The DenCity Project is a collaboration project between 21 organisations that develops innovative solutions for sustainable passenger, freight and waste transport in dense urban areas, with high demands on transport efficiency, attractiveness, accessibility and sustainability.
DenCity is a collaborative project between industry, academia and society. The project is managed by the Swedish national arena for collaboration within transport efficiency, CLOSER, at Lindholmen Science Park. 50% of the project is co-financed by the Swedish innovation agency, VINNOVA within the UDI-program and the remainder by the participating parties.

**PROJECT PARTICIPANTS**

- Volvo Group
- Chalmers University of Technology
- CLOSER at Lindholmen Science Park
- COOP Logistics
- Ericsson
- Fesiflo
- Göteborgs Frihamn AB
- City of Gothenburg Parking Company
- City of Gothenburg: Urban Transport Administration
  - Department of sustainable waste and water
  - City Planning Authority
- University of Gothenburg: School of Business, Economics and Law
- PostNord
- RISE Viktoria
- Schenker AB
- Sustainable Innovation
- Swedish Digital Trade Federation
- Volvo Cars
- Region Västra Götaland
- Älvstranden Utveckling

**MAIN AUTHORS:**

- Lina Olsson, CLOSER/Lindholmen Science Park AB
- Sönke Behrends, Chalmers University of Technology
- Magda Collado, RISE Viktoria
- Fredrik Cederstav, Volvo Group
- Roland Elander, Sustainable Innovation
- Elisabeth Karlsson, Handelshögskolan Göteborgs Universitet
- Staffan Bolminger, FOG Innovation
- Martin Svanberg, SSPA
- Linda Andersson, Ramböll
- Jonas Wilhelmsson, Ericsson
- Jacob Lindkvist, Älvstranden Utveckling
- David Backelin, Urban Transport Administration, City of Gothenburg
EXECUTIVE SUMMARY

Aim and scope of the project

The DenCity project has taken on a specific challenge – urbanisation – to develop transport and mobility solutions for future dense urban areas. The urbanisation implies an increased competition for the attractive urban space as well as increased impacts on environment and human health as more people and goods will need to be transported using the same infrastructure. For 2.5 years, the DenCity project has jointly developed, tested and evaluated innovative solutions for future, dense cities - opening up for business opportunities and scalable solutions both nationally and internationally. More specifically, the project has developed electrified distribution trucks, solutions for transporting goods and waste on urban waterways, service development for both passenger mobility and last mile deliveries, as well as planning for needed physical and digital infrastructure. The overall objective is that the solutions developed will result in reduced congestion and environmental effects, new products and services as well as increased quality of life.

Decisions made within urban development processes have a direct effect on transport of both people and goods. Traditionally, freight transport is not included in the urban planning process to the same extent as passenger transport. Since the way of planning cities is changing, it becomes more and more important to take a holistic perspective on transport and to include all different modes of transport, for people, goods and waste. As an example, cities are now planning for a lower number of trips with private cars in favour of public transport, biking and walking, which implies the need for more home deliveries and other services. Cities are dynamic places, and we are in the middle of a rapid transition period where new technologies and services (digitalisation, automation, connected solutions and electromobility to mention a few) are altering the transport sector, as we knew it with strong implications for transport patterns in urban areas.

The densification of cities leads to complex challenges related to transport. At the same time, new urban development projects open up for new forms of collaborations to test and develop innovative solutions and processes. In the DenCity project, actors from city- and transport planning authorities, transport providers, transport buyers, OEMs, IT-industry, start-ups, real estate developers and academia developed solutions in close collaboration, integrating their different perspectives and experiences. This unique approach - integration of goods- and passenger transport in several demonstrations and urban planning processes - increases the chances of succeeding.

One of the key targets of DenCity is to consolidate the more and more fragmented urban transport operations and to develop transport solutions that integrate goods, waste and passenger transport. The developed solutions should offer a high quality of service to receivers, be efficient (in terms of space, time and resources) and sustainable (in economic, social and environmental terms). Furthermore, the developed solutions focus on the entire urban transport chain and take their starting point in solving the “life puzzle” for people living and working in cities. This integrated approach can help minimising the need of private car ownership through smart mobility- and logistics solutions, developing broker solutions for mobility and delivery services utilising the same digital and physical infrastructure.

Results

Taking its starting point in the vision and challenges of one of the largest ongoing urban development projects in Scandinavia, but with focus on scalable and generic solutions, the project has developed, tested and evaluated the following solutions:

- **ZERO EMISSION DISTRIBUTION:** Electric vehicles for distribution of food in cities, enabling efficient
zero-emission deliveries in terms of noise, emissions and particles and enabling new ways of delivering goods, for example silent deliveries during off-peak hours which means more space for people during the day.

- **URBAN WATERWAYS**: Development and test of a multimodal transport chain including barge, cargo-bike and small electric vehicles in order to make use of the largely un-utilized infrastructure (waterways) in Swedish cities

- **ENABLING INFRASTRUCTURE FOR DENSE CITIES**:
  - Development of mobility solutions and their integration in the urban planning process
  - Business model and blue-prints for an Urban Consolidation Centre, servicing an entire urban area with consolidated goods and waste transport
  - Digital platform integrating mobility and delivery services for people living and working in dense urban areas

- **URBAN DELIVERIES AND SERVICES**: Development and preliminary testing of a last/first mile distribution concept enabling consolidated e-commerce parcel flows by use of a neutral delivery infrastructure in real-estates.

- **SYSTEM INTEGRATION AND EFFECTS**: Integration of the different solutions into a collective transport system as well as integration of freight into the urban planning process. Collective solutions require an urban logistics infrastructure, which in turn requires an urban planning process, which takes the long-term development plans into consideration.

During the initiation phase and second phase of the DenCity project (run between 2015-2018) it has been confirmed that the different professions involved, in this case city planners, traffic planners and freight professionals are traditionally working in “silos”, with little or no interaction. The collaboration arenas that projects like DenCity provide, is one way of opening up the borders between different authorities and involved organisations, increasing the knowledge sharing, creating a dynamic collaboration environment and, in the long run, enable more efficient planning. Furthermore, innovation projects where several actors are involved and together implement innovative solutions, contribute to increasing the awareness of the addressed issues.

Overall, the project and its developed solutions have raised a lot of interest from different actors, which in itself indicates that the targeted problems as well as the proposed solutions are relevant. The developed solutions are at a different technology-readiness-level, but no major obstacle has been observed which indicates feasibility to continue the initiated development and move towards an implementation phase. From a system perspective, it is clear that the solutions benefit from not being developed in isolation, and in particular that an integrated city and transport planning, involving multiple types of actors, is needed to develop efficient solutions. However, such a way of working does not happen overnight, but this project hopes to contribute to this development. The challenge for cities is to implement a physical planning that enables new technologies and services, and stakeholders from academia and industry must together with the cities show how these technologies and services can be used. In order to do this, demonstration of new solutions and business models for urban mobility is an important part of the transition to a sustainable system as it provides valuable information to involved actors.

By performing successful demonstrations combined and in small scale, this project has shown that it is feasible with new alternative solutions to meet the need of sustainable transport of goods and people in dense cities.
## LIST OF CONTENT

1 Problem definition and challenges addressed ............................................................................. 1
  1.1 Introduction ..................................................................................................................... 1
  1.2 Case River City and Frihamnen ..................................................................................... 3

2 The DenCity system ................................................................................................................. 4
  2.1 From business as usual towards an integrated approach on transport- and city planning .... 4
  2.2 Vision and approach ....................................................................................................... 5

3 Results and solutions developed ............................................................................................. 7
  3.1 Zero emission distribution .............................................................................................. 7
     3.1.1 Introduction .............................................................................................................. 7
     3.1.2 Scope ....................................................................................................................... 7
     3.1.3 Learnings ................................................................................................................ 8
     3.1.5 Next step ................................................................................................................ 9
     3.1.6 Summary ................................................................................................................ 9
  3.2 Urban waterways ............................................................................................................... 10
     3.2.1 Introduction ............................................................................................................. 10
     3.2.2 Scope ....................................................................................................................... 10
     3.2.3 Main results ............................................................................................................ 11
     3.2.4 Summary and future development ........................................................................ 13
  3.3 Enabling infrastructure for dense cities .............................................................................. 13
     3.3.1 Mobility as a Service ............................................................................................. 13
        3.3.1.1 Network ecosystem for MaaS ...................................................................... 14
        3.3.1.2 Integrating mobility in city planning ............................................................. 15
        3.3.1.3 The Mobility Broker .................................................................................... 16
        3.3.1.4 Mobility services and mobility packages for users ...................................... 17
        3.3.3 Digital Infrastructure ......................................................................................... 18
        3.3.3.1 Introduction .................................................................................................. 18
        3.3.3.2 Requirements ............................................................................................... 19
  3.4 Urban deliveries and services ............................................................................................... 20
     3.4.1 Customer driven service ......................................................................................... 20
     3.4.2 Demonstration set-up ............................................................................................. 21
     3.4.3 Demo phase ............................................................................................................ 22
     3.4.4 Evaluation .............................................................................................................. 23
  3.5 Physical infrastructure and integration with urban planning process ................................ 24
     3.5.1 Physical infrastructure .......................................................................................... 24
     3.5.2 Business model for Urban Consolidation Centre .................................................... 26
     3.5.3 Integration of city logistics into urban planning process ......................................... 37
  3.6 Effects and system evaluation .............................................................................................. 28

4 Discussion of results and learnings at system level ................................................................. 29

5 Dissemination and impact ...................................................................................................... 31
OUTLINE OF THE REPORT

CHAPTER 1
describes the background and addressed challenges of densification of cities and gives an introduction to the urban development project River City and Frihamnen, which the project has been working closely with.

CHAPTER 2
presents the vision and approach for carrying out the project and gives a brief overview of the different work packages and developed solutions.

CHAPTER 3
covers the results from the project and is structured according to the different work packages: zero emission distribution, urban waterways, enabling infrastructure for dense cities, urban deliveries and services, system integration and system effects.

CHAPTER 4
covers the discussion of results and learnings at a system level from the different work packages and developed, demonstrated and evaluated solutions.

CHAPTER 5
gives an overview to dissemination and results from the work package focusing on strategic communication carried the project. The chapter also covers impact and in-direct results from the project.

CHAPTER 6
presents areas of future research and development and the next steps for the project in terms of moving towards an implementation phase.
1 PROBLEM DEFINITION AND CHALLENGES ADDRESSED

1.1 Introduction

Densification of cities and the need of space-efficient transport solutions
Urbanisation is a fact and by 2050 more than 80% of the European population will live in urban areas. Sweden is one of the countries in Europe with the highest rate of people living in cities, currently almost 90% of the population, and this number is expected to increase. There is currently a changing planning paradigm in cities, where city planners and authorities globally are planning for both redevelopment of and new high-density attractive urban space, in existing city centres as well as centrally localised brown-field areas (land areas previously used for industrial or harbour purposes). In line with the densification of cities, the competition of the attractive urban space is constantly increasing, meanwhile the transport need of both people and goods are increasing rapidly. Individuals working and living in urban areas have increased demands on high-level transport and mobility solutions and are demanding more individualized transport- and delivery solutions. This has resulted in a fragmentation of transport flows and an increased number of deliveries, while the number of car trips also has increased in cities. Local authorities are facing major challenges in order to create and sustain attractive, liveable and dense urban areas. Sustainability, energy efficiency, reduced overcrowding and noise, as well as a vibrant city environment is to be matched with the service and delivery requirements from residents and employees.

UN-Habitats has developed five planning principles for cities. The principle of population density of at least 150 people / km² is seen as an important supporting principle for achieving a well-functioning city. Dense cities balance between being a risk or an opportunity for people and business in the future and the DenCity project addresses both sides. Cities are drivers for economic growth as they play a role as matchmakers between people and jobs. Today, 19% of the world’s population lives in the 300 largest cities. Together, these 300 cities generate 48% of global GDP and by 2025 68% of global growth is expected to occur in the world’s 1,000 largest cities. But cities also affect people and the environment in a negative manner, the possibilities that dense cities provide also poses a risk to us. Trade exchanges with surrounding areas, household purchases, commuter trips etc. generates a lot of transportation and induces traffic. Traffic exposes residents to risks such as air pollution, noise, accidents, etc. There are many advantages to increase efficiency in the transport of goods and people in the city. The starting point needs to be a city built for its people, who wants a safe, accessible and vibrant urban environment with a high quality of life. There is an urgent need to integrate transport development into the urban planning process in order to create transport solutions that are answering to all the challenges addressed above, to make the most of the attractive urban space and to create more space for people.

From parking and private car ownership to mobility solutions
Parking has a correlation of 0,79 with car mode share (McCahill et. al. 2016). The availability and costs of parking significantly influences travel patterns and can even undermine any positive effect that the availability of public transport and cycling infrastructure can have on vehicle miles travelled. Parking policies vary significantly from country to country, but they can be generalized into two types of parking norms: parking minimums and parking maximums. Parking minimums, common in the US, are codes that demand that developers build up a minimum amount of parking based on floor space, number of apartments or offices or even very detailed criteria such as four spaces for every hole on a golf course (The Economist, 2016). The negative effects of parking minimums are that they can create more supply of parking than is actually demanded by the market. After the city of London abolished parking minimums in 2004, parking reduced from 1,1 parking per flat to 0,6 per flat. On the contrary, parking maximums cap the amount of parking that can be built per unit. Mexico City, notorious for having some of the world’s worst congestion, switched to parking maximums and implemented what resembles a bonus-malus system, in which 50% of the development costs over the parking maximum would have to be paid to a fund that would then be used for funding public transport. According to the ITDP, more
than 40% of the land used in Mexico City is dedicated to parking. Since 2009 to 2013 6,750,000 square meters of parking have been built, summing up to approximately 1.7 million euros, money that could have funded 18 high capacity bus lines to move 3 million users per day.

In the 1950’s and 60’s Swedish experts went to other countries, especially the United States, to get inspiration. This led to implementing minimum parking norms in Sweden. During those and following decades traffic and parking increased a lot. To fulfil the demand of parking in the future, the parking norms required that the property developers built an overcapacity in the parking system. In recent decades this has become a problem as availability to parking and other car infrastructure has led to more traffic, less attractive urban environments, expensive construction costs and local, regional and global environmental problems.

During the last decade more and more cities in Sweden realised these problems and several cities try to create more efficient parking planning and use lower parking norms as an incentive for reduced car traffic. Instead, accessibility with different types of travel modes have become important in both an urban and sustainable perspective.

Integration of goods and passenger mobility
Decisions made within urban planning has a direct effect on transport of both people and goods. Traditionally, freight transport is not included into urban planning to the same extent as passenger transport, as highlighted in the Swedish Roadmap for City Logistics, published in 2014. Furthermore, the roadmap points out that a holistic perspective considering transports to, from and through an urban area where for example localisation of a terminal for freight handling and consolidation has consequences for the overall traffic flow within the area. Freight transport needs to be included in the overall transport planning in cities and to be equalised and connected to the planning for an efficient passenger transport system. Overall, there is a need to increase the knowledge and awareness of freight, but to do that it is important to understand the planning processes as well as to increase the knowledge of freight transport. As the way of planning cities are changing, it becomes more and more important to take a holistic perspective on transport and to include all different modes of transport, for passenger, goods and waste. As an example, instead of using a set parking norm several cities are now planning for a lower number of private cars in new urban areas, which could imply a need for more home deliveries and other services as an alternative.

Cities are dynamic places, and we are in the middle of a rapid technology development where new kinds of services, digitalisation and connected solutions and electromobility to mention a few are altering the system as we knew it and the transport pattern in urban areas. The DenCity project has been jointly developed and carried out by OEMs, transport operators, local authorities, building and housing companies and experts from academia and institutes with the overall aim to address and integrate transport of people, goods and waste into the urban development process as well as developing and demonstrating innovative and space-efficient transport solutions. Through this broad approach, the project takes a unique and holistic perspective on one of the main societal challenges right now - urbanisation.
1.2 Case River City and Frihamnen

City development projects globally are struggling with similar issues as mentioned above, and an ongoing project in Sweden pioneers in addressing these challenges. In Gothenburg one of the largest urban development projects in Scandinavia, RiverCity Gothenburg has the objective to build a total of 25,000 new apartments and 45,000 new workplaces in the very city centre. Urban development within the existing city structure means not only possibilities but also challenges because of its consequences for the existing traffic system.

The vision of River City is to connect the city, embrace the water and reinforce the city centre. These are stated strategies of the City Planning Department which go hand in hand with DenCity’s vision. Urbanization on both sides of the river composed of smaller areas, each with their own unique characteristics.

Frihamnen is the main area of focus to achieve a coherent city due to its geographical location, see figure 1 below. This area has been used as a case study in DenCity’s framework. Frihamnen is a vital part of the process of unifying the centre of Gothenburg across the river and out towards Kvillebäcken, Lindholmen and Backaplan. Frihamnen is planned with a mixed land-use into a dense inner-city area with a high level of variation and will also act as a test-bed for modern mobility. DenCity and the planning of Frihamnen have been an ongoing parallel work process with both parts well-integrated in each other’s work. The area mainly comprises of three piers located near large traffic infrastructure and Göta älv and demands, therefore, a higher level of conscious urban planning and traffic planning. The area is being planned with sustainability in mind to create an attractive city. Neighbourhoods are being designed for pedestrians and bicyclists, as an example car parking will be located on the outskirts of Frihamnen at a distance equivalent to stops for public transport.

With this vision and the challenges mentioned above as a starting point, the ongoing DenCity project takes a holistic approach on the urban supply chain, developing and testing innovative and space-efficient transport solutions both for first and last mile of goods deliveries and passenger transport while having a strong and integrated connection to the urban development process.
2 THE DENCITY SYSTEM

2.1 From business as usual towards an integrated approach on transport- and city planning

Business as usual is fundamentally based on the perception of unlimited resources. As cities get denser and both volumes due to urbanisation, e-commerce and higher demands of passenger transports and delivery services this all changes. A new paradigm is evolving with high demand on liveable cities both comprising high level of transport services and less congestion, pollution and noise emissions. These new and contradictory needs require new answers. More transport is obviously not the solution. We need to do things differently and become radically more efficient with our resources such as roads and vehicles. One vehicle and its movements in the city must be seen as a capacity that needs to be used to its maximum during all of its route. The future is multi use where new innovative concepts, cooperation and technology goes hand in hand with user needs and behaviours with the one objective to be efficient.

To study the development of paradigm shifts, researchers have developed the multi-level perspective (MLP), see Figure 2 below. The MLP emphasizes co-evolution of technology and society and distinguishes between three levels: 1) the socio-economic landscape, 2) the socio-technical regime, and 3) the niche innovations. The landscape represents the wider context which affects the societal development, e.g. globalisation, sustainability goals, an ageing society and cultural values. The regime represents established practices and guides actors to optimise the current system through incremental change, using the capabilities and resources of dominant players. Radical change is restricted since the technologies, regulations, user patterns and infrastructures are manifest in slowly changing policies, prevailing norms,

Figure 2: Multi-level perspective on transitions applied to the DenCity project (adapted from Geels, 2012)
and world views. Hence, the performance of radical novelties, which must compete with technologies that benefit from well-developed systems, is initially low. They therefore emerge in niches, which are protected spaces (e.g. demonstrations), which shield them from mainstream market selection. Niches are important because they provide locations for technological and institutional learning processes and space to form networks of actors that support innovations. In Figure 2 below niche innovations is illustrated through the different demonstrations performed in the DenCity project.

Paradigm shifts (or system innovations) come about through the interplay between dynamics at all levels. As the landscape changes, the regime may experience stress and is typically slow to adapt, creating a fertile soil for niches to grow. In the context of urban mobility, we observe several developments at the landscape level, including urbanisation (leading to an urban planning paradigm based on high-density urban areas), digitalisation and individualisation (leading to an exponential growth of e-commerce), which destabilise the current urban mobility regime based on car dependence and fragmented urban logistics, which in turn creates a window of opportunity for technological innovations. Several of these are addressed in the work packages of the DenCity project, which in this way provides the resources for technical specialisation and demonstrations which help to build up internal momentum (Figure 2).

2.2 Vision and approach

The idea behind DenCity is to consolidate the more and more fragmented transports carried out (see Figure 3 below) and to create space-efficient transport solutions making the most of the urban space in a system that integrates goods (incl. waste) and passenger transport, see Figure 4 below. The developed solutions are focusing on the entire urban transport chain and is taking its’ starting point in solving the “life puzzle” for people living and working in cities as the same time that solutions should be efficient (in terms of space, time and resources) and sustainable (in economic, social and environmental terms). Furthermore, an integrated approach to transport of people, goods and waste has been used in the project, which for example means minimising the need of private car ownership through smart mobility – and logistics solutions, developing broker solutions for mobility and delivery services utilising the same digital and possibly physical infrastructure.

*Figure 3: Business as usual - fragmented transport flows of goods into the city and waste from the city*
Bearing in mind the certain prerequisites and vision of the urban development project Frihamnen in Gothenburg (see chapter 2.2), but with focus on scalable and generic solutions the project has developed, tested and evaluated the following solutions, in five different work packages (WP):

- **WP1 ZERO EMISSION DISTRIBUTION**: Electric vehicles for distribution in cities, opening up for efficient zero-emission deliveries in terms of noise, emissions and particles and enabling new ways of delivering goods - for example silent deliveries during off-peak hours which means more space for people during the day

- **WP2 URBAN WATERWAYS**: Development and test of a multimodal transport chain including barge, cargo-bike and small electric vehicles in order to make use of the very un-utilized infrastructure (waterways) in Swedish cities

- **WP3 ENABLING INFRASTRUCTURE FOR DENSE CITIES**:
  - Digital platform integrating mobility and delivery services for people living and working in dense urban areas
  - Business model and blueprints for a Urban Consolidation Centre (UCC), servicing an entire urban area with consolidated goods and waste transport
  - Development of mobility solutions and their integration in the urban planning process

- **WP4 URBAN DELIVERIES AND SERVICES**: Consolidated e-commerce distribution and return flows through the development of neutral delivery infrastructure in real-estates

- **WP5 SYSTEM INTEGRATION AND EFFECTS**: Lastly, integration of the different solutions in an overall system and into the urban planning process in order to gain a joint understanding among the involved actors of how and when freight and mobility solutions should be raised in the process in order to in the long run implement the developed solutions.

During the initiation phase of the project a workshop-series involving the entire project consortium was carried out, following the backcasting methodology in order to create a joint vision and roadmap for the project and more specifically for the developed mobility- and delivery services (WP3 and WP4). A joint vision and gap-analysis pinpointing the main issues to solve before realising the vision was developed, see summary at www.dencity.se Above this, the workshop-series also resulted in an overview of current state (e.g related projects), definition on scope and delimitations for the project, a mapping of stakeholders and relations between the different actors, a draft on KPI’s for evaluation of the DenCity project, suggestion and prioritisation of mobility- and delivery services to develop further during the project.
3 RESULTS AND SOLUTIONS DEVELOPED

3.1 Zero emission distribution

3.1.1 INTRODUCTION
Already in 2013 there were requests from stakeholders to test emission-free goods distribution in connection to Sendsmart and the Off-Peak projects in Sweden. There were also requests from city authorities to test more sustainable transport solutions. DenCity started in December 2015. At that time, the ambition was to be able to drive emission free in a city area with a range of roughly 5 km. This would increase air quality and decrease noise for people living and working in the city areas. When driving outside this city zone the vehicle would drive on HVO to enable better emissions than regular diesel fuel.

Volvo Group already had a hybrid truck that was tested in both the Off-Peak and the Clean Truck Stockholm investigation. However, the range was not enough for expected customer applications and the truck technology was not further developed. The business case to have parallel drivelines did not seem good enough for a further development of this technology. The scope for this project was therefore initially to test a new “Dual mode” truck with two axles with an extended range from 2 to 5 km. It was anticipated that environment zones named for ex. “Ultra-low emission zones” etc. would be implemented in city centres in the near future and possibly “bio zones” a bit outside (ex. Eu6 with biofuel). After roughly six months, there was a request from Volvo Group to change the project scope to test a fully electric truck instead. The battery evolution had contributed quite rapidly during that first year and the business case for a fully electric truck had improved. Volvo also had an advantage with experience from the electric Bus line (55) already developed in Gothenburg. So, after a renegotiation of the scope in API, the new delivery date was set to summer of 2018.

3.1.2 SCOPE
The scope of the project was to develop a fully electric truck, equipped with a refrigerated unit and optimized for city distribution of chilled food, and perform a pilot in DB Schenker’s commercial flow for deliveries to COOP stores around Gothenburg city.

At first, it was estimated that the driveline needed was five battery packs (each 49 kWh). Deep analyses and discussions with with the carrier (TGM), DB Schenker and COOP including simulations of actual customer routes, payload and total power need, as well as a balance with maximum road weight limitations, resulted in an updated and changed specification. The range with a Battery Electric Vehicle (BEV) can vary depending on commission, commercial route and strategy. The final specification is a 16 ton two-axle truck with three battery packs, fridge unit and a payload of 7 tons. Expected range varies between 80-100 km per day based on night charging (at depot). DB Schenker, together with the haulier TGM, has analyzed COOP routes and created new optimized routes for COOP, in order to meet the requirements of the vehicle and also test the vehicle as much as possible. The vehicle range should cover all COOP stores in the Gothenburg city area, see Figure 5.
3.1.3 LEARNINGS
The political focus on the global warming challenges and specifically the Paris climate agreement and thus also Swedish government ambitions on reducing CO2, has put more pressure on urban transport restrictions. The industry is now aiming for a crisper but still moving target. Most hauliers, logistics service providers and retailers also have ambitious targets for CO2 reductions already by 2030. To meet these targets, we need to shift from being dependent on fossil fuel and move toward sustainable alternatives such as electrification of truck fleets. The evolution of battery technology and the global competition has also accelerated during the timeframe of this project which enables a future shift.

The challenges for Volvo Group and all OEMs with this technology are also different compared to combustion engines. Focus will shift from driveline, service contracts and spare parts to optimal specifications, range predictions and new business models. This new technology also opens up for new competition and off-peak deliveries.

The time to bring the vehicle from development departments to on road commercial missions was short. However, the process for road approval was very time-consuming. The truck was ready from the factory in the beginning of 2018 but expected road approval will not be ready until end of 2018. This means that the field test will not be able start during this phase 2 project. A two-day test activity including energy measurements will be included in the project scope and will be performed within Volvo premises at the end of June 2018. The results of the energy measurements of different commercial loads performed in Gothenburg in late June will be explained in Appendix 2. By the end of this year, the truck will start running in the commercial traffic of DB Schenker.
3.1.5 NEXT STEP
When scaling up to fleets, it is necessary to take a more holistic view on how to optimize the drivelines per fleet and how to recharge batteries in a more efficient way. When applying for a next phase of the project, phase 3, the target will be to scale up from one truck to at least three. Other topics that need to be further investigated in order to reach implementation are:

- Vehicle specification vs. range and payload
- Business model for electric truck fleets
- A more precise range prediction based on driver behaviour, payload and PTO usage.
- A more mathematical approach to real ranges with input data such as weather conditions and road resistance.
- Off-Peak, two-shifts and opportunities with indoor stores and terminals
- Additional charge points and payoff-times for different logistical setups
- New services such as configuration tools, Fleet Management and driver support.

There are also plans to add a 150 kW charger in the city of Gothenburg as an additional charge point. Suggested spot is at Falutorget near Renova. This will be the first public 150 kW charger for commercial vehicles in Gothenburg and is an indirect positive result of the DenCity project.

3.1.6 SUMMARY
In order to pave the way for electrification of goods deliveries on a large scale it is important to have a very tight collaboration with city authorities and logistics service providers as well as hauliers. Some policies might be adjusted such as time windows for goods transports. Furthermore, there is a need to create space for charging infrastructure with available services for truck drivers while charging. The new technology means disruptive opportunities that we still have not fully explored. This can have positive implications on work conditions for drivers, new schedules, less noise, new logistic terminals, new time windows for deliveries and new ways of handling energy storage. The market and cities have responded in a very positive way so far. What still has to be tested is the possible range when a truck is fully loaded and when all power consuming equipment is engaged. It is also important to further explore the business case for electric trucks. The future services linked to electric vehicles are also still very immature.
3.2 Urban waterways

3.2.1 INTRODUCTION
Making use of urban waterways to transport goods and waste is one way to reduce the environmental impact caused by road freight. As infrastructure for goods transport, urban waterways around the world are currently unutilized to a large extent. However, a number of initiatives have been set up for a variety of goods (palletized goods, containerized goods, parcels, waste and recycled material) in for example Amsterdam, Paris, London, Lille and Utrecht (Trojanowski and Iwan, 2014). Also, a number of cities have committed themselves to using urban waterways when developing their urban mobility plans; Brussels, Paris, Berlin, Budapest, Vienna and Pisa (Janjevic et al., 2014). The following main learnings can be drawn from these initiatives. First, cost is a major issue, in particular within the start-up phase, which often prompts the need for financial support. Secondly, instead, environmental gains are the main reported benefits; less congestion, noise, accidents and fuel savings. Thirdly, different types of policy measures are often required to get the initiatives started, and the municipalities are often (but not exclusively) the initiator. Fourthly, though there are exceptions, the initiatives have emerged in cities in which the unique transport geography makes it suitable to make use of waterways for transport, e.g. Amsterdam and Venice with narrow streets and dense waterways. They have also emerged in large cities in which congestion is a major issue, such as Paris and London. Fifth, many of the reported initiatives requires the involvement of multiple actors, including municipalities, transport operators and shippers of goods. Given that Gothenburg differs from the aforementioned cities with regards to for example transport geography, the main purpose of the work package was to investigate the feasibility of using waterways for transport of goods and waste in Gothenburg. The results ought to be transferable to other Swedish cities in which there are dense waterways such as Stockholm.

3.2.2 SCOPE
The main activity in the work package was to perform a two-week long demonstration – a test of the concept of urban waterway transport in Gothenburg with real goods and waste. The planning of the demonstration was led by SSPA and done primarily in cooperation with TK and K&V. As the task was to test the feasibility of the concept of urban waterway transport, there was a large degree of freedom, as many types of goods and waste were feasible to transport in theory. The planning consisted of meetings within the project group as well as a number of investigations prior to the demonstration regarding for example the suitability of transporting different types of goods and waste, the different types of loading units (containers) that could be used, assessing different set-ups for loading and unloading (e.g. onboard crane or not), the suitability of different quays around Gothenburg, investigating what types of barges and boats that could be adapted to be used in the demonstration and which potential actors should be included. Based on this, an initial set-up was suggested, and discussions were held with actors that could perform the actual demonstration; barge and boat operators; a third-party logistics company, two last mile distribution companies (one with cargo bikes and one with a micro-terminal and an electric vehicle for distribution), and a waste handling company. In the end, a number of solutions were possible, and the following factors shaped the decisions on the design of the demonstration; (1) it had to be a secure solution – the goods cannot be left unattended at any time; (2) the rather low availability of barges (e.g. barges for bulk commodities) that could be adapted to be used within the demonstration; (3) technical specifications of barges and boats (stability and dimensions), for example, barges could not rise more than two meters above the water surface in order to be able to pass under bridges; (4) cost which limited the adaptations that could be made for the demonstration as well as the scale of the demonstration; (5) existing quays that were possible to use for loading and unloading.

In the end, the selected set-up was to transport parcels and waste on the same barge. The parcels were loaded into two 1 m3-containers supplied by the third-party logistics provider located next to a quay just outside the city centre in Gothenburg (point 1, figure 7). The containers were rolled on to the barge manually, see figure 8. The barge was driven by a two staffed tug-boat which transported the containers to two quays in the city centre (point 2 and 3, figure 8). Transportation to final customers was done by one electric vehicle and one city cargo bike carrying one container. Waste was loaded onto the barge from the second quay in two containers (9 m3), using a lift-dumper truck. It was then transported to a quay near a combined heat and power plant outside the city centre (point 4, figure 7). As there were
no available quay next to the power plant, truck transported was required for the final transport. The main reasons for the selection of parcels and the type of containers was that this was deemed as feasible to do, in particular as it fitted with final distribution using the cargo bike and electric vehicle. Pallets and other solutions were considered but would have required larger adaptations of the existing system. Similarly, waste in containers was the most reasonable to collect given the budget as well as available containers and their fit with the barge.

Figure 7-10 illustrates the performed demonstration.

In order to make learnings from the demonstration, interviews with actors were held both and after the demonstration. The demonstration was filmed and time studies for transport and handling were done. The captain kept a logbook to report on key challenges and issues observed from his perspective. In addition, two master theses have been done within the context of the project. The first investigated barriers, drivers and key factors in implementing urban waterways (see Jandl, 2016). The second investigated using urban waterways from a business model perspective (see Horvath and Wu, 2017).

3.2.3. MAIN RESULTS
The demonstration showed that the concept of transport of goods and waste on urban waterways worked well in small scale, in the sense that the transport were carried out in accordance to a predefined time schedule, the goods arrived in the same time as if it would have been transported with truck, no goods or waste was damaged or lost. Furthermore, the participating actors did not experience any major problems that could not be overcome if the system is to be implemented. As the demonstration were performed for a limited period of time, the following learnings are suggested that should be taken into account if developing and implementing urban waterways transport in larger scale.

Infrastructure: A main difference between road and urban waterway transport is the infrastructure; both quays used for transhipment as well as the actual waterways may need improvement but are not regulated and taken care for in the same manner as for road transport. When searching for suitable quays to load and unload before the demonstration, it was apparent that even though there are urban
waterways in Gothenburg, the current quays may be a barrier that needs to be overcome, due to both ownership as well technical issues. For example, outside the city centre there is a lack of quays. In particular, there are three 3PL companies located next to the Göta Älv, but only one has a suitable quay next to it, though they do not own/rent that quay. Similarly, along Säveån, it was hard to find suitable quays for unloading waste. This indicates that if urban waterway transport is to be implemented, suitable quays need to be built. A cost estimation within the project showed that a quay may cost about 3 million SEK to construct in Säveån, and a larger one about 8 million SEK in Frihamnen, though dependent upon a number issues such as scale and design. Also, if quays are to be used in Frihamnen, there may be an issue of competition of space for quays as space next to the water is a very attractive area for apartments.

Regarding the waterways, water depth and air draft (the height between the water and the bridges) set condition for which barges that can be used. To some extent, innovative designs could in the future be used to overcome this, but barges will still be limited in volume. Also, dredging in some places along Göta Älv and Säveån would facilitate navigation as well as accessibility of some quays.

Cost: The cost of the demonstration is not representative for the future, as the barge was not purpose-built, the maximum capacity was not utilized, and the system was only used for a short period of time which implies that there are learning effects that could increase efficiency and lower cost. However, based on the demonstration, two variables that significantly influences cost were identified. First of all, barge transport is more time consuming than road transport. Barges are significantly slower, e.g. it took almost 2 hours from Lindholmen to Sävenäs, which in comparison would take about 15-30, minutes by truck, depending on road congestion, which makes personnel cost significantly higher for waterway transport. Secondly, this could to some extent be overcome by transporting a larger volume on each individual barge. For the waterway characteristics of Säveån, a purpose-built barge could potentially carry five 20 feet containers of waste, which could lower the transport cost significantly. Based on cost estimations of two actors offering urban waterway transports, it was estimated that the cost of transporting waste from Frihamnen to Sävenäs could amount to between 800-1000 SEK when the system is scaled up. However, there is room for lowering that cost significantly by developing autonomous barges, which would reduce personnel cost as well as electric barges which would lower energy costs. Also, estimations on the saving due to reduced external cost amount to about 200-250 SEK, of which the majority constitutes cost of congestion.

A large interest from municipalities and industrial actors. It is often argued that a modal shift from road to other more sustainable transport modes such as waterways is hampered by cultural resistance, as people may be reluctant to changes. This was not observed within the work of the demonstration, rather there has been a strong interest from different types of actors, and for example partners such DHL was very keen to test the concept of urban waterways, investing both time and their brand in the demonstration. The project has been in contact with a number of companies that were interested to participate in the demonstration in various ways but that were not feasible in the end as for example only one barge were to be used. Also, the demonstration held a media-event that was well visited. In all, there seems to be a strong interest both from municipalities and industrial companies to continue to develop the concept of urban waterways.

Designing the future system: Implementing urban waterway system is a rather comprehensive task. Depending on the types of goods to be transported as well as the final distribution, different types of loading units will be suitable. A major issue that was revealed in the demonstration was that goods need to be watched over throughout the entire day, e.g. it can not be left unattended at any time do to risk of thefts. This makes transferring goods from one actor to another time consuming, as actors need to meet up. Similarly, as all goods was not possible to deliver each day, there has to be a return flow to pick up that undelivered goods. Hence, if the system is to be implemented, transferring goods between actor is a key issue that needs to be resolved, either through actors waiting for each other, through the use of micro-terminals or potentially via other set-ups of larger more safer containers in which goods can be left unattended.

In the demonstration, goods and waste was transported on the same barge. It is suggested in the future that these should be separated, at least on a barge level, as there are economies of specialization in designing barges for one type of goods/waste and there are also return flows which means that the barge is
(almost) always loaded with either full or empty containers. Also, the different types of business models with different types of relations and contracts with actors needed indicates that it is better to separate the two. However, the systems should to some extent be integrated, at least using the same quays for loading and unloading, as well as perhaps the same micro-terminals for distribution of goods/collection of waste.

POLICY: The viewpoint in the project, in line with the literature is that policy support may be needed to facilitate the implementation. This project confirms that cost of urban waterways is high, and the within the literature identified measures for support such as investment in quays, cranes and barges with electric propulsion (Trojanowski and Iwan, 2014), may facilitate the implementation in Gothenburg as well. A second option is regulations, e.g. that prohibit the use of distribution trucks during certain hours within the city centre of Gothenburg to avoid congestion. Such measures may facilitate implementation of urban waterway transport as well.

3.2.4. SUMMARY AND FUTURE DEVELOPMENT
The demonstration shows that it works well with transport of goods and waste on urban waterways in small scale, but that the cost might be a barrier. A number of important paths for future research and development are needed in order to facilitate implementing and making the concept of transporting goods and waste on urban transport more viable. Regarding barge development, barges first need to be purpose-built, adapted to the local geographical circumstances and transport geography to be cost-efficient. Second, to be even more environmentally friendly, the development of electric barges may make waterway transport even more attractive as well as reduce cost. Thirdly, as personal cost is a major cost component, the development of autonomous barges may lower the total cost and make urban waterway transport more competitive.

A key issue for future research is how actors can coordinate their distribution with each other, both on a horizontal as well as on vertical levels. For the 3PL companies located along the Göta Älv river, it could be beneficial if a barge could pick up goods at each company in order to reap advantages from economies of scale within transport, but such a set-up requires business models that benefits all actors. It also either requires constructing suitable quays at each stop, if they are not to use the same quay, or additional truck transport to the quay that is to be used.

Urban waterway transport need to be designed to the context of dense cities. The competition of space of quays may be approached as done in Paris, where parts of a pedestrian quay is closed for a few hours during day to allow a barge to unload quays for distribution of containers. Such a set-up may not be attractive for citizens, but these volumes in Gothenburg would be significantly lower than in Paris, and quays would need to be closed for shorter period of time in Gothenburg which may make it a feasible option. However, this type of set-ups need to be investigated further, and implemented early in the planning process of the cities.

3.3 Enabling infrastructure for dense cities
In work package three a supporting infrastructure that enables efficient passenger, goods-mobility and waste - management services are developed. A key element is to ensure that developed service offerings will meet the residents, visitors and those working in the dense urban environment needs and willingness to pay, as well as viable business models for commercial actors.

The following chapter is divided into different sub parts, which together build a supportive service infrastructure: Mobility as a Service (MaaS) and Digital platform. Further elaboration on planning implications for physical infrastructure follows in chapter 3.5.1.

3.3.1 MOBILITY AS A SERVICE
While individual mobility services will have great transformational potential, the holy grail of transportation is when you are able to seamlessly integrate multiple mobility services in a single platform that can handle payments and travel planning across multiple providers. The MaaS paradigm shift will
be experienced first in urban areas, which means this will have high implications for city and real-estate development. To address this change the DenCity project has worked with the hypothesis that MaaS should be included early on in the real estate development process and should be offered directly to residents and tenants by the real estate developers.

One of the biggest paradigm shifts in the transport sector is the substitution of car ownership with access to mobility services instead. The trend is so strong that traditional vehicle manufacturers are investing millions into buying or partnering with mobility service start-ups. Another very tangible disruption is the arrival of self-driving cars which, if shared, can significantly reduce the costs of transport while at the same time maintaining the same or higher levels of mobility.

3.3.1.1 NETWORK ECOSYSTEM FOR MAAS
Traditionally the City planning authority decides on a zoning plan for a given area which dictates the number of parking spots based on the housing and commercial units to be built. This business as usual approach however has led to a car-centric development in cities. Furthermore, meeting the parking norm demands high investments from the real-estate developers (one parking spot in Frihamnen is estimated to cost 350 KSEK but the amount varies between different areas) and takes up a lot of valuable land (up to 25m2).

Offering mobility demands a change in the way that different actors relate to each other. The Heart Model featured in Figure 11 below, which was created in collaboration between the projects S3 and DenCity, explains the new dynamics needed for offering mobility instead of parking.

Under the DenCity scenario a real estate developer can create a Mobility Service Plan that include a range of mobility services that can give the same or higher degree of accessibility and mobility to the area. The mobility service plan can serve as a tool for negotiating a reduced parking norm with the City Planning Authority, which in the case of Frihamnen will be 75% lower. The agreement demands that part of the savings from the reduced parking be placed in a Mobility Fund, which should generate enough funds for paying for the Mobility Service Plan for a minimum of 20-25 years. This has been previously tested in Umeå municipality, where the project “Gröna Parkeringsköp” showed that 40% reduction in parking equals an

![Figure 11. The heart model (M. Collado, S. Dolins, 2017)](image-url)
equal percentage reduction in trips made with a car (Umeå Kommun, 2013). The project concludes that the model is transferable to similar projects in Umeå city centre and similar geographies in Sweden.

Together with the request for a building permit approval a real estate company can submit a Mobility Service Plan to the City planning authority. There are other actors that are required to evaluate such plan, such as the Urban Transport Administration (Trafikkontoret). It is therefore suggested that a Mobility Forum is formed between the necessary authorities so that they can together evaluate and approve the mobility service plan in order to ensure the mobility demands of the area are met. Trafikkontoret is also responsible for planning, together with the Public Transport Provider, the public transport routes, stops and operating schedule for the area. High accessibility of public transport is crucial for the Mobility Service Plan and therefore it’s important that Trafikkontoret and the Public Transport Provider are involved.

A series of workshops and interviews were carried out to fill in Osterwalder’s value proposition canvas, this resulted in a generalized scope of mobility needs of the user groups, also known as customers, of the Frihamnen development. Three main customer groups were formed: 1) Residents are those owning or renting an apartment in DenCity. 2) Businesses are those that have operations or are employed in DenCity, meaning they travel to the area and stay for a significantly long period per day, performing small trips during their stay. 3) Short-term visitors are those that are coming to DenCity for shopping, entertainment or to make use of one of the services (e.g. parents leaving children off at school).

The mobility needs per customer, their pains and gains were then assessed, and a series of matching mobility services has been proposed. Known as the DenCity Mobility Service Index, the list serves a general reference and guidance of the available mobility services that can be considered based on specific needs.

3.3.1.2 INTEGRATING MOBILITY IN CITY PLANNING

For mobility to substitute parking it must be successfully included in the property development process and a number of key steps must be carried out and regulations fulfilled. The following (see Figure 12) is a summary of how mobility can be included throughout the three main steps of the city development process. Results are based on Gothenburg as an example.

![Figure 12](image)

*Figure 12 The figure shows the relationship between the real estate developer and the Mobility Broker in a real estate project, from planning to operations.*
3.3.1.3 THE MOBILITY BROKER

The Mobility Broker is the actor in charge of utilizing the mobility fund for carrying out the mobility service plan. As observed in the heart model (Figure 12 above) this actor’s position in the value chain is between developers, mobility suppliers and the customer. The real estate developer can directly employ the Mobility Broker, this is particularly convenient when there is only one developer involved, or purchase the services from a third party, this can be better suited for a group of developers.

The Mobility Broker has the competences for negotiating with Mobility Service Operators and procuring the necessary mobility services to carry out the mobility service plan. The Mobility Broker also handles the customer relationships with the Users, offering them advice and customizing a mobility plan specific for their needs. This way, the Users are able to benefit from multiple mobility services (e.g. car-sharing, delivery services, autonomous on-demand shuttles, etc.) under a single integrated platform and in a single location. Users would otherwise not have access to some of the services or would have to purchase individually from each supplier at potentially a higher cost.

This is a completely new actor in the mobility ecosystem and its role is still under fluid phase. To better define a potential role, we carried out interviews and workshops with private commercial actors in Sweden that are currently offering mobility services or performing some of the functions that this role demands (e.g. UbiGo and Sunfleet). The following table summarizes the main value propositions of the Mobility Broker towards the other actors in the value chain:

<table>
<thead>
<tr>
<th>DEVELOPERS</th>
<th>MOBILITY SUPPLIERS</th>
<th>CUSTOMERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propose mobility services for the area already at the detailed planning phase.</td>
<td>Offer a preferential customer pool.</td>
<td>Evaluate mobility needs and provide advice on mobility package.</td>
</tr>
<tr>
<td>Agreement for a guaranteed level of mobility services for customers.</td>
<td>Reach new customer segments that suppliers can’t reach themselves, e.g. by bringing in new customers that have initially joined because another mobility service.</td>
<td>Single offering, booking, monitoring and payment settlement.</td>
</tr>
<tr>
<td>Mobility broker agreement can be used for a reduction of parking.</td>
<td>Increased utilization rate of their services.</td>
<td>Access to multiple transport options without having to duplicate contracts.</td>
</tr>
<tr>
<td>Ease upstream integration of mobility suppliers.</td>
<td>Lower marketing and customer acquisition costs.</td>
<td>The MaaS platform is not exclusive to a housing association, meaning customers benefit from its diffusion in other parts of the city/country.</td>
</tr>
<tr>
<td>Guarantee having the best supplier for each mode and preferential price thanks to competition among suppliers.</td>
<td>Synergies with other mobility suppliers to close transport chain.</td>
<td>Access to mobility services at a reduced/subsidised price are a benefit as a tenant/resident.</td>
</tr>
</tbody>
</table>
Currently in Sweden there are four potential mobility brokers, although they individually don’t encompass all the value propositions mentioned above. These are:

- **UbiGo**: a Swedish SME formed as the result of the Vinnova financed Go:smart project (Vinnova 2012-2014). Ubigo started operating a second MaaS pilot in March 2018 in Stockholm.
- **Sunfleet**: Volvo’s car-sharing company has been offering car-sharing for residential developments for several years and represents one of its fastest growing markets. Car-sharing is the base service but can be complemented with bike-sharing, cargo bikes, public transport and even small electric vehicles.
- **EC2B**: is a startup company that focuses on mobility services for real estate. Their services are being offered at Riksbyggen’s housing association Viva in Gothenburg.

### 3.3.1.4 MOBILITY SERVICES AND MOBILITY PACKAGES FOR USERS

Among the expected responsibilities of the mobility broker is that to give counselling on the mobility services that developers should include in their offer. The mobility broker is also expected to evaluate the mobility needs of each resident group or household. The needs will vary significantly depending on the context of the area and also the specific needs of the users and it is therefore hard to conclude on specific mobility packages. A hierarchization of the services (see Figure 13 below) suggest that:

- **Designing the area**: The area should be designed with mixed land use planning, which promotes walking and biking as the main mode of transport.
- **Designing the area and promote**: Public transport should be the main mass transit transport mode.
- **Offer as part of the rent**: The mobility fund finances car-sharing, cargo bike-sharing and bike-sharing. Also, to be financed is the provision of independent delivery points, e.g. delivery lockers or delivery rooms, where customers can receive and send packages from multiple logistics companies. Tier three is direct responsibility of the developers.
- **Supporting infrastructure**: Additional services that developers can finance and include in order to further increase the value proposition of their own property. This can include areas platforms for exchanging goods and services, apps for parental carpooling, on-demand shuttles, digital taxi queues, ride-sharing zones and charging for electric vehicles.

![Figure 13. Hierarchy of mobility services, M. Collado, 2017](image-url)
3.3.3 Digital Infrastructure

3.3.3.1 INTRODUCTION
The digital platform should support and complement the physical infrastructure and set policies to provide attractive and flexible transport solutions of people and goods. It should also serve as the back end on which the customer facing demo(s) will be implemented, ideally by a range of service providers developing individual applications and solutions on top of DenCity resources brokered by the digital platform.

In short, the digital infrastructure should act as a mobility broker for a growing ecosystem, where providers can offer mobility services to consumers and enterprises. It should be "open" to all participants in the ecosystem but controlled and governed, based on commercial agreements. It should allow for both wholesale and retail business models, where a service provider should be able to create bundled services based on agreements with eco system stakeholders.

We have assembled requirement inputs from a range of sources, including articulated use case definitions from workshops with project stakeholders and beyond. Guiding principles for the digital platform is openness and transparency, which will be required to be successful. Well documented, securely accessible, APIs to access ecosystem resources on agreed commercial terms therefore remain the key remit of the DenCity supporting digital infrastructure.

The eco system is complex and should be equally accessible to all participants, independent of size or financial muscles. This is an important aspect, both from a business and technology point of view. If "business as usual" is set to prevail DenCity will not succeed. This "democratization" aspect is probably the most difficult to address and introduces the inevitable question of who is providing, operating and commercializing the digital mobility broker. Ideally, it’s a neutral party, acting on the behalf of the DenCity common good.

One key project finding is that existing participants of the logistics eco system are not common to / reluctant to the idea of equal openness and sharing of data. Specific concerns have been raised on topics of liabilities, insurance and secure audit trails of hand-overs in an end-to-end delivery chain involving more than one party facing the end consumer.

The digital mobility broker can be designed extremely broad (resolving “all” functional requirements) or quite basic. Two extremes. This, again, falls back on the remit of the (operator of) the digital platform. Either designed as a fully-fledged control tower with ample application execution capabilities - or an extremely efficient API broker on which any ecosystem partner can develop specific solutions.

Our requirements below take an (example) middle ground, stating basic functionality we believe should be within the digital platform itself, while listing some optional capabilities that could be considered.

It should also be noted that the overall functionality of the DenCity digital mobility broker can / should be implemented at lower hierarchical levels, e.g. within the boundaries of a full-service premises. Same functionality applied to the ecosystem within the building.
3.3.3.2 REQUIREMENTS

The digital platform is the core orchestrator of the eco system and should be designed to:

- Establish an eco-system where end users and providers can be onboarded by a highly automated process. Onboarding should support both technical and commercial aspects.
- Provide integration points with related eco systems to support system-to-system transparency
- Manage (bundled) product offers between/across providers
- Manage (bundled) product offers between/across passenger transport & logistics services
  - mobility packages
  - mobility + logistics packages
  - orchestrate value-add services on top of goods delivery (e.g. install a dish-washer)
- Support multiple business models, based on flexible charging, billing and settlement
- Manage and broker authentication and authorization, including orchestration of digital keys
- Manage and audit transfer of responsibility (liability) between actors in the eco system
- Manage and broker meta data & information - e.g. goods track & trace
- Manage a hierarchy of delivery options (alternative delivery points)
- Manage prioritization of deliveries - express vs budget
- Orchestrate last minute changes to ordered deliveries
- Recognize and manage multiple interactions with the end user, recognizing that many actors in the eco system have a relation with the end user - e.g. through Dencity app, logistics company app, online retailer app, social media app etc
- Take into account “machine learning data input” in order to make increasingly better decisions (e.g. DenCity user preferences, traffic situation, environmental zone regulations)
In addition to the basic requirements above, a mobility broker may very well also support wider use cases related to traffic management and congestion policing:

- Possibly act as a “traffic control centre”
- Possibly include fleet management / dispatching functionality of own or integrated transports
- Possibly optimize route planning, handling of returns and optimize consolidation based on given parameters
- Possibly orchestrate time slots for loading / off-loading in physical mobility hubs

### 3.4 Urban deliveries and services

DenCity targets a convenient and sustainable lifestyle in dense cities without owning or using a car for managing daily needs. The number one challenge within Urban deliveries and services is today’s dramatically increased volumes of e-commerce parcel deliveries paired with constantly rising customer expectations, which calls for efficient and customer appealing delivery services.

The system of DenCity comprises both digital (3.3.3) and physical (3.5.1) infrastructure that supports delivery services. The approach for the developed and demonstrated demo for urban deliveries is therefore based on e-commerce parcel deliveries and a customer driven service design. It is also designed to be a coherent part of the distribution process with both the digital and physical infrastructures of DenCity as well as operating as a stand-alone solution in traditional distribution systems (i.e. business as usual).

#### 3.4.1 CUSTOMER DRIVEN SERVICE

In WP4 the purpose has been to develop and test a subscription service/distribution concept, with the aim to cater for the in- and outgoing freight transport needs of households and smaller businesses without using a car. In line with the overall objective of the DenCity project, i.e. to develop innovative solutions for sustainable passenger and freight transport in dense urban areas, with high demands on attractiveness, accessibility, sustainability and efficiency, the distribution concept developed in WP4 is likely to lead to both positive environmental effects as well as increased quality of life for users and residents.

The whole process from development of distribution concept, to testing and eventually evaluation has been permeated by fundamental features of the Living Lab theory, like multi-stakeholder collaboration, knowledge sharing and user involvement (Schuurman, De Marez and Ballon, 2015). Living Labs is a research domain in development and the current literature stream in the field is somewhat inconsistent and sometimes even contradictory. However, generally it is considered to involve open innovation, exploration, experimentation and evaluation, where open innovation takes place in a process of co-creation with internal and external parties.

The initial steps of developing the distribution concept “full service residential building” involved literature review, trend analysis and workshops, resulting in four different distribution concepts. All suggested concepts were based on a high level of customer service the last/first mile or metre of the parcel delivery. The four concepts were discussed and evaluated in co-creation sessions based on consumer panels with potential users of the future distribution concept. The different solutions have different planning implications in terms of physical infrastructure (see chapter 3.5.1).

The distribution concepts discussed in consumer panels were (see Figure 15):

1. Parcel boxes in the premises of apartments.
2. Integrated reception boxes, where a box is installed in the apartments’ front door which can be opened both from inside and outside;
3. In door delivery, requiring a code locked entrance door to the apartment;
4. Wherever you are delivery, requiring communication via app and an advanced distribution system to be able to deliver or redirect parcel to e.g. a café, a gym or an office.
3.4.2 DEMONSTRATION SET-UP

The fourth distribution concept, with boxes in the premises of apartments (see above) was the chosen concept for the next step in the process, the demonstration phase. As mentioned above, the demo targets both apartment and office buildings with distribution of parcels from PostNord delivered to code locked parcel boxes in shared spaces. The solution is generally perceived as attractive for the stakeholders. However, the investment in parcel boxes together with the uncertainty of the solution’s implementation after the demonstration made several approached stakeholders hesitant.

The final choices of properties were a tenant Property called “Hästskon” and a shared office space, both located in Jönköping. With that settled, the most time-consuming action was the distribution process within PostNord as targets were both a scalable set up, and a good customer experience as close as possible to a launched solution. An external factor that prolonged the demo set up significantly was the new requirements from the Swedish government that PostNord was to set up a process for adding tax on all parcels from e-commerce outside the EU. With a deadline set short in time this unexpected circumstance absorbed all process development resources until it was up and running in steady state, resulting in a delayed launch for the WP4 demonstration.

Another central issue in the set-up the demo was the customer sign up process (with GDPR, which came into force during the demo, in consideration). The objective with the demo is both to gain knowledge and understanding about the whole process in order for the tested solution to be scalable, and to learn about the consumers’ needs, demands, behaviours and acceptance.
As partner for parcel boxes, Renz Sweden was approached and showed commitment to be part of the demonstration. They also contributed with a number of prospects for the demo from their sales activities. Renz offers a complete solution, with a hardware comprising parcel boxes with a touchscreen and a cloud service with interfaces for distribution companies and their drivers, residents in apartments and the property owners, called myRENZbox. It is an independent delivery platform for both post and parcels. It is independent in the meaning of supporting multiple operator processes and could therefore work as a general delivery point for both different parcel couriers as well as for local service agencies and tenant to tenant deliveries.

The parcel boxes are connected to Internet with landlord admin functions. The end users administer their personal accounts at tenant.myrenz.com. The locker system of the parcel boxes is integrated towards multiple entrance access systems so that the same authentication method could be used for accessing the building as well as the boxes. The end users of myRENZbox uses pin code and/or key cards/badges to authenticate themselves. The authentication is done in front of myRENZbox’s so called central unit, a 3.5-inch touchscreen. Notification of customers getting parcels is preferably distributed via app or SMS. However, one necessary compromise in the demo was notification via e-mail. This will be evaluated and although it might not be the most preferred solution, many customers have e-mail in their smartphones.

3.4.3 DEMO PHASE
After thorough efforts to find both the correct physical setting and fine-tune the underlying IT infrastructure, among other things, the demo phase was initiated in early May 2018. As described above the demo consists of two cases: a tenant property and a business hotel, both located in Jönköping. Before the demo started information material was distributed to all potential users. A delegation from WP4 also visited one of the regular tenant meetings to inform about the demo and also answer questions. Before the demo started about 50 residents were registered for the test.

Initially, production disturbances occurred, leading to a need to pull the emergency brake resulting in a total stop of parcel flows. By accident the parcel boxes in the demo was visible as an optional delivery point to people living nearby but not actually invited to this demo. The massive interest of people choosing this delivery option with parcel boxes is a positive indication on future demand and could be interpreted as good matching between customers’ expectations and the delivery solution tested in this demo. To get a controllable parcel flow, test parcels with some giveaways were sent to those users who had registered for the demo.

The approximate ratio of number of boxes in relation to number of apartments is 1 to 10 in the demo. It is based on ratios from other markets however with various differences in prerequisites.
With this ratio, presupposed enough capacity at peak delivery periods it is a quite astounding small space required for a large number of apartments (+300). The demo will continue after DenCity phase 2 is finalized in order to evaluate peaks in number of parcel deliveries and also having the process in action for a planned DenCity phase 3 with additional services with the concept of “Fullservicefastigheten”, full service premises.

The target population in DenCity is a cross section of the population with regard to socio-economic factors. The frame population of this demo is somewhat different from a cross section of the population with a higher age profile and a lower purchasing power. Since the demo is recently launched and will continue during a reasonable period of time, it is too early to report on the socio-economic factors of the sample and consequently to draw any conclusions.

In the demo phase, data collection was made using three different approaches: a user blog (an activity-by-activity based self-report) and a web survey representing qualitative data and activity-based data captured from PostNord’s and Renz Sweden’s production systems representing quantitative data.

In social science, e.g. in consumer behaviour, the use of diaries is an established approach to gain insights and understanding about the lives of individuals (Siemieniako, 2017; Sudman and Ferbee, 1971). One benefit of using diaries is overcoming recall problems, which is a common cause of bias in research methods such as surveys where systematic data is collected. One way to overcome this recall problem is to let respondents/users write self-reports of their experiences and valuations in an open-ended fashion on an activity-by-activity basis (Robinson and Godbey, 1997). Diaries can be used independently or in combination with other research methods (Siemieniako, 2017).

3.4.4 EVALUATION

In line with the Living Lab approach, the demo concept including technological artefacts (parcel lockers) was tested in real life and evaluated. When considering the demo concept based on the users’ value models, an estimation of the potential of the tested concept can be done. The purpose of the evaluation was to provide concrete results that lead to highly relevant recommendations for the future design of the “full service residential building” concept. Three perspectives were covered in the evaluation:

- The distributor’s production conditions related to the demo concept, e.g. how the demo concept applies to scalability, efficiency in operations and resource utilization.
- The users’ assessment of the demo concept in terms of perceptions and valuation, e.g. how is the demo concept perceived regarding convenience, user friendliness, service level, safety and user efficiency.
- The digital interface of the demo concept, e.g. the timing, frequency and content of information communicated to users via the interface. What is the preferred interface (web, e-mail or app)? Should information and communication be based on push or pull principle?

To ensure adequate data capture the following methods/channels have been used for data collection: a blog where users are encouraged to share experiences continuously during the test; e-mail addresses and phone numbers for possible feedback and questions to three WP4 parties (Renz Sweden, PostNord and the School of Business, Economics and Law at University of Gothenburg); IT systems capture data about parcel flows (frequencies, volumes, timings, waiting times, return volumes, etc.); and two user surveys (one during ongoing demo and one after demo completion).

Knowledge about the users’ perceptions and experiences of the tested concept is vital in order to follow up and improve the demo concept to best match the needs and expectations of potential users. How did the test participants perceive the concept of parcel boxes based on their needs and preferences? What problems occurred during the demo period (everything from information, communication, scope and content of demo concept to purely practical issues regarding functionality of the parcel lockers, lighting and security in delivery area, etc. are of interest)?

Initial findings from the first web-based user survey indicate that the production systems of both Renz Sweden and PostNord function according to plan. Only a couple of minor issues related to registration
and authorisation have been reported, while no one has experienced problems related to accessing the parcel lockers. The general perception so far is that the tested concept with parcel lockers is seen as a time saving delivery service with a higher level of service and convenience compared with ordinary pick-up points. Also, the respondents believe that they will increase their share of online shopping when more distributors (e.g., DHL, Schenker, Bring etc.) are let into the parcel lockers. Thereby, the objective of the first of the two user surveys, to ensure production and get initial feedback on the tested concept, is fulfilled. When the demo has been running for a couple of months a more comprehensive user survey will be carried out, allowing a more profound analysis of the users’ attitudes, perceptions, behaviour and preferences, which will be vital knowledge to have as input for refinement and further development of the delivery service.

3.5 Physical infrastructure and integration with urban planning process

The DenCity system, i.e., space-efficient transports for sustainable and attractive neighbourhoods, require collective transport solutions, which consolidate the fragmented goods flows into one system which uses large-scale transport modes for the transport through the urban area to achieve economies of scale, and smaller vehicles for the last-mile distribution, which are adapted to the DenCity environment. In order to achieve this division of work, there is a need for logistics activities, such as sorting, storage and transhipment, both in the target area as well as in suburban locations. These activities require and physical infrastructure, which in turn requires that a stronger consideration of logistics issues in the urban planning process. This section defines the requirements of this physical infrastructure, discusses the implications for business models and the integration of city logistics in the urban planning process.

3.5.1 PHYSICAL INFRASTRUCTURE

Transportation has been divided into different categories for a target group oriented local traffic planning (based on frequency, delivery of goods and so forth) with different groups having different needs for accessibility, see Figure 17. The claim to surface area nearest to the buildings has to be evenly divided in the DenCity while other functions with a large number of users need to be strategically placed geographically in the area.

![Figure 17. Planning implications for developed solutions](image)
3.5.1.1 DELIVERY AND WASTE

Based on the logistics activities required for collective logistics solutions (see Figure 4) and the accessibility needs outlined above (Figure 17), the following types of an urban logistics infrastructure can be defined (Figure 18).

Urban Consolidation Centre (UCC)
The UCC is the key facility for consolidating the fragmented logistics flows into one system. The goods from different operators are destination-sorted here, i.e. they are sorted in a way that allows short routes with many stops in the same street(s) in the DenCity area. Furthermore, these relatively small goods volumes are consolidated into larger flows so that they are big enough to economically transport them by large-scale modes, such as urban waterways. Hence, the UCC needs to provide space for storage (to match different arrival and departure times) as well as transhipments. The UCC needs to handle incoming and outgoing goods via waterways and road infrastructure. The location of the urban consolidation centre has to allow good accessibility by road and water as well as relatively closeness to the main shippers of parcels, i.e. the distribution terminals of logistics service providers. Since some space-demanding activities take place here, the facility requires a significant amount of land. As closeness to the receivers is not required, it allows a strategically location from where it can serve the whole urban region.

Transfer Platform
The transfer platform (TP) is the gateway to the DenCity area. Here the destination-sorted loading units are transhipped from the vessel to smaller vehicles such as cargo bikes or micro vans take place. To match different arrival and departure times of vessel and last-mile vehicles, a storage area is required. The TP has to be in the DenCity area with access to water to allow for both transhipments and short distribution distances to the receivers. On the other hand, the TP attracts many vehicle movements, and hence should not be located in a sensitive area. The negative effects of the TP can be minimized for other urban demands such as mobility for pedestrians along the river by designing it as a temporal TP, i.e. a waterfront side that is only used a limited period of the day. In this way, it allows optimized and flexible supply chain on the receiving end regarding space requirements. If space is available for a permanent physical facility, additional logistics activities can be placed here, such as pick-up point for packages or stocking of goods for nearby retailers, creating optimized and flexible supply chain on the receiving end regarding delivery times. The TP can also be combined with other functions like facility management which also may serve as a way to create an even workload for employees.
Loading zones
Loading zones are areas where distribution vehicles can be parked close to the receiver. From here the last-meter of the delivery takes place: The shipment is unloaded from the vehicle (de-consolidation and transhipment from vehicle to curbside) and transported manually to the building. Loading zones have to be available on all streets in the DenCity area.

Goods reception
Goods reception areas allow access to an (unmanned) storage area in the facility of the receiver’s address. Access is granted to both delivery company and receiver (e.g., with digital keys for recipients, or delivery to cars), allowing flexible deliveries without the limitations of delivery time windows or failed deliveries.

3.5.1.2 PASSENGER TRANSPORTATION
A high level of transportation will occur with public transportation. Public transportation should be designed for a high level of capacity and service both inside and outside of DenCity.
Design for a high number of bicyclists and its varying speeds as well as the design for bicycle infrastructure and parking. There is a large potential for broadening bike sharing schemes with a variety of bicycle models (conventional bikes, electric bikes, cargo bikes and so forth).
Allow a buffer in capacity for planned MaaS services (a high number of carpool and car rental users, space for services and so forth).

3.5.1.3 CHALLENGES
A comprehensive policy decision-making scheme regarding goal conflicts between policies and urban development as well as market and user preferences:
Which parameters should be used to optimize the DenCity-system? Should the urban qualities correspond on a city level? Should the economic aspects be analysed on a city level and/or for the individual user? (Example: if the criterion is a reduced number of travelled distances in the area then this could lead to more heavy traffic. Is the criteria less heavy traffic then that could lead to longer travelled distances within the area)?

Generating policies around:
The degree of flexibility and responsibilities in regard to DenCity compared with conventional supply chain logistics (namely does DenCity have to be perceived as beneficial for every individual user?). Deliveries carried out all the way to the end user (based on fuel type, minimum filling factor, time of the day, size of the vehicles, etc).
The degree of flexibility and management in the DenCity supply chain regarding the flexibility of the end user compared to benefits as a whole.

Technology
Comprehensive decisions regarding the size should be taken into account. In regard to the physical size, the decision-making process is usually inverted, as there’s usually no surface area for expanding successively. Requirements for the layout, dimensioning and sizing should, therefore, be included in the detailed planning process and the dimensioning of an area where the functions and size may evolve organically to meet the needs.

Future opportunities: Technology in the facilities and vehicle selection. There is little knowledge of tomorrow’s technology as well as market preferences, so locking up to one system may be a mistake.

With regards to passenger transport, there is an established structure and the challenge mainly concerns creating more attractive solutions. The remaining chapter hence focus on further development of freight transport.

3.5.2 BUSINESS MODEL FOR URBAN CONSOLIDATION CENTRE
In Europe, it has initiated many projects to build systems for consolidation of goods with the aim of reducing the number of vehicle movements in the city. Most of these have been supported during the initial phase, but very few have survived when the external funding has ended. A major challenge is to
create structures and opportunities for a robust business model. Within DenCity, values and problems have been highlighted from a business perspective.

In the work with the business model, focused has been on the business around the Urban Consolidation Centre (UCC). Six different perspectives were highlighted through a Business Model Canvas (BMC) and Value Proposition (VP) for each perspective. Business Model Canvas and Value Proposition in six different perspectives are reported (in Swedish) at www.dencity.se A number of workshops were conducted with a broad participation and reference groups and reference persons were engaged between the workshops.

**SOLUTIONS:** The result shows that there is a great opportunity to create a robust and self-supporting business model for a UCC. There is some readiness to pay for increased quality in delivery and return of goods as well as handling of waste. Our work also showed that there was a demand for additional services who can utilizing the UCC infrastructure, for example utilization of machinery, real estate services and other businesses that have the advantage of being close to a UCC. These additional services can be an important part of the business model, they can also balance the workload of a UCC during the day.

**CHALLENGES:** The mayor challenge for the business model around the UCC is that it must be developed gradually, and it is also not currently included in today’s freight chain. Initially, revenue streams are not enough to carry the business model. However, there are so great values to gain for society (for example, reduced congestion, pollution and noise), for property owners (a better street environment increases the value of the property) as well as for carriers to UCC (which can deliver to a UCC at any time instead of dispersed addresses in a neighbourhood) that a contractual or legal regulation that creates an economic foundation funding for a UCC is well motivated.

### 3.5.3 INTEGRATION OF CITY LOGISTICS INTO URBAN PLANNING PROCESS

Based on the established project management methodology (XLPM), the project has examined the possibility of establishing an approach to identify where in the urban development process solutions for City Logistics (freight and waste logistics) for a development area need to take place.

The project was implemented in three parts:

1: **Adaptation** to XLPM-methodology-effect chain: Based on the target image of an urban development area, a chain of effect goals, utilities, abilities, results and activities were identified. 2: **Stakeholder** and requirements analysis: Based on the result from part one, an analysis has been made of which stakeholders need to be involved in the urban development process and what requirements are essential to ensure that City Logistics’s are achieved as a part of the area targets image. 3: **Effect Chain Adaptation to the City Development Process:** Based on the result from part one and two, we identify where in the urban development process the results which were identified need to be implemented.

The work has resulted in a methodology consisting of 5 steps, which has been tested but not verified, see figure 19 below (in Swedish).

**STEP 1** On the basis of the directive for the development area, formulate effect goals and utilities
**STEP 2** Break down utilities to abilities and results
**STEP 3** Identify tools (i.e. legislative, strategic) in order to implement results in the planning process
**STEP 4** Identify key stakeholders responsible for realizing the results
**STEP 5** On the basis of the analysis in step 3, identify where in the urban development process results need to be implemented

Some key findings from the project are lessons learned and conclusions drawn from developing the methodology, which has also been the basis for a review of the method. This has resulted in that step 3 need to be implemented earlier in the process, as well as a review of step 2 and 4 where it becomes important to find the right level of detail to be able to calibrate the results and deliverables against the urban development process without it becoming too vague. The project has contributed to optimizing the work process significantly and thereby increasing the overall application of the method, which makes it more accessible to other cities/projects to use. The method is not solely specific for city logistics but can be applied on different themes that need to be addressed in the urban development process, thereby increasing the area of usage to which the method is applicable.

Given the projects allocated time and resources we have not been able to fully verify the method, as this
would have called for a more comprehensive study. Furthermore, the project has not verified that the method actually results in a more effective integration of city logistics in the planning of new areas with a reduced risk of issues being overlooked, as this would require a test of the method on a real case and a follow up after the implementation phase. Still, we believe that the methodology in its current state can be used to support the process of integrating city logistics and other thematic issues in the planning process.

3.6 Effects and system evaluation

In order to assess the sustainability performance and land-use efficiency of the DenCity solutions (WP 1-4), a case study was defined which calculates the external costs and land demand of the urban transport activities in the DenCity area (see ‘Appendix – System Evaluation’ for details on method and results). Due to lack of data, a high data uncertainty and limitations in terms of methodology, the results in terms of external costs and space demand are highly uncertain. However, the results still reveal the general effects of the DenCity solutions in high-density urban areas where residential and offices are the dominating forms of land use. Taking these limitations and this context into account, the general observations are the following:

- The biggest sustainability challenge of urban transport are congestion, noise and space consumption. Air pollution, accidents and climate change play a minor role.
- Most of the externalities are generated and imposed on the urban network, the externalities in the area where the solutions are implemented are relatively small in comparison to the impacts of the whole urban transport chain.
- Passenger cars and service vans dominate the externalities and space demand, the share of urban deliveries is relatively small.
- Electrifying trucks and vans reduce noise and eliminate climate change but cannot mitigate increasing congestion problems on urban access roads and space conflicts in dense urban areas. In fact, the demand for increasing service levels of receivers of e-commerce deliveries may actually increase logistics traffic and land consumption if conventional deliveries to pick-up points are replaced with deliveries to the receivers’ doors.

**Figure 19. Planning implications for developed solutions**
• In order to reduce traffic and space consumption requires consolidated deliveries. However, limiting this consolidation on the target area has limited effects in terms of total externalities generated in the whole urban area, as most of the externalities are caused on the urban network. Hence, strategies for sustainable urban logistics for dense and attractive neighbourhoods require to go beyond the target area and to consider the whole urban transport chain. Along this transport chain using different modes of transport which are adapted to the differing operational conditions is key: Transport to and from the target area should be consolidated to achieve transport volumes big enough for large-scale transport modes such as urban waterways or big trucks, while small-scale vehicles such as electric micro-vans and cargo bikes are assigned to last mile deliveries in the target area. A remaining challenge for urban logistics in dense neighbourhoods are service visits which are by far the biggest user of urban space and source of externalities. This highlights the need for mobility management solutions for this sector, e.g. by including services in MaaS solutions (see chapter 3.3.1) and building-based services (see chapter 3.4).

4 DISCUSSION OF RESULTS AND LEARNING AT SYSTEMLEVEL

The ongoing densification create enormous challenges for cities and all the involved actors. At the same time the challenges open up for opportunities to develop, test, evaluate and further on implement innovative sustainable transport solutions, new possibilities for cooperation and more efficient planning. The addressed issues in the DenCity project are complex, and cooperation between authorities (local, regional and national), industry and academia are a vital prerequisite. During the initiation phase and second phase of the DenCity project (UDI phase 1 and 2) it has become quite clear that the different professions involved, in this case city planners, traffic planers and freight professionals are traditionally working in “silos”, with little or no interaction. The collaboration arena that projects like these provide is one way of opening up the borders between different authorities and involved organisations, increasing the knowledge sharing, creating a dynamic collaboration environment and in the long run enable a more efficient planning. Furthermore, innovation projects where several actors are involved contributes to raising the issues on the urban mobility agenda. In the second quarter of 2018, the Swedish Government published a Strategy for Liveable Cities - Politics for Sustainable Development in Cities - a strategic document including efficient freight transports in cities and referring to the coming national freight strategy. Freight is now starting to appear on the urban development agenda, and when implementing innovative solutions in small scale – this creates the basis of wider awareness.

Different enabling technologies are evolving rapidly, whereas new ways of planning, rules and legislation, business models and infrastructure takes longer time to adapt/implement. The challenge for cities is to implement a physical planning that enables the new technology, and stakeholders from academia and Industry must together with the cities show how the technology and services can be used. If this will be done in a successful way this will lead into larger, societal changes (see Figure 3 chapter 2.3). Due to do this, demonstration of new solutions and business models for urban mobility is an important part of the transition to a more sustainable system as it provides valuable information to involved actors.

POLICY AND URBAN DEVELOPMENT

A flexible approach is needed in order to build a resilient and robust city, but flexibility also demands large and sometimes in the long run unnecessary investments. This also relates to the fact that services and infrastructure needs to be in place when residents are starting to move in, even though a larger volume is needed for an economically viable business model. There is a lack of data, mainly for freight, in order to plan, calculate and dimension sufficiently. For example, increasing e-commerce flows and levels of service- and maintenance vehicles will require new ways of planning the residential areas, but since solutions such as those demonstrated in this project (see chapter 4.4) still are in rather early stages - it is hard to say to what extent and how much space that will be needed. This is a typical “hen and egg” issue, as sufficient data and information is needed early in order to make the right decisions and for example set policies and decide on what solutions to use and the other way around.
Related to urban development, the discussions during the 2.5 yearlong DenCity project have covered key infrastructure for barges and multi-modal solutions, charging infrastructure for electric vehicles, nodes for consolidation and both physical and digital infrastructure for mobility- and delivery services. Below follow key lessons learned:

• When working in close cooperation with a specific case, as with Frihamnen in this project, and elaborating on specific measures, transport solutions and policies to implement - it has become quite clear that opening up the process for dialogue, involve new kinds of actors and perspectives is key in order to be prepared for different scenarios and to create solutions with societal benefits. Traditional separation of fields (logistics sector has little knowledge about urban planning, and urban planners have little knowledge about logistics) is a big barrier for progress - even though awareness and willingness for cooperation is there, finding a common ground to get to action is difficult.

• The service development process for the mobility- and home delivery services has resulted in several lessons learned such as; the need for early regulation and policy discussions in order to plan for efficient last mile transport solutions (e.g. obligation to use UCC or not); the planning process needs to be more inclusive in order to cope with the transformation towards mobility services rather than traditional parking norm.

• Innovation projects where several actors are involved contributes to raising the issues on the agenda. And even though there is a lack of data, a more generic conclusion can be drawn that physical infrastructure is key for system integration - as integration is achieved through logistics activities (consolidation, transhipment, sorting, storage, etc.), which require a physical infrastructure in the neighbourhood.

• Lastly, space-efficient transports for sustainable and attractive neighbourhoods require collective (integrated) transport solutions, as the evaluation shows that independent solutions (BAU) lead to too much traffic. The urban planning plays a significant role for enabling system integration and to create space for logistics- and new mobility solutions.

TECHNOLOGY

Several different technologies have been included in the project and a first general conclusion can be drawn that the timing for testing and introducing the demonstrated and developed solutions to the market is good, although the level of maturity differs somewhat. Related to the maturity of the technology, the following lessons learned can be drawn:

• There is a market demand for electric distribution trucks (both nationally and globally), although if a majority of all goods and waste transports in urban environments should be based on electrified vehicles in a future scenario, there is a need to rethink rules, regulations, business models and infrastructure. The demonstrated distribution truck is ready for industrialisation, however there is still a lot of research, investigation and testing to be done related to the new changes at system level that is needed in order for the technology to be implemented on a larger scale - such as route optimisation and charging infrastructure.

• There is a strong demand both locally and nationally for increased multi-modal transport solutions including barges in city logistics, but lots of areas for further investigation and development before the solution is ready to start being used and implemented in a larger scale, see chapter 4.3.2.

• There’s a catch 22 problem when taking the first step into contracting a mobility broker. The mobility broker needs a big enough customer base to be able to negotiate a bulk good price with mobility providers. Mobility services can more effectively be integrated in new developments, but these lack the initial volume of consumers. This requires that the services are initially subsidised during a transition period when the residents and therefore customers are moving in, i.e through a mobility fund. The demand is there (locally, nationally and globally) but in order for the solutions to be scalable and implemented in real estate- and urban development projects tests in smaller scale is important in order to learn and dare to take the leap, and in the long run implement in larger urban development projects such as Frihamnen.

• We currently see an exceptional increase of e-commerce flows, which implies that the dimensioning of for example parcel lockers in real estates is complicated - as the prognosis for future goods flows are hard to estimate. In this project only, parcels have been included in the demonstrated and evaluated solutions, however many argue that the large volumes and with that larger potential for positive system effects will come when also finding similar delivery solutions for
unmanned grocery deliveries. What we know is that it is clear that a transition from traditional delivery points to new solutions, such as for example delivery to your home, trunk, closets parcel locker is happening. From a technological perspective, parcel lockers and similar solutions are available but when it comes to finding solutions that are available for multiple transport operators to use and creating a successful business model, more research and investigation is needed.

MARKET & USER PREFERENCES
As argued in the introduction chapter, individuals working and living in urban areas have increased demands on high-level transport and mobility solutions and are demanding more individualised transport- and delivery solutions. New tech-solutions and services are developed constantly in order to meet these changes user preferences, and new urban development projects need to have an inclusive approach to these new solutions. Key learnings related to market, user preferences and business models from the project follows below:

- There need to be a customer base available to pay for services from start, which requires that the services are initially subsidised during a transition period for example using a mobility fund.
- New actors and actor constellations are emerging when shifting towards more service-oriented mobility solutions, for example property owners are getting more and more involved in providing services to tenants. When DenCity phase 2 started up, a planned deliverable from WP3 was business model for MaaS solutions, but during the project time it has become clear that it is more interesting and correct to work with business ecosystems rather than single business models due to this transition.
- Related to above, there has been several discussions during the project about emerging possibilities such as local entrepreneurship and new types of roles in urban areas that are being developed for lower car ownership and with more focus on service. For example, urban consolidation centres and nodes for transport and mobility services could also provide additional services such as home delivery, removal of wrapping, assembly of goods - which opens up for new types of roles and possibilities for a “mobility broker”.
- As said in chapter 4.4.4, knowledge about the users’ perceptions and experiences of the tested concept is vital in order to follow up and improve the demo concept to best match the needs and expectations of potential users. As the demo was delayed, only preliminary results have been gathered at this point, but a more comprehensive user survey will be carried out when the demo has been running for a couple of months (after the project has ended), allowing a more profound analysis of the users’ attitudes, perceptions, behaviour and preferences, which will be vital knowledge to have as input for refinement and further development of the delivery service.
- Regarding electric distribution, the market and cities have responded in a very positive way so far. However, issues such as for example business case, legal aspects, service-development are also still very immature. The challenges for Volvo and all OEMs with this technology are also different compared to combustion engines. Focus will shift from driveline, service contracts and spare parts to optimal specifications, range predictions and new business models.

5 DISSEMINATION AND IMPACT

The strategic communication goals during the project have been to create a role model and good example for development and implementation of innovative and integrated transport solutions for goods, waste and people in dense cities, and in the long run contribute to strengthening the Swedish competitiveness in urban mobility. More specifically, sharing knowledge and recommendations in order to contribute to:

- decreased fragmentation of transport flows in cities
- increased usage and sales of electric vehicles for goods distribution in cities
- increased usage of urban waterways
- increased consolidation of e-commerce flows
- promote service-development for mobility and deliveries
- promote enabling technology such as digitalisation for mobility- and delivery services
The project partners have been very active in presenting the project and its results at conferences, seminars and other relevant occasions (both locally, nationally in Sweden and internationally). The project and its approach, holistic perspective and results is very relevant, both in Sweden but also internationally, and has raised a lot of interest. An important tool for dissemination and spreading project results has been visualisations, filming the different demonstrations (see DenCity.se) but also through communication about the project in social- and traditional media.

DenCity has impacted different strategic research agendas and technology platforms both at national but also European level, mainly through contribution in terms of learnings, interest from stakeholders and through highlighting further areas for research and development. The project has been invited to present its results in different governmental forums, both in Brussels but also at the Swedish Government Office. Through continuous dialogue with the reference group, CLOSER Round Table: Urban Mobility, the project has reached a broad group of Swedish stakeholders and its results has helped to move the positions onwards also for actors that’s not directly involved in the project.

The project has also resulted in several spinn-off projects and indirect results have had a positive impact for involved project partners or stakeholders, to mention a few:

- Volvo Cars: Attending the DenCity project has given great insights about how modern city planning has an impact on personal mobility and that it will affect the future product lineup of Volvo Cars. These insights have been one of the reasons for making the XC40 shareable through the Volvo on Call app.
- A Mobility Forum has been founded within the city of Gothenburg, with representatives from several different authorities, focusing on new urban development projects and related mobility and transport issues and which several involved actors have pointed out DenCity as an inspirational example.
- DenCity has served as a reference point for raising the awareness of the addressed issues in Sweden for the last couple of years. The DenCity project partners has been very active in networking with other actors working with integrating MaaS and city logistics with urban development.
- For Volvo Group and partners, the DenCity project has pushed the development further for example by showing the actual demand from other involved parties. The project has also helped to identify the need to work with new solutions for charging infrastructure, from a more systematic and logistical approach and has for example resulted in the spin-off project ELLOG (https://closer.lindholmen.se/en/projects-2/ellog).

6 FURTHER RESEARCH AND DEVELOPMENT: PHASE 3

The results from this two-and-a-half year long project shows that there is a need for change in perspective, and that the transition to an integrated city- and transport planning is not happening overnight. This means that there is a necessity of very long-term perspectives. However, when implementing innovative solutions in small scale – this creates the basis of wider awareness. Based on synergies between different pilots and when transferring knowledge between cities we can start to scale up and actually implement the solutions as fully functional parts of the city transport system. The consortium in the DenCity projects aims for a next phase and will apply for a third and final stage within UDI. Phase 3 of DenCity will take its starting point in the developed solutions and will continue to strive towards an implementation of smart urban mobility and logistics solutions through a broad approach and the initial draft application includes:

- Scaling up the test- and pilots with fully electric distribution and refuse trucks on more markets
- Joint conceptualisation of how urban waterways can become a natural part of the urban freight system in the two largest cities in Sweden
- Conceptualisation and innovation procurement for a UCC servicing a new urban area under development including additional services such as shared solutions
- Consolidated home deliveries utilizing physical and digital infrastructure available for multiple transport operators, focus on return flows and space-utilization in real-estates
• Testing business models and roles for a so-called "Mobility broker" in a real context, based on commercial terms and with real users
• Generalization, dissemination and management: Establishment of a forum for exchange of experience, joint understanding of best practice for freight and transport issues related

7 REFERENCES


McCahill et. al. (2016). Effects of Parking Provision on Automobile Use in Cities: Inferring Causality. Transportation Research Record: Journal of the Transportation Research Board


GLOSSARY AND LIST OF ABBREVIATIONS

Detaljplan: Zoning plan or local plan
BrF: Bostadsrättsförening. Homeowners association.
Byggherrarna: Real estate developers.
Byggnadsnämnden: Local building committee
Fastighetskontoret: Property Management Administration
SBK: Stadbyggnadskontoret. City Planning Authority.
TK: Trafikkontoret. Urban Transport Administration.
ÄU: Älvstranden Utveckling.
K&V: Kretslopp & vattenförvaltningen. Department of sustainable waste and water
APPENDIX 1: System evaluation

In order to assess the sustainability performance and land-use efficiency of the DenCity solutions (WP 1-4), a case study is defined which calculates the external costs and land demand of the urban transport activities.

Method and approach
The case used for this study is the area of Frihamnen. As this area is not built yet, it is not possible to use primary data on transport and traffic flows for this area. Hence, data from a traffic count in the area of Vasastan in Gothenburg is used, which represents similar characteristics in terms of land use (density and mix of residents, businesses and offices) compared to the intended land use and density of the Frihamnen area. The case study includes three main steps:

1. Estimating the demand for transport: The first step includes the estimating of the number of 1) passenger trips to and from the area, 2) deliveries and pick-ups of parcels, 3) deliveries and pick-ups of pallets and 4) service visits. The demand for transport is generated by private residents, offices and businesses (shops, cafés, restaurants, etc.) Data sources used are planning documents for Frihamnen (to estimate number of residents, offices, etc.) and freight trip generation literature (to estimate the amount of deliveries per business). The output of this step is the amount of passenger, parcel, pallets and service trips (including to and from the area).

2. Estimating the resulting traffic: This step converts the number of trips into vehicle movements, e.g. the number of vehicle routes necessary to deliver the trips estimated in step 1. The data sources used in this step is the traffic count data from the city area Vasastan in Gothenburg, as well as secondary data on vehicle routes and fill rates. The output of this step is number of van, truck and passenger car movements to and from the area per hour of the day.

3. Assessment the traffic’s external impacts and land demand: The final steps assess the external costs of the vehicle movements from step 2. Impacts assessed are climate change, air pollution, noise, accidents and congestion. Furthermore, the demand for land (parking time in the area) is estimated as well. External cost data used for the assessment is based on Ricardo AEA (2014).

SCENARIO DEFINITION
This case study considers four types of urban transport, which are assessed in four scenarios, see Table 1 below. The transport types considered are 1) the delivery of parcels by vans, 2) the delivery of pallets by trucks, 3) maintenance and service activities by vans, and 4) passenger cars. The first scenario (business-as-usual ‘BAU’) represents today’s operations based on internal combustion engines, low delivery service, fragmented logistics and a significant role of the passenger car for urban mobility. Scenario 2, 3 and 4 take a long-term perspective (year 2030) and assume a large-scale implementation of the DenCity solutions. The differences of the scenarios for each transport type are described below.

<table>
<thead>
<tr>
<th>TRANSPORT OF PARCELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>This transport type includes deliveries of small units from both logistics service providers as well as from retailers with own-account transport operations. These include home deliveries from e-commerce, e.g. parcels and grocery bags (business-to-consumer B2C), as well as smaller deliveries to businesses, e.g. shops, offices, etc. (business-to-business B2B). Figure 1 shows the logistics setup of these deliveries in the scenarios of this case study.</td>
</tr>
</tbody>
</table>

Table 1: Scenario definition
In the BAU Scenario, the deliveries are executed by vans (<3.5 tons), with internal combustion engine as driveline (Diesel Euro 6). There are no consolidation activities, e.g. each operator delivers its receivers with own vehicles. The B2C shipments are delivered to pick-up points, from where the parcels are picked-up by the receivers, by either bike or walking.

In Scenario 1, for all deliveries electric vans are used. B2B shipments are delivered to parcel boxes in apartment buildings, which involves high service levels for the receivers, as they do not need to fetch the deliveries from pick-up points (‘full service residential building’ as developed in WP4). There are no differences in the way of delivering B2C shipments.

In addition to the changes of Scenario 1, Scenario 2 also includes an urban consolidation center in the DenCity area, from where both B2B and B2C shipments are delivered to the receivers in a consolidated way. B2B deliveries (which tend to be relatively big and hence relatively few stops on one route), are delivered by electric micro vans, while B2B shipments (which tend to be relatively small and hence have many stops per route) are delivered with cargo bikes.

In Scenario 3, the UCC is placed in a suburban area, from where the shipments are transported on a barge (urban waterways as developed in WP2) to the DenCity area. The distribution is done in the same way as in Scenario 2.

Figure 1: Transport of parcels - Scenario 1 (top), scenario 2 (middle), scenario 3 (bottom)
TRANSPORT OF PALLETs
This transport type includes deliveries of larger volumes from both logistics service providers as well as from food retailers. These include deliveries of pallets businesses, e.g. shops, restaurants, cafés, etc. Figure 2 shows the logistics setup of these deliveries in the scenarios of this case study.

In the BAU Scenario, the deliveries are executed by medium-duty-vehicles (MDV, < 26 tons), with internal combustion engine as driveline (Diesel Euro 6). The deliveries are executed during daytime.

In Scenario 1, the Diesel MDVs are substituted with electric trucks (‘Zero emission distribution’ as developed in WP1), and in Scenario 2 the deliveries are also shifted to night-time. There are no further changes in Scenario 3, i.e. it is equal to scenario 2.

![Figure 2: Transport of pallers - Scenario 1 (top), scenario 2 (bottom).](image)

PASSENGER CARS
This transport type includes passenger trips by car. The driveline of the car is an internal combustion engine (50% Diesel Euro 6, 50% Gasoline Euro 6). The modal share of passenger cars is 35% (the remaining 65% of passenger trips are performed by other modes, e.g. public transport, walking and cycling).

In Scenario 1, all passenger cars are electric. Furthermore, there is no need anymore for a private car, as infrastructure and mobility solutions are fully implemented (as developed in WP3 ‘Mobility as a Service’). Hence, the modal split of passenger trips by car is reduced to 10%. There are no further changes in Scenario 2 and 3, i.e. they are equal to scenario 1.

SERVICES
This transport type includes all service visits to residents, offices and businesses (shops, cafés, etc.). Service visits include all commercial vehicle movement which do not have the delivery of goods as core activity and usually require some kind of activity at the premises. These include for example cleaning,
maintenance, repairs, etc. Service visits are executed by vans with internal combustion engines (Diesel Euro 6). As service visits are not addressed in the DenCity solutions, there are no changes in the logistics setup of these operations in the scenarios, except for the driveline which is assumed to be electric in all scenarios.

EVALUATION RESULTS
Some general results from the evaluation include that most of the external impacts are generated when driving to and from the area on the urban network (e.g. urban access roads). The externalities generated in and imposed on the target area where the solutions are implemented are generally small (approximately by a factor of 10). An additional general observation is that congestion and noise impacts dominate the externalities, while the impacts on climate change, air pollution and accidents are relatively small in the context of this case.

IMPACTS PER UNIT DELIVERED
The effect of the scenarios on the impacts per parcel delivered to the DenCity area are displayed in Figure 3. The conventional way of delivering parcels imposes significant externalities on the DenCity area, from which congestion, noise and climate change are the most significant impacts (BAU). Introducing electric vehicles eliminates climate impacts and reduces noise, but the shift from pick-up points to deliveries to the apartment buildings leads to more traffic and hence more impacts on accidents and congestion (Scenario 1). Reducing these impacts in the DenCity area, requires consolidated deliveries with vehicles which are adapted to the urban environment (Scenario 2). However, the total improvement potential of these solutions is limited as they do not have any effect on the impacts generated on the network. Reducing these impacts which are dominated by congestion and noise requires consolidated deliveries on urban waterways (Scenario 3).

Figure 3: External costs (in €-cent) per parcel delivered by impact type and scenario in the DenCity area (left) and in the urban network (right).

The effect of the scenarios on the impacts per pallet delivered to the DenCity area are displayed in Figure 4. Delivering pallets with conventional trucks contributes to congestion and noise in the DenCity area and also contributes to climate change (BAU). Electrifying the vehicles are a promising solution for eliminating climate impacts and reducing noise impacts, however, electrification alone cannot mitigate congestion impacts (Scenario 1). These can be reduced by off-hour deliveries, but these lead in turn to higher impacts from noise (Scenario 2).
Figure 4 External costs (in €-cent) per pallet delivered by impact type and scenario in the DenCity area (left) and in the urban network (right)

EFFECTS ON TOTAL IMPACTS
Analysing the total impact of all logistics operations (including both deliveries of pallets, parcels, services and passenger cars) through the whole urban area (including the trips through the urban area and the trip within the DenCity area), reveals passenger cars dominate the external impact, while service visits and deliveries of parcels and pallets play a minor role (Figure 5). Accordingly, reducing the modal share of passenger cars from 35% to 10% has a significant on the total externalities. Furthermore, the combined DenCity solutions (Scenario 3) practically eliminate the external effects of both pallet and parcel deliveries.

Figure 4 External costs (in €-cent) per pallet delivered by impact type and scenario in the DenCity area (left) and in the urban network (right)
Regarding the space efficiency it can be observed that service visits are dominating the demand for space in the DenCity area (Figure XX6-a). This is due to the fact that services require much more time per visit than loading or unloading of pallets and parcels, and hence occupy the space for a longer time. Furthermore, it shows that the combined logistics solutions (scenario 2 and 3) significantly reduces the total space demand for deliveries. Still, the total demand for space including both passenger cars, deliveries and service visits is probably still at problematic levels, as the demand reaches capacity limits during long period of the day (Figure 6b).

![Figure 6: Space consumption (in vehicle-hours) in DenCity area (on-street parking) by transport type (a) and by hour (b)](image)

**CONCLUSIONS**

The goal of this case study was to assess the improvement potential of the DenCity solutions on the sustainability of urban transport. Due to lack of data, a high data uncertainty and limitations in terms of methodology, the presented results in terms of external costs and space demand are highly uncertain. However, the results still reveal the general effects of the DenCity solutions in high-density urban areas where residential and offices are the dominating forms of land use. Taking these limitations and this context into account, the general observations are the following:

- The biggest sustainability challenge of urban transport are congestion, noise and space consumption. Air pollution, accidents and climate change play a minor role.
- Most of the externalities are generated and imposed on the urban network, the externalities in the area where the solutions are implemented are relatively small in comparison to the impacts of the whole urban transport chain.
- Passenger cars and service vans dominate the externalities and space demand, the share of urban deliveries is relatively small.
- Electrifying trucks and vans reduce noise and eliminate climate change but cannot mitigate increasing congestion problems on urban access roads and space conflicts in dense urban areas. In fact, the demand for increasing service levels of receivers of e-commerce deliveries may actually increase logistics traffic and land consumption if conventional deliveries to pick-up points are replaced with deliveries to the receivers’ doors.
- In order to reduce traffic and space consumption requires consolidated deliveries. However, limiting this consolidation on the target area has limited effects in terms of total externalities generated in the whole urban area, as most of the externalities are caused on the urban network.
Hence, strategies for sustainable urban logistics for dense and attractive neighbourhoods require to go beyond the target area and to consider the whole urban transport chain. Along this transport chain using different modes of transport which are adapted to the differing operational conditions is key: Transport to and from the target area should be consolidated to achieve transport volumes big enough for large-scale transport modes such as urban waterways or big trucks, while small-scale vehicles such as electric micro-vans and cargo bikes are assigned to last mile deliveries in the target area. A remaining challenge for urban logistics in dense neighbourhoods are service visits which are by far the biggest user of urban space and source of externalities. This highlights the need for mobility management solutions for this sector, e.g. by including services in MaaS solutions (see chapter 3.3.1) and building-based services (see chapter 3.4).
APPENDIX 2:
Energy measurements for electric distribution truck

This Appendix refers to chapter 3 “Results and developed solutions” under 3.1 Zero emission distribution.

Three different tests were performed in a confined area at Volvo premises at Torslanda, Göteborg. It was carried out under the following conditions:
One lap of roughly 3.2 km was driven twice with at least one stop after every lap. This was defined as one cycle. Results from each cycle were recorded and these figures below show an average of three cycles. Variation for each lap was relatively low.

Tests 1 and 2 had six stops and Test 3 had 42 stops. The tests were performed as explained below:

Test 1: No freight load* and no fridge unit engaged.
Test 2: No freight load but with fully engaged fridge unit at full boost.
Test 3: No freight load and no fridge engaged but with “stop-and-go” cycles of 42 stops.

*) For safety reasons it was unfortunately not possible to load any weight in the box.

The table below shows the results for the different test cycles. Results are displayed as an average value for each cycle.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST 1</th>
<th>TEST 2</th>
<th>TEST 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy cons. (kWh/100 km)</td>
<td>68</td>
<td>87</td>
<td>77</td>
</tr>
<tr>
<td>Estim. range (km)</td>
<td>151</td>
<td>118</td>
<td>133</td>
</tr>
<tr>
<td>Time (min)</td>
<td>32</td>
<td>31</td>
<td>42</td>
</tr>
<tr>
<td>Mean speed (km/h)</td>
<td>39</td>
<td>39</td>
<td>29</td>
</tr>
<tr>
<td>Total dist (km)</td>
<td>20.5</td>
<td>20.5</td>
<td>20.5</td>
</tr>
<tr>
<td>N:o of stops</td>
<td>6</td>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td>Stop time (s)</td>
<td>94</td>
<td>121</td>
<td>225</td>
</tr>
<tr>
<td>Mean Aux (W)</td>
<td>2287</td>
<td>8008</td>
<td>2217</td>
</tr>
</tbody>
</table>

Table 1. Test results. Temp: +28°. Sunny weather. Boost temp from +22 to +2°.

DISCUSSION:
This was the first measurement of a Volvo FL electric on highway conditions. The mean speed was around 30-39 km/h and the maximum speed was 70 km/h. The estimated range with the type of driving we performed here is calculated based on a usable SOC-window of 70% of 150 kWh usable installed energy. 70% is the smallest window. It could be higher also. Note though that the driver was not a professional driver and not trained for this vehicle nor any eco-driving. This means that the ranges could possibly be further extended. The cooled box was closed at all times (test 2).
Adding freight load will however reduce the ranges so a commercial test is needed to get a better picture of realistic ranges and actual energy consumption in commercial traffic.
CLOSER is a Swedish platform for collaboration, knowledge and innovation for increased transport efficiency. The results of our work are new solutions for the freight transport system needed to build a sustainable society.

CLOSER is hosted by Lindholmen Science Park.

For more information & contact:
Lina Olsson, Project Manager DenCity
lina.olsson@lindholmen.se