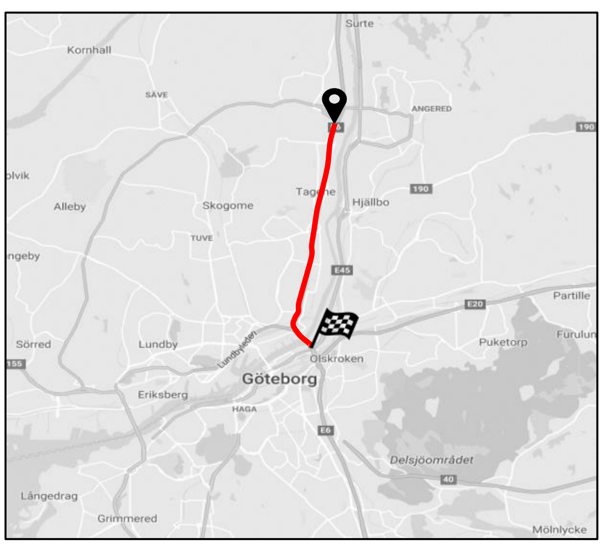

Figure 4. The E6 road stretch in Gothenburg selected for the simulation study.

The choice of the stretch has included considerations of where there is logistic movement, where there is congestion, where relevant data can be available and also that the stretch could be considered for a demonstration of DPLF. The stretch has a length of around 8.5 km and starts in Hisings Kärra and to the end of Tingstadstunneln.

Data on traffic flows has been possible to obtain for southbound traffic so the model only simulate traffic going south on the chosen stretch. The data collected register different traffic types which are categorized in passenger cars, passenger cars with trailer, trucks, trucks with trailer and buses, shown below.

Passanger cars	Passanger cars with trailer	Buses	Trucks	Trucks with trailer
				

Figure 5. Traffic types identified in the collected data on the simulated stretch

This study includes scenarios with present traffic demand but also future scenarios with expected traffic demand in 2040. This is due to the fact that traffic demand is expected to increase which will have a substantial impact on traffic conditions. By using figures provided by Swedish Transport Administration predicting that the passenger cars will increase 27.0%, and trucks 18.2% until 2040 compared to 2016 the effects of DPLF with an increased traffic demand has been able to be simulated (Trafikverket, 2016b).

This case study mainly considers prioritizing freight vehicles, either trucks or trucks with trailers, to use the priority lane at the rightmost side. Five scenarios were designed for an in-depth analysis:

1. Base scenario; The rightmost lane is a priority lane for buses, the two other lanes are democratic lanes
2. Democratic scenario; All lanes can be used by all traffic users
3. All freight priority scenario; Buses, trucks and trucks with trailer are allowed to use the priority lane
4. Truck priority scenario; Only trucks without trailer and buses are allowed to use the priority lane
5. Truck with trailer priority scenario; Only trucks with trailer and buses are allowed to use the priority lane.

The scenarios 3-5 are considered most interesting to understand the effects of DPLF.

6.3.2 Simulation results and analysis

The simulation uses the traffic demand of a normal weekday in 2016 in terms of vehicles per hour estimated from real data. The demand and time-of-day profile differ between vehicles types. While passenger cars peaks in the morning and afternoon, trucks (especially trucks with trailers) has a more even curve throughout the day (see figure 6).

In scenarios 3-5 where trucks are given access to the priority lane, the travel time gains for trucks are positive and the effect is more obvious during the rush hours. Also travel time gain for passenger cars are positive when all trucks are given priority as more capacity on the other lanes is available which creates a win-win situation. However, buses may suffer from slight travel time augmentation during the rush hours, especially when all trucks are allowed to use the priority lane even though the social benefits are positive in these scenarios. The negative effects on travel time for buses can be potentially mitigated by using dynamic information since bus schedules and positions are traceable.

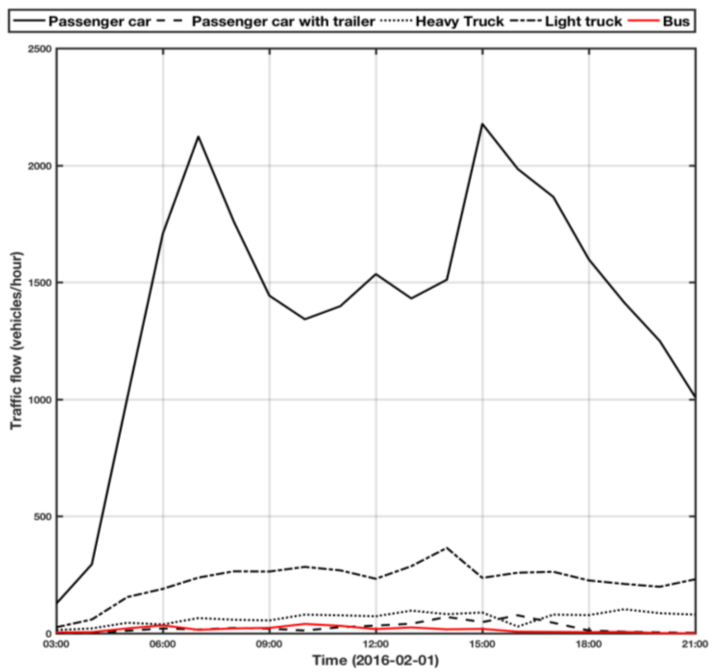

Figure 6. Simulated traffic flow (vehicles/hour) for the five types of vehicles using present traffic demand

When looking at the future traffic demand in 2040 peak hours are obvious for passenger vehicles in the morning and afternoon, meanwhile demand of trucks is higher during day time (see figure 7). In addition, the peak hours last longer than the counterpart period of present traffic demand since much more vehicles need to be released from the congestion mode, especially for the afternoon peak.

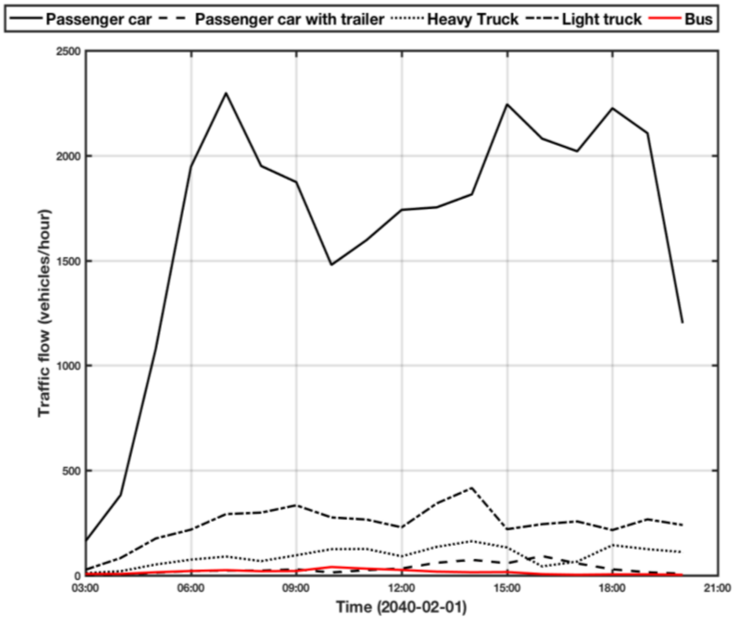

Figure 7. Simulated traffic flow (vehicles/hour) for the five types of vehicles using future traffic demand in 2040.

If all trucks or all trucks with trailers are allowed to drive in the bus lane in 2040, the priority lane capacity is reached in the peak-hours. Thus, the priority lane become heavily congested, and travel times for buses and trucks are significantly increased. Moreover, the congestion on the priority lane leads such small gaps between vehicles that it becomes difficult to enter the road stretch from the on-ramp. Also, vehicles in the middle lane are blocked by the small gaps which makes it difficult to go to the off-ramp by lane changing. It is observed that the travel times associated with all vehicle types are significantly increased in this scenario. Nevertheless, if only trucks without trailers are given access to the priority lane, the findings are similar to the results of the present demand because the lane capacity in the priority lane is not reached.

The cost benefit analysis that assesses the social effects of the scenarios includes all five scenarios, both for present traffic demand and future traffic demand in 2040. The costs and benefits for private traffic and business of the scenarios that are evaluated in this study are primarily accessibility, by decreased or increased travel times. These are "translated" to SEK using travellers and freight transport companies' valuations of the travel times, which are based on the measurements of the travellers and transport companies willingness to pay (see 6.2.1). In the CBA, the benefit of travel time gains for private companies are as important as public operators' or travellers. This is because gains for private companies are dispersed into society and accrues to private citizens in the long run.

Input data to the CBA in one end comes from travel times saving described in chapter 6.2.1 and partly from ASEK (Trafikverket, 2016a). Detailed description of the input data to the

CBA can be found in the report for WP4[11], but the results of the CBA for the different scenarios are included in the table below.

	Passenger cars	Passenger cars with trailer	Trucks without trailer	Trucks with trailer	Buses
Value of Travel Time (SEK/h)	137	312	283	397	2198
2. Democratic scenario; All lanes can be used by all traffic users					
Travel time gain (h)	-9.47	-0.83	-7.33	-1.78	0.04
Travel time gain (SEK/day)	1295	258	2076	705	-185
Total benefit scenario 2	**4149 (SEK/day)**				
3. All freight priority scenario; Buses, trucks and trucks with trailer are allowed to use the priority lane					
Travel time gain (h)	-34.93	-2.15	-4.77	-1.17	0.01
Travel time gain (SEK/day)	4779	672	1350	464	-21
Total benefit scenario 3	**7244 (SEK/day)**				
4. Truck priority scenario; 100% trucks without trailers can use priority lane					
Travel time gain (h)	-16.53	-0.98	-1.05	-0.36	0.23
Travel time gain (SEK/day)	2261	306	299	144	-1037
Total benefit scenario 4	**1972 (SEK/day)**				
5. Truck with trailer priority scenario; 100% trucks with trailers can use priority lane					
Travel time gain (h)	-24.70	-1.43	-3.16	-0.40	0.12
Travel time gain (SEK/day)	3379	448	895	158	-541
Total benefit scenario 5	**4338 (SEK/day)**				

Table 5. Result of the CBA for present traffic demand

[11] Available at https://closer.lindholmen.se/projekt-closer/kringfartslogistik

Several conclusions can be drawn from the CBA for the present traffic demand, the first is that all scenarios have a positive social benefit which imply that on the simulated stretch there is not sufficient bus traffic to fill up the capacity of the priority lane. The highest social benefit is to let all freight vehicles use the priority lane. When only trucks with trailers can use the priority lane, the buses are slowed down more than when all trucks can use the bus lane. This is the main reason why the scenario with only trucks with trailers can use the bus lane generates a lower social benefit. We see the same effects in the scenario where only trucks without trailers can use the bus lane; the delay of the buses increases compared to the scenario where all trucks can go in the bus lane. This may seem counter intuitive but is an effect of the design on the road and the ramps, letting all trucks go in the bus lane reduces interaction between the vehicles.

However, with the future traffic demand in 2040 when bus and truck traffic is expected to be considerably higher the most beneficial policy for the society is to allow only trucks without trailers into bus lane. This is because the trucks with trailers are so large and take so much road capacity that they would block the bus lane and slow the buses down. This would cause congestion for all other traffic (including passenger cars) because it would block the on-ramp vehicles that try to enter the simulated stretch. This means that the value of the travel time gains for the trucks with trailers would be smaller than the value of the travel time loss for buses and passenger cars.

In this specific use case the capacity in the priority lane is not fully used and can therefore accommodate all trucks without slowing the buses down to any large extent, which explains why it is beneficial for society to let all trucks use the priority lane. However, the analysis also show that it is not possible to make any general statements regarding the social benefits and efficiency of letting trucks use the priority lane. On the contrary, a simulation and analysis of the consequences is always needed for any unique case. The key question will always be how much unused capacity that is available in the priority lane compared to the number of trucks that are let into the priority lane.

6.4 Factors for implementation of DPLF

As shown above there is potential for social benefits in giving trucks, or at least some trucks, priority on ring roads where road capacity is not fully utilized. However, with an increasing traffic demand it will be relevant to determine which freight vehicles that should be granted access to a priority lane as the priority lane will become more congested. This section will analyze how DPLF could be used as incentive for more sustainable freight transports and which regulation that enable or prohibit implementation. Further, technology and service definition required to implement and demonstrate DPLF will be defined.

6.4.1 Regulation for DPLF

New technology has made it possible to prioritize and control the traffic system which can lead to more efficient use of existing infrastructure through better and easier traffic management. This can also create possibilities to stimulate change of behaviour that contribute to societal goals. By giving priority to vehicles that meet certain requirements on their vehicles or logistics solutions it would be possible to create incentives for more sustainable transports. However, legal concerns need to be considered before implementation. In dialogue with Transportstyrelsen about obstacles and opportunities in regulations and laws related to DPLF, it has been possible to acknowledge what needs to be done within the legal framework to be able to implement DPLF[12].

There are currently basic laws such as the Vienna Convention and Swedish regulations, including “Trafikförordningen” (1998: 1276), “Väglagen” (1971: 848), “Plan och bygglagen PBL” (2010: 900), and “Vägmärkesförordningen” (2007: 90), which provides opportunities and obstacles to have priority lanes and democratic lanes in the same road network. There are also obstacles to allowing freight traffic in bus lanes. With today's regulations, it is not easy to introduce priority lanes since public roads should be open to public traffic. Freight traffic also has harmonizing rules within the EU and Sweden (Vienna Convention) where the importance of equal access to the public road network is a part.

All vehicles may travel on the road as long as it is not forbidden. In lanes for public transport, other vehicles are prohibited from operating. An authority would need to have the mandate to reserve certain infrastructure and control which traffic to be granted access to the priority lane. The space and tools available today are to prohibit all traffic and exempt vehicles with permission which must be communicated with appropriate road signs. Any restrictions on a general permission must be compatible with “Väglagen” in the sense that it is still considered that the road is used for general traffic. Basically, the intentions of land use must be followed and that it needs to be in the public interest. This is handled in addition to “Väglagen” also in local plans.

The degree of restriction on priority services can of course vary. If only part of the road, such as one of several lanes, is used for priority traffic, the remaining lanes are still available. Municipalities prohibit all traffic and exclude vehicles authorized in some cases today. However, there are no examples today on this type of prohibition on public roads.

In the way we use today's regulations, there are legal challenges to implement DPLF. In the long run, DPLF is very interesting and may be a part of the development of a major change in the transport system, including using autonomous vehicles, high capacity transport (HCT), platooning, electric roads, etc.

What needs to be investigated for DPLF is now:

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[12] More information on regulation is available in the report for WP6 on https://closer.lindholmen.se/projekt-closer/kringfartslogistik

- Can we prohibit all traffic on a lane and then allow traffic based on certain criteria within the framework of "Väglagen" and "Plan- och bygglagen"?
- Which authority in this case is mandated to prohibit and allow traffic and operate and administrate new technical systems?
- Is it possible with smaller adjustments of existing regulations or is a more comprehensive makeover necessary? This in order to get new features, such as DPLF, to work well in the transport system.

The investigations or projects implemented may benefit from co-ordination or co-planning with regulatory investigations for other functions in the system such as the above-mentioned autonomous vehicles, HCT etc.

6.5 Technology and service development for DPLF

The Original Equipment Manufacturers (OEMs) have gotten a long way in communication and the possibilities to connect vehicles are greater than ever. The standard moves towards higher levels of communication solutions, which will support the possibilities to make a system architecture for prioritization more automated and dynamic. Actors on the market have already developed similar solutions in other projects and the technology exists to develop a specific technical solution for a system architecture to dynamically prioritize freight. Automation strongly moves forward and the higher degree of automation in the priority system, the better. The idea of prioritizing freight traffic, when requirements are met, and the traffic situation allows it, is to make better use of existing infrastructure by using the available capacity in a priority lane.

To present the roles, functionality and requirements in a Priority Service different blocks in the system architecture and use cases are illustrated and described in this chapter. Some of the technology in the use cases already exists and can therefore be developed within one year, however before the jurisdiction, connection to authorities and transport company is ready perhaps three years is a more realistic time horizon for a complete system development. Blocks in the system architecture fig. 8 shows the different blocks in the suggested system architecture of a Priority Service to support the idea of dynamic prioritization. A short introduction of each block is described below, and more details regarding how the blocks interact will follow in the use cases A-H, which are presented in chapter 6.5.1. More details are to be found in the report for WP5[13].

[13] Available at https://closer.lindholmen.se/projekt-closer/kringfartslogistik

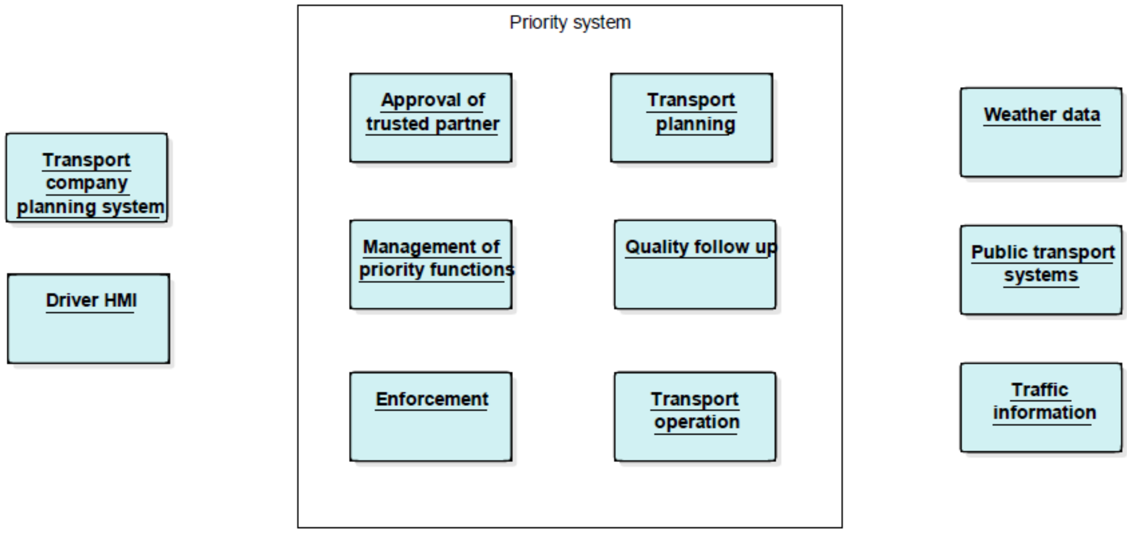

Figure 8. The system architecture supporting DPLF.

The core of the priority system

- *Approval of trusted partner* is the functionality to assess the access application sent by the transport company against pre-defined criteria, in order to participate in the Priority Service.
- *Management of priority functions* is the interface used by traffic management center/s who has the overall responsibility of the daily usage of the Priority Service.
- *Enforcement* contains the possibility for revisions and/or inspection from authorities. This block is important in order to make sure that the priority service is used as intended and that both users and non-users of the service comply with the conditions.
- *Transport planning* is the block used for planning and requesting a time slot in the Priority Service for a specific transport mission by the transport company/driver, after gaining approval as trusted partner.
- *Quality follow up* is used for quality reports and can be interfaced by several roles, both the transport company itself, analysts at the traffic management center and possibly other authorities. It could also be used as self-assessment for the transport company or to analyze the use of the whole Priority Service.
- *Transport operation* contains the actual execution of the transport and the options of getting access or not getting access to the priority lane.

Blocks connected to the priority system to feed and receive data

- *Transport company planning system* is the interface the transport company uses in order to send an application to access the Priority Service, to request for a priority at a certain time slot and to follow up and analyze completed transport missions using the Priority Service. The interface/add on might be integrated in the existing planning system of the transport Company.

- *Driver HMI (Human Machine Interface)* is the interface of the Priority Service for the driver. It could be accessible via an app in a smartphone in the short term and possibly be integrated in the existing Fleet Management System (FMS) in the long term.
- *Weather data* could be a possible source of information to connect in the architecture. Possibly the weather situation could be determined as a risk and in certain defined weather situations the priority functionality could automatically be set on pause.
- *Public transport systems* is important to be connected to in order to have the synchronization between buses and freight transport in the priority lane.
- *Traffic information* could be used in the same way as weather data. If disturbances in traffic, the system could on certain criteria automatically be set out of order and pause the priority functionality.

6.5.1 Use cases for DPLF

This chapter will describe an overall background of the logical groups of functionalities and use cases A-H.

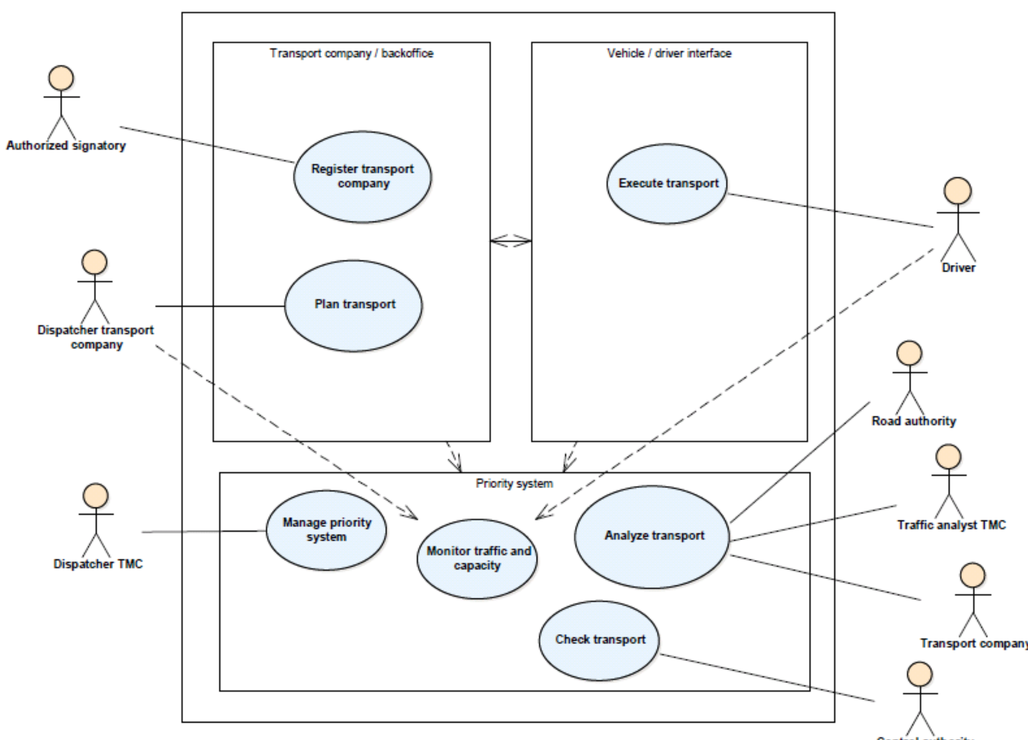

Figure 9. Roles and activities in the system architecture for DPLF.

Fig. 9 is an overall image of the roles and activities in the system architecture. The three boxes *Transport company/back office*, *vehicle/driver interface* and *priority system* could be described as logical groups of functionalities.

- The box *Transport company/back office* will be the ones applying to become a trusted partner and in that way get access to the Priority Service. This is the task of the authorized signatory – which is someone at the transport company having the mandate to make such decisions. The planning of the actual transport is also done in this interface, and the responsible could be a dispatcher at the transport company. The interface used could be the transport company's own FMS, a website, connected API's, an app or another back office system.
- *The vehicle/driver interface* is dedicated for the driver, and the communication could be via an app in a smartphone in the short term or through the FMS in the long term.
- The box named *Priority system* is the core of the architecture where the relevant traffic management center (dispatcher TMC) adds the demands to access the priority functionality. They are also the ones having the possibility to manually run or outrun the priority functionality if disturbances in e.g. traffic. This box also has the information of capacity in the priority lane, and the driver and/or dispatcher will get the answer on their request to access based on this information.

The functionality of checking and analyzing transports is also in the *Priority system*-box. Checking transport could be of interest for control authorities in order to ensure enforcement. Analyzing transport can be of interest both for the road authority to e.g. see the overall picture of usage of priority functionality. For the transport Company it could be of interest to analyze their transports to measure time gains. And for the Traffic management center it could be interesting to see changes in traffic patterns, changes in queuing time etc.

Identified use cases are thoroughly described in appendix 4 and summarized below:

A. Manage priority service; the overall coordination of the Priority Service
B. Application for trusted partner; for the transport company to get access to the Priority Service
C. Monitor traffic and capacity; to evaluate if there is satisfying conditions in traffic and level of available capacity to let in priority requests
D. Plan transport; requests for priority ahead of time for planned transports
E. Cancel transport; cancellations of approved requests for priority due to e.g. changes in transport assignment
F. Execute transport; interaction between driver and system when executing approved transport in the priority zone

G. Check transport; control and supervision from control authorities for enforcement of Priority Service

H. Analyze transport; follow up on parameters connected to the priority service, performed both by the transport company, traffic analysts at the traffic management centre/s and road authority

6.5.2 Choices when designing a priority system

The use cases can be applied when designing and developing a system architecture in a future demonstration project. When designing, planning and carrying through a demonstration a few technological choices need to be made. There are multiple solutions and multiple interests between actors and all choices favors actors differently. Recommendations are summarized in the following bullet points, it is however important to have the different possible interests in mind.

- Focus on cellular communication rather than short range communication as this is likely the future, and no large investment costs are needed
- A technical solution can be built both with and without an interchange node. If it is a large or a complex system architecture with several interactions, there is an advantage in using an interchange node.
- Use an app in the short term for the interfaces, and look further at using API's and FMS in a larger scale implementation when the open standards are sufficiently developed
- During a demonstration the existing functionality of geofencing can be used, but needs to be complemented by camera based reading in order to reach the precision needed.

7 Dissemination and publications

The results from the Ring road logistics project have continuously been presented at different events, both in Sweden and abroad, and raised lots of interest. Some examples are FFI program conference in 2016, Transport Efficiency Day – TREFF- in 2017, FFI Resultat conference 2017, Infrastruktur- och transportdagen in Örebro 2018, the freight network in Gothenburg 2018, Transport Research Arena in Vienna 2018 and will be subject for presentation at Transportforum 2019. Further, the project will result in 2-3 academic papers by Chalmers university of Technology and KTH.

Within the framework of the project, a workshop was organized together with K2, the Swedish knowledge center for public transport, on the 5th of April 2018 where this project was presented. The aim of the workshop was to stimulate dialogue, identify positive synergy effects and find areas where cooperation between freight- and public transport operators could contribute to sustainable mobility. At the workshop, the results from this project was presented and thus discussed among stakeholders from both the public transport sector and freight sector. The participants agreed that there are several positive effects to be found by prioritizing transports of high value, regardless whether it concerns transport of people or goods. In order to tackle the expected future increases in both freight and passenger transport, there is a need to find new ways to use the infrastructure more efficient.

Also, as the project has the aim to prepare for a future demonstration, it has been important to consult with public transport operators who today has priority lanes in a few cities in Sweden. Various meeting has been held with representatives from the public transport sector in Gothenburg and Stockholm to identify both obstacles and possibilities for dynamic priority lanes for freight on ring roads. From these meetings it is clear that many obstacles still need to be considered, but there could be some great potential in considering a smart system for prioritizing for both public transport and goods. One of the most important aspects is to guarantee that the priority lane is only used by authorized vehicles, which already today is difficult. To give access to freight vehicles with high social value to the priority lanes could complicate both control and enforcement. This has been considered as an important part of the technology and service development, but still needs to be investigated further regarding practical functionality.

During the project period, Ring road logistics has regularly been up for discussion within the round-table Urban Mobility in CLOSER. The round-table consists of cities, regions, transport operators, OEM:s, transport buyers etc. They have provided useful input to the development of the project and has also been a forum for dissemination of the results.

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	Increased knowledge on current traffic conditions on ring roads and the social value of giving freight transport priority. The workshop with K2 and various meetings with public transport operators have given a deeper insight in the overall ring road system.
Be passed on to other advanced technological development projects	X	The technical system architecture identified in this project, is possible to test in a demonstration in the CEF-financed project Nordic Way2 which is related to C-Roads. Nordic Way2 aims to test and develop C-ITS services that relate to the technical system architecture explained in chapter 6.5
Be passed on to product development projects	X	See above
Introduced on the market		
Used in investigations / regulatory / licensing / political decisions	X	There need to be substantial changes in the existing regulations in order to achieve the potential of social value that has been described in this project. Future dissemination of the results will be to influence decision makers to make it easier to implement DPLF.

Thanks to the large interest the project has raised, and the successful partnership that has been built around the questions in Sweden, the Ring road logistics project has during its duration created the possibility to be up-scaled and further develop into a special work package on Access Control within the EU-financed, via the Connecting Europe Facility programme (CEF), project Nordic Way2[14], which aims to test and demonstrate C-ITS services that relate to the technical system presented in chapter 6.5. Nordic Way2 will develop and test systems for connected and cooperative vehicles and traffic management systems. Nordic Way2 is also closely related to C-Road which is a platform for testing and implementing C-ITS services with cross-border harmonization and interoperability[15]. Nordic Way2, which will run until December 2020 with pilots planned during 2019 or 2020, mainly focus on technical development and demonstration, whereas other aspects related to DPLF, such as adjustment of the legal framework and business model, need to be further developed in another project. This is described further in 8.2.

8 Conclusions and future research

The purpose of this project has been to investigate the effects of dynamic priority lanes for freight, in terms of the efficiency of the use of existing infrastructure, and to prepare for a full-scale demonstration.

There are many parameters to consider and the system that has been investigated includes several stakeholders and different aspects related to sustainable freight transport in urban areas. It can however be stated that dynamic priority for freight would generate a net social benefit when comparing to the current traffic system layout in this specific case study. This include potential monetary benefits for both transport companies and industry due to shorter travel time and higher precision in estimated time of arrival. In this case study, the social benefits when implementing dynamic priority lanes for freight are considerably higher when all freight vehicles are allowed to use the priority lane. Social benefits of implementing dynamic priority lane for freight are also high in a future traffic demand when congestion level is estimated to increase. In a future traffic demand scenario it will however be essential to perform dynamic priority for freight with high precision, and with fewer vehicles, otherwise the system risk to jam up, risking both security and longer travel time for all traffic users. In a future scenario it will thus be more relevant to give priority to freight transports with certain characteristics, according to a criteria list for sustainable freight or commodities with higher value. These values can either reflect the cost that a longer travel time has for the transport companies, or how much these companies are willing to pay for shorter travel time or higher travel time reliability. These parameters mainly depend on the class of vehicle, the type of goods being transported and the payload.

To give certain freight transports priority on ring roads could also work as incentives for a more sustainable freight transport system and increase goal achievement on both local,

[14] http://vejdirektoratet.dk/EN/roadsector/Nordicway/Pages/Default.aspx

[15] https://www.c-roads.eu/platform.html

regional and national policy objectives related to transport, environment and business development. In order to bring about a change in the transport system towards overall goals, policies and strategies, an open criteria list for prioritization requirements is proposed. The requirements and the level of requirements must be adapted to the most important objectives, type of area referred to and the type of transport referred to. As an example, to only give access to a priority lane for vehicles with pre-set requirements, such as electric driveline, could work as an incentive for better environmental qualifications of freight vehicles. However, for a priority lane to have any effect on the vehicle fleet, it would be important to have the same system in many road stretches and cities in the country. Other qualifications could include social sustainability, such as fair working conditions and following laws and regulation, or transport efficiency, such as consolidation or high filling rate. Furthermore, efficient use of existing infrastructure, decreasing travel time and increasing reliability in estimated time of arrival for some transport could increase reliability and resilience for modal shift and creating a more reliable freight corridor network. This is however an aspect that must be investigated further.

In order to only give access to a priority system for freight vehicles which fulfill pre-set requirements that increase overall goals for more sustainable transports there need to be a supporting technical and service system for access control. By connecting actors such as authorities, transport companies and public transport operators in a system architecture, authorization, access and compliance could be developed to administrate dynamic prioritization for freight. Use cases which describe roles and requirements in a possible system architecture have been developed and a definition of choices that need to be made before starting that process has been identified, e.g. cellular communication, the usage of a smartphone as the interface in a demonstration and usage of zone management to identify a priority zone. Parts of the needed technology exists today and a prototype for demonstration is expected to be developed and tested within one to three years (as described above in the framework of Nordic Way2).

However, there are today still some barriers for implementing dynamic priority lanes for freight. They lie mainly within the legal, organizational and political framework. With today's regulations, it is not easy to introduce priority lanes - since "public roads should be open to public traffic". Freight traffic also has harmonizing rules within EU - the Vienna Convention - where the importance of equal access to the public road network is an important part. All vehicles may travel on the road network as long as it is not forbidden. The only tool available today are to prohibit all traffic and allow vehicles with permission. It can be problematic in relation to the Roads Act. The next step is to investigate the possibility of prohibiting traffic on part of the road and then re-allow vehicles with permission, which needs to be analyzed further. The question to answer will be whether it is compatible with the Road Plan and Building Act. It may also be interesting to investigate the interest and the ability to use specification of road use in overall plans. This has not yet been used to a large extent by public roads. In parallel with investigating solutions within the framework of today's regulations, it should be appropriate to investigate the needs and opportunities for regulatory changes.

8.1 Continuation and future research

Ring road logistics has now been the subject for a pre-study (between 2015 – 16) and this feasibility study (between 2016-18) which show that there is both social and technological potential for dynamic priority lane for freight on ring roads in metropolitan areas. However, there are several obstacles in order to implement DPLF where one of the major issues for implementation lies within the legal framework. It would thus be important to further investigate effects on the traffic system after implementation and evaluate business models and possible changes in the legal framework for implementation. It would also be beneficial to test and demonstrate a potential technical system for DPLF as little research has been done in the area which connects authorities with OEM's in system integrations. Here it will also be important to investigate questions regarding responsibility for the technical system for dynamic priority for freight, such as who will manage the system and determine which freight vehicles that should get access to a priority system.

The suggestion is to continue with two separate projects that could run parallel with the following agendas:

1. Test of technical system that enable DPLF
2. Broader system analysis of DPLF

8.1.1 Test of technical system that enable DPLF

The purpose of a technical test would be to show a system that enable dynamic prioritization, access control and capacity allocation for freight transports, which creates potential for a more effective use of existing infrastructure. Potential activities would be:

- Illustrate how a system for dynamic priority lane for freight vehicles could work in form of a test
- Set up a digital system for information exchange between actors such as traffic management, public transport operator, freight transport company and vehicle manufacturer
- Establish an adapted system for monitoring

This technical demonstration will be carried out within the EU-project Nordic Way2 which is a CEF-funded project that started in 2017 that aims to develop and test systems for cooperative ITS (C-ITS) services with cellular and short range G5-communication. In Nordic Way2 applications that allow effective data exchange through wireless communication technologies between components and actors of the transport system (vehicle-to-vehicle or vehicle-to-infrastructure) will be developed and tested. In the project, the Nordic countries Sweden, Finland, Denmark and Norway are included and different applications are planned to be tested in the different countries and also cross-border functionalities. In the Swedish pilot, the technical aspects of DPLF (explained in 6.5) are planned to be tested with the aim to develop services related to the following use cases listed in chapter 6.5.2:

A	C	D	E	F
Manage priority service; the overall coordination of the priority service	Monitor traffic and capacity; to evaluate if there is satisfying conditions in traffic and level of available capacity to let in priority request	Plan transport; requests for priority ahead of time for planned transports	Cancel transport; cancellations of approved requests for priority due to e.g. changes in transport assignment	Execute transport; interaction between driver and system when executing approved transport in the priority zone

After discussions with the Swedish Road Administration, city representatives and public transport operators in the Stockholm and Gothenburg area there are especially two road stretches that are interesting for a pilot (see appendix 5 for more information). Both include bus lanes as these could be used as an example and test area for how freight vehicles can get access to a designated priority lane. It could be possible to get a permit to execute a test of DPLF in these already existing priority lanes.

- In Stockholm E4/E20 Södertäljevägen northbound between interchange Bredäng and Västertorp is of most interest where the system can be tested with a lane for public transport. On this stretch there are less busses which minimize the disturbance in traffic. There are also many freight transports on this stretch as it is a major arterial for freight movements into and through Stockholm
- In Gothenburg E20 Alingsåsleden west going between interchange Torpamotet and Ånäsmotet is of most interest. There are less buses on this stretch and there are only two public transport operators using the priority lane, making it easier to have an overview of all vehicles using this road segment. This road segment is frequently used by long-haul transports connecting to E6 south going from E20.

These stretches are considered most beneficial from numerous perspectives:

- The stretches are monitored by traffic cameras which enable monitoring of the pilots.
- The stretches are not considerably congested by public transport vehicles which lower the risk of negative impact on accessibility for public transport operators and lower the risk for accidents.
- The stretches contain few on- and off ramps which reduce complexity and risk for accidents.

8.1.2 Broader system analysis of DPLF

This project has resulted in a great deal of insights in how a system for DPLF can be formed and what effects it would lead to, but also several new research questions has been risen that need to be addressed. The purpose of a broader system analysis would be to further evaluate effects on the overall traffic system after implementation and assess business model, legal conditions and enforcement for DPLF. Investigations are also needed, of how future traffic systems can become more efficient by using prioritization for several road users such as public transport or other road users with high social value. During this project it has been acknowledged that dynamic priority includes much more than just prioritization for freight on ring roads. It can be a part of a larger system for more efficient use of the infrastructure and increase mobility for several road users, such as public transport, autonomous vehicles, platoons and freight. Therefore, this project should preferably in the continuation phase include a wider range of stakeholders that are necessary for a systems perspective of dynamic prioritization. Activities could include:

- More simulations of a broader traffic system that include dynamic prioritization and include more road users
- Establish an action plan for legislative adaption for implementation of dynamic prioritization on a larger scale
- Analysis of criteria for prioritized transports considering traffic situations and compositions
- Analysis of business models for system platform and prioritization and cost for development and implementation
- Evaluate and suggest system for surveillance and enforcement

9 Participating parties and contact persons

CLOSER, Lindholmen Science Park AB	Hannes Lindkvist
DB Schenker Consulting	Emelie Klasson
KTH	Xiaoliang Ma & Junchen Jin
Chalmers University of Technology	Sönke Behrends & Ivan Sanchez Diaz
VTI	Maria Börjesson
Swedish Transport Administration	Catrin Wallinder & Arne Lindeberg
City of Göteborg	Magnus Jäderberg
City of Stockholm	Robin Billsjö & Amanda Baumgartner

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