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HARMONY

Holistic Approach for Providing Spatial & Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era

D6.4 Applications of the freight tactical simulator and forecasting

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Responsible Author(s):	Michiel De Bok (TU Delft, Significance), Ali Nadi(TU Delft)
Responsible Co-Author(s):	Lorant Tavasszy (TU Delft), Sebastiaan Thoen (Significance), Sofia Giasoumi (Significance)
Peer Review:	Jos Streng (Rotterdam), Barry Zondag (Significance)
Quality Assurance Committee Review:	Maria Kamargianni (UCL), Emmanouil (Manos) Chaniotakis (UCL)
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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ABM	Agent Based Model
AR	Autonomous (delivery) Robot
B2B	Business-to-business
B2C	Business-to-consumer
C	Consumer
CEPs	Companies of Express and Parcel deliveries
CL	City logistics
CO2	Carbon dioxine (emissions)
DC	Distribution Centre
EB	Electric Bicyle
GHG	GreenHouse Gases
hh	Household
LCV	Light Commercial Vehicles
LEV	Light electric vehicle
MCA	Microhub Catchment Area
MS	Modelling Suite
P	Producer
QGIS	Geographic Information System software
TAZ	Traffic analysis zone
TFS	Tactical Freight Simulator
TOD	Time-of-day
TT	Transhipment Terminal
UCC	Urban Consolidation Centre

V-MRDH model	Traffic model for the Metropolitan Area of The Hague and Rotterdam
VKT	Vehicle Kilometre
VOT	Value-of-time
ZE	Zero emission
ZEZ	Zero emission zone

EXECUTIVE SUMMARY

Metropolitan areas are faced with the challenge to design and implement innovative solutions to address inefficiencies in the freight and passenger transport system and to cope with pollution, increased travel times, poor regional connectivity and accessibility. New disruptive freight and passenger mobility services are starting to emerge as solutions to transport problems. Against this background, HARMONY's main goal is to develop the HARMONY Model Suite – a spatial and transport planning tool, which will enable metropolitan planning organizations to develop and evaluate policy strategies, prioritize policy measures, analyse new mobility concepts and to lead the transition to a low-carbon new mobility era.

The Tactical Freight Simulator (TFS) is the component of the HARMONY MS that simulates the demand for urban freight transport. The TFS is a multi-agent simulator that represents the decision-making of freight agents on the level of individual firms and individual freight shipments and can be applied to quantify the effect of future scenarios on the urban freight transport system.

Doing so aims to support local authorities such as the City of Rotterdam to ensure sustainable development of city logistics. The general policy objective of metropolitan planning organizations is to ensure the accessibility and livability of the city. And this needs to be achieved in a dynamic environment of city logistics with many innovations in new technologies and services such as drone or automated robot deliveries, or the growth of e-commerce demand.

Challenge in developing such a simulator for city logistics is the wide scope of technological developments. In this deliverable the TFS was applied to the following use cases in city logistics:

- Use case 1: Microhubs
- Use case 2: Zero Emissions Zones
- Use case 3: Crowdshipping
- Use case 4: Spatial planning scenarios for logistic facilities.

Summary of findings

This section summarizes the lessons learned from evaluated use cases in simulation experiments using the TFS component of the HARMONY MS.

Use case 1: Micro hubs

The light electric vans have a higher capacity so on average have fewer tours from the micro hubs; this is considered an operational advantage. The hybrid and full-collaboration models show better vehicle utilisation than the individual carrier model. The full collaboration model with light electric vehicles leads to the fewest vehicle kilometres in and outside the study area.

Use case 2: Zero emission zone

Calculations confirm that emissions are reduced dramatically, by 90%, inside the ZEZ. At the city scale, this corresponds to a reduction of almost 10% of whole emissions produced by freight transport. At a regional level, the reduction of impacts is marginal. Using UCCs reduces emissions within the ZEZ areas but slightly increases the vehicle kilometres travelled (VKT) outside the ZEZ. The rerouting of freight vehicles around the ZEZ or to and from the UCCs can

lead to substantial increases in local freight traffic: this is an important side effect that needs to be mitigated.

Use case 3: Crowd shipping

Crowd shipping could improve the efficiency of the freight transport system in delivering parcels. However, since a large share of crowd-shipping parcels will be delivered by travellers using personal cars, the net impact of crowd-shipping is an increase in total vehicle kilometres particularly in residential areas. The side effects could be mitigated by applying control policies on crowd-shipping platforms and services.

Use case 4: Spatial planning

Spatial planning policy for the allocation of logistic facilities influences freight transport demand, accessibility, and emissions. Centralization of the DCs has a positive influence on the vehicle kilometres. Despite the increasing demand for the new DCs, there will not be enough space in South-Holland to build new industrial areas. Cooperation with the main stakeholders such as regional authorities, local authorities, logistic service providers, and carriers is required to develop sustainable and efficient policies for new logistic facilities.

Conclusions

The application of a new city logistic simulator shows the possibilities of using simulation to study the impacts of new technologies and services in city logistics at system level. The explorations have taught us that although the technology seems to be ready for innovative solutions, the logistical organisation or business models and policies are not yet well developed. Simulation tools such as TFS can contribute to this development by showing potential impacts of system-wide impacts by getting a common understanding of the pros and cons, and barriers, challenges and opportunities of new solutions. This can stimulate the relevant stakeholders in urban logistics to collaborate which becomes ever more relevant and necessary in the age of growing urbanization.

To create more value from the simulations with the TFS, future work can focus on the integration of the different use cases into broader logistic scenarios. These use cases are complementary as micro hubs can be considered in combination with a spatial planning scenario and extended in a scenario with a crowd-shipping service where the micro hubs also serve as a location for the pick-up or drop-off of parcels. By combining the use cases, a holistic logistic scenario is created with consistent assumptions across the use cases. The development of broad logistic scenarios requires regional coordination and the involvement of logistic stakeholders. The results from the individual use cases can be used to feed the discussion between these stakeholders.

1 Introduction

1.1 Project Summary

HARMONY's vision is to assist metropolitan areas with evidence-based decision-making, by providing a state-of-the-art model suite that quantifies the multidimensional impact of various policies, investments and mobility concept applications, while simultaneously identifying the most appropriate solutions and recommending ways to exploit the disruptive mobility innovations. HARMONY proposes an integrated approach through the development of the HARMONY MS, which integrates new and existing sub-models. This integrated approach is necessary to understand if, how and to what extent new policies, investments and mobility concepts can produce results that are in line with the objectives set by authorities.

The HARMONY MS is envisioned as a **multi-scale, software-agnostic**, **integrated activity-based** system that combines various models, which enables end-users such as planners, decision-makers, researchers and transport operators/providers to couple/link independent models and analyse a portfolio of regional and urban interventions for both passenger and freight mobility, including policies and capital investments, land-use configurations, economic and sociodemographic assumptions, travel demand management strategies and new mobility service concepts. The main objective behind the model system's architecture is to enable the evaluation of such interventions with regard to their impact on land-use, economic growth, transportation networks, energy, vehicular noise and emissions, while, at the same time, providing recommendations for Sustainable Urban Mobility Plans (SUMPs) of the new mobility era, see Deliverable 8.3 (HARMONY, 2022b).

In WP6 an advanced agent and activity-based freight model for urban and regional logistics and freight transport is developed. This is the Tactical Freight Simulator (TF) that simulates individual firms, shipments, and the logistic decision-making choices of freight stakeholders. It calculates the disaggregated freight demand and assigns it to truck tours and their corresponding trips. The Tactical Freight Simulator (TFS) (consists of four functional modules: the shipment synthesizer which simulates the choices on a long-term tactical level, the parcel demand synthesizer which identifies the parcel demand, the shipment scheduling module which deals with decisions on a short-term tactical level and the parcel scheduling module that simulates short-term parcel related decisions.

1.2 Deliverable Objectives

D 6.4 present the application of the TFS in a number of city logistic case studies. D6.4 aims to present and describe the implementation of the HARMONY TFS for the following case studies:

- Use case 1: Microhubs
- Use case 2: Zero Emissions Zones
- Use case 3: Crowdshipping
- Use case 4: Spatial planning scenarios for logistic facilities.

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1.3 Deliverable Structure

D6.4 is divided into the following sections:

- Section 2 provides a brief description of the Tactical Freight Simulator and the use cases developed for Rotterdam.
- Section 3 describes the microhubs use case.
- Section 4 describes the zero-emission zones use case.
- Section 5 describes the crowdshipping use case.
- Section 6 describes the spatial planning of the logistics facilities scenario.
- Section 7 concludes with general observations and recommendations.

The sections on use cases each provide an introduction to the use case, a methodological description, and a discussion of the results. Learnings are generalized in a conclusion.

2 Tactical freight simulator

2.1 Background

One of the challenges in city logistic planning for the City of Rotterdam is to ensure the sustainable development of city logistics in Rotterdam. The Tactical Freight Simulator aims to assist in the analysis and evaluation of city logistic policy measures.

General policy objectives are to ensure accessibility and liveability of the city. And this needs to be achieved in a dynamic environment of city logistics with many innovations in new technologies and services such as drone or automated robot deliveries, or the growth of e-commerce demand. The underlying issue is the general absence of policy support tools. Such tools can be used to calculate the impact of planning policies (pricing, location planning of logistic facilities), future trends in logistics (growth of e-commerce, freight transport) as well as the impact of new technologies and services (Autonomous vehicles for CL, crowd shipping, zero-emission vehicles, micro hubs). The Tactical freight Simulator is designed to address such issues in the philosophy of the spatial and transport planning tool 'HARMONY Model Suite'. Challenge in developing such a simulator for city logistics is the wide scope of technological developments and the absence of existing standard methodologies for policy support for city logistics.

2.2 Overview of the Tactical Freight Simulator

The Tactical Freight Simulator (TFS) is the component of the HARMONY MS that simulates the demand for urban freight transport. The TFS is a multi-agent simulator that represents the decision-making of freight agents on the level of individual firms and individual freight shipments and can be applied to quantify the effects of future scenarios on the freight transport system.

The TFS distinguishes three main segments of urban commercial vehicle movements: Freight Shipments, Parcels, and Services. The model also distinguishes two phases. The first phase is the long-term tactical level that simulates shipment- and parcel demand in the shipment synthesis or demand modules. The second phase is the daily scheduling of the final transport movements in the scheduling modules. Separate scheduling modules are developed for freight shipments and parcel delivery because the size and consolidation of individual products (shipments or parcels) are inherently distinct.

The next Figure shows the building blocks of the TFS. The TFS receives inputs from the strategical simulator (WP4) and provides input to the operational simulator (WP7).

Most of the inputs to the TFS are based on standard data from conventional transport models: networks, socio-economic data, and additional data on the location of logistic nodes. The firm population is synthesized from the zonal employment by industry sector: this synthesizer is part of the Strategic simulator from HARMONY. For a description see Deliverable 4.2 (HARMONY, 2022). The aggregate commodity demand matrix is derived from an external source, preferably an intermodal freight transport demand model. The TFS was developed using a freight commodity demand matrix (for base year and forecast years) from the Dutch

National Freight Model BasGoed. In one of the case studies, the commodity demand forecast will be based on regional freight demand forecasts from the European scale TRUST model.

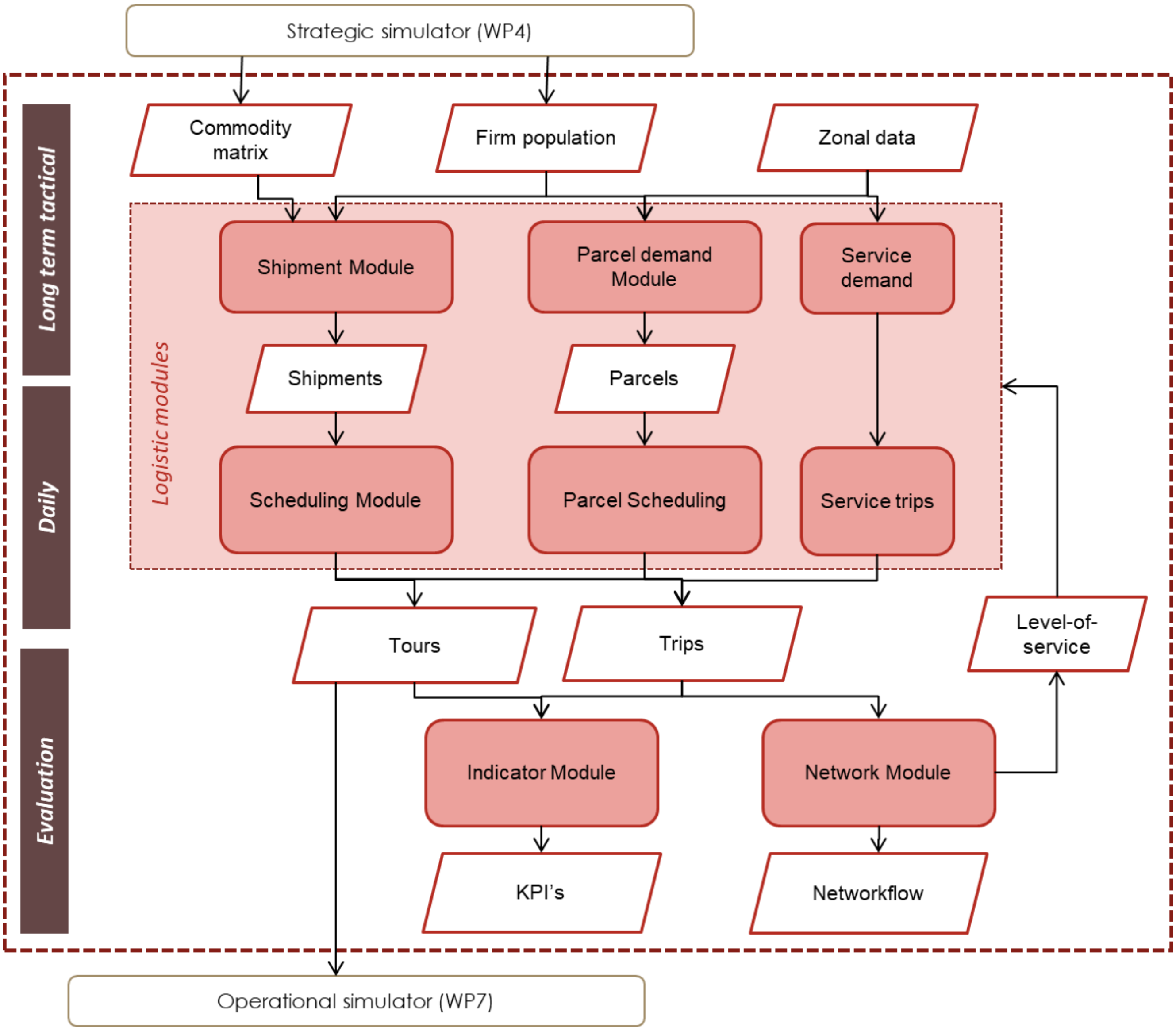

Figure 2-1:The HARMONY Tactical Freight Simulator

2.3 Overview of use cases

Challenge in developing such a simulator for city logistics is the wide scope of technological developments. In this deliverable the TFS was applied to the following use cases in city logistics:

Use case 1: Micro-hubs

The increasing competition for urban space has driven logistics facilities outside of city centres to peripheral locations (Dablanc, et al., 2014), increasing the vehicle kilometres for logistics. To defragmentise the B2C last-mile delivery streams, micro hubs are introduced as a possible solution as they can increase the consolidation of inner-city deliveries (Aljohani & Thompson, 2016). As per the definition of the Urban Freight Lab (2020), micro hubs are "logistics facilities inside the urban area boundaries where goods are bundled, which serve a limited number of destinations within a bounded spatial range and allow a mode shift to low (or zero) emission vehicles or soft transportation modes (e.g., walking) for last yard deliveries.

The objective of this use case is to explore the impact of nine different scenarios of the large-scale implementation of micro hubs on the transportation system. Although it is a well-studied topic in city logistics, it is not completely clear how different configurations of a micro hub concept will affect the transportation system in terms of transport movements, number of travelled kilometres, etc. The case study explores three different design aspects: location, type of vehicles (delivery robots, cargo bike, LEV), and the business model (individual/full collaboration). Assumptions in the simulation scenarios are based on the Rosie demonstration in the HARMONY project, retrieved from the literature, as well as other recent Living Labs in Rotterdam (van Duin, et al., 2022).

Use case 2: Zero-emission zone for City Logistics

Rotterdam has announced the introduction of a Zero-Emission zone for all city logistics vehicles in the city center. The ZE-emission zone spans the whole area of the city within the orbital ring road. It is necessary for the city to assess of the impact of this measure. The TFS provides a means to quantify the impacts.The zero-emission zone implies restricted access to the city centre (only with zero-emission vehicles are allowed) and consolidation of shipments in urban consolidation hubs (UCCs) on the outskirt of the city. The ZE-emission zone spans a ± 40 km^2 area of the city within the orbital ring road. The simulations are based on the transition scenario presented in the Road Map zero-emissions City Logistics. Two types of behavioural responses are considered: a shift from the conventional vehicle to vehicles with a zero-emission driveline, or a shift of distribution structure where shipments are first consolidated via an UCC and distribution within the ZEZ takes place using LEVV, cargo bikes or small electric vans or trucks.

Use case 3: Crowd shipping

Crowd shipping is one of the new opportunities and business models for last-mile logistics, that links parcel carriers to individual travellers on digital platforms. Crowd shipping is considered a solution to make use of the capacity of passenger transport in delivering parcels to customers. It could work in parallel with traditional delivery methods (conventional carriers) to make last-mile delivery more sustainable and efficient (Punel et al.,2018 & Rai et al., 2017). Although crowd shipping seems to be beneficial in terms of capacity utilization in the transport system, its pros and cons have not yet been explored thoroughly due to its complexity. In this use case, the TFS module is used to simulate the impacts of different implementation scenarios of crowd shipping services in the study area. With this simulation experiment, the viability of crowd shipping is explored by assessing its positive and negative impacts on both freight and passenger transport systems.

Use case 4: Land use planning of logistic and industrial sites

The increasing competition in urban space has driven many logistic activities outside of the city centres into peripheral locations, also referred to as logistic sprawling (Dablanc et al., 2014). In addition, the size of logistic facilities is scaling up: almost half of the total logistic surface area is hosted by large distribution centres of >20.00 m2 (Onstein et al, 2021). The locations of these facilities have a direct impact on accessibility, liveability, and sustainability, including visual intrusion of the landscape. Regional coordination of the location planning of logistic facilities can be an effective tool to mitigate the external impacts of new logistic facilities but policies are lacking. In this use case, the TFS was used to simulate the impacts of two different land use planning scenarios for logistics facilities on local traffic flows and emissions.

3 Use Case 1: Microhubs

3.1 Introduction

3.1.1 Context

In the Netherlands, from 2025 on a zero-emission zone (ZEZ) policy for logistics will be implemented in the centre of large cities like Rotterdam. This policy necessitates a shift to green vehicles that is undeniably a significant step towards decreasing the CO2 footprint which has become a national and global focal point. A potential consequence of this policy, following the entrance prohibition of diesel (ICE) vehicles into the ZEZ, is the confinement of Business to Customer (B2C) last-mile delivery of goods, which constitutes a large part of the logistic streams that run in an urban environment. In parallel to that, there is increasing competition for urban space which drives logistics facilities outside of city centres to peripheral locations (Dablanc, et al., 2014), taking its toll on the kilometres the service providers have to travel. To deal with the constrained B2C last-mile delivery streams, and operate as efficiently as possible in and around the introduced ZEZ, microhubs are introduced as a possible solution as they can increase the consolidation of inner-city deliveries (Aljohani & Thompson, 2016).

As per the definition of the Urban Freight Lab (2020) microhubs are “logistics facilities inside the urban area boundaries where goods are bundled, which serve a limited number of destinations within a bounded spatial range, and allow a mode shift to low (or zero) emission vehicles or soft transportation modes (e.g., walking) for last yard deliveries”. Microhubs generally generate a two-stage delivery process, as depicted in Figure 3-1. In the first stage, defined as ‘last mile delivery’ and referred to as tour type 1, the consolidated goods are delivered with high-capacity vehicles such as trucks from depots located outside the city to the microhubs. This is followed by the second stage, defined as ‘last yard delivery’ and referred to as tour type 2, where goods are deconsolidated and delivered with zero-emission vehicles to customers (Anderluh, et al., 2020). This delivery process, combined with the ZEZ policy which imposes the deployment of green vehicles only, can lead towards more efficient, organized, and greener last mile deliveries.

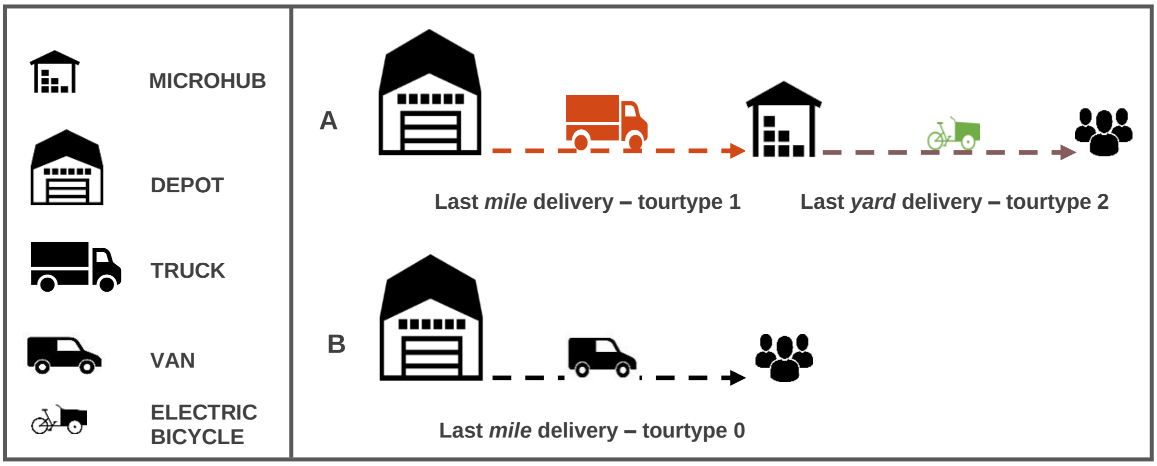

Figure 3-1:Last-mile and last-yard delivery process

When designing the configuration of microhubs in an urban setting multiple aspects should be considered, such as their location, the type of vehicles to operate them, and the business model to be adopted for their operation. In regards to the location, the microhubs should be placed in strategic positions in the city to ensure their easy access by trucks, as well as close to areas that present large parcel demands to ensure their sustainable operations in the long run and be able to exploit them in the best possible way. Different types of zero-emission vehicles can operate the microhubs that vary in speed, capacity, operating costs, operational range, accessibility (car-lanes, cycle-lanes, pedestrian areas), etc. which can affect the number and locations of microhubs. Concerning the business model, microhubs can be operated by a single CEP (courier express parcel service), or multiple CEPs following a shared logistics or white-label business model. The latter can be further segregated into a hybrid or full-collaboration model. Obviously, all business models have benefits and drawbacks, depending on the point of view, but it is important to note that the shared logistics model can lead to more efficient urban land use which constitutes one of the most pressing issues in modern urban land management.

3.1.2 Objective of the use case

The use of Microhubs is a well-studied topic in city logistics, but it is yet not completely clear how different microhub configurations affect the transportation system in terms of transport movements, number of traveled kilometres, etc. The objective of this use case is to use the Tactical Freight Simulator (TFS) to investigate the impact of microhubs on the transportation system in case they would be implemented at a wider scale across the city centre, and make a comparison with the current state of last-mile delivery. Currently, the last-mile delivery process is usually performed with vans that visit the customers directly from the depot and is referred to henceforth as tour type 0 (see Figure 3-1.B). Except for the fact that the majority of vans still run on a diesel engine, which makes them incompatible with the ZEZ policy, they also contribute greatly to the number of vehicle movements in a city which is particularly undesirable as they run empty most of the time.

The three microhub design aspects mentioned previously (location, type of vehicle, and type of business model) will be the main pillars in designing distinctive microhub configurations (scenarios) to be simulated in the TFS. Input for the simulator will be based on the Rosie demonstration in the HARMONY project, retrieved from the literature, as well as other recent Living Labs in Rotterdam (van Duin, et al., 2022).

3.1.3 Use case characteristics

The use case focuses on the parcel logistics streams taking place in the Rotterdam city centre. This area is ideal to examine the concept of microhubs due to its limited vehicle accessibility. Its high pedestrianization currently acts as a hindrance to delivery operations with larger vehicles. The city centre area which will be explicitly served by the microhubs is henceforth referred to as Microhubs catchment area (MCA) and is depicted with orange colour in Figure 3-2. The MCA is/lies inside the ZEZ of the city (see the combined orange and green area in Figure 3-2), which explains the need for a separate name. For this use case, it is assumed that the microhubs are operated by the CEPs currently operating in the investigated area, while the number of parcels each CEP will handle is calculated according to their current Business-to-Customer (B2C) market shares presented in Table 3-1.

Table 3-1: CEPs current market shares for B2C deliveries in the Netherlands

CEP	Share in NL
PostNL	63%
DHL	28%
DPD	3%
GLS	3%

UPS	3%

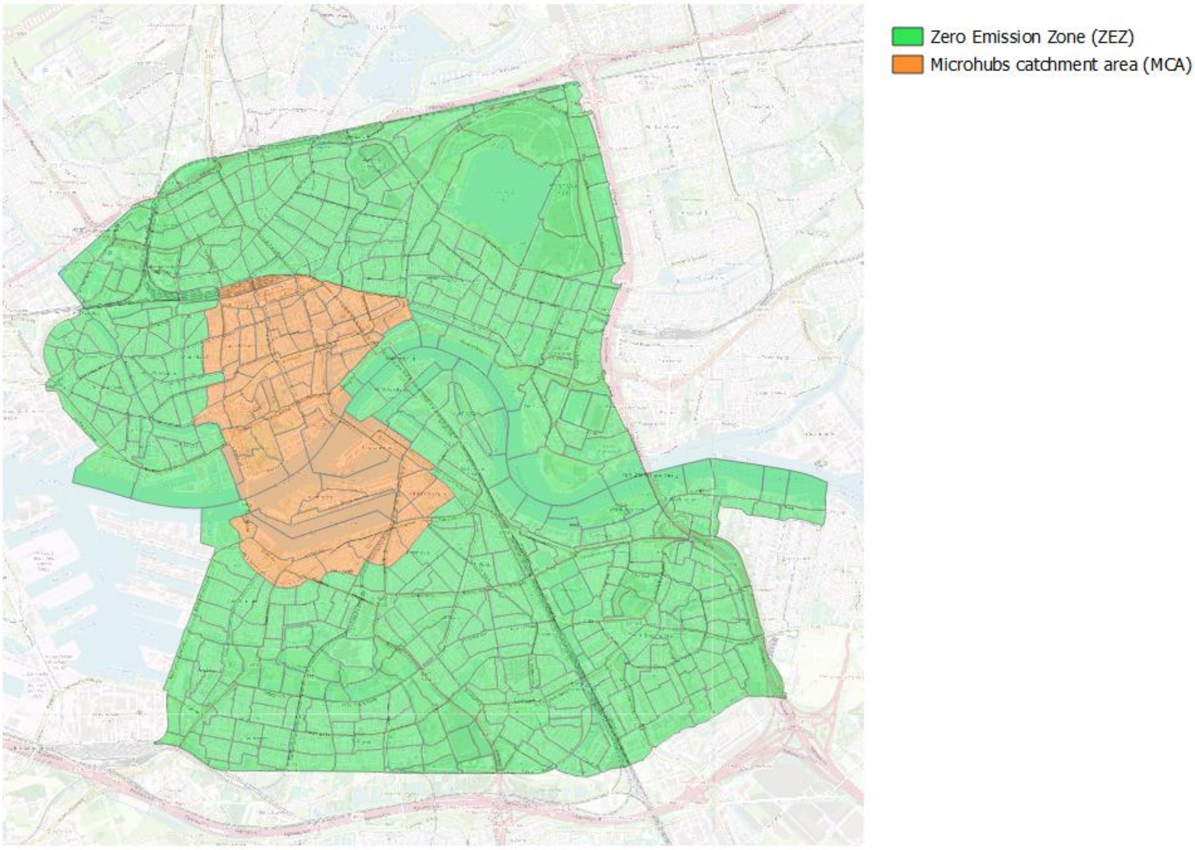

Figure 3-2 Geographical boundaries of the study area

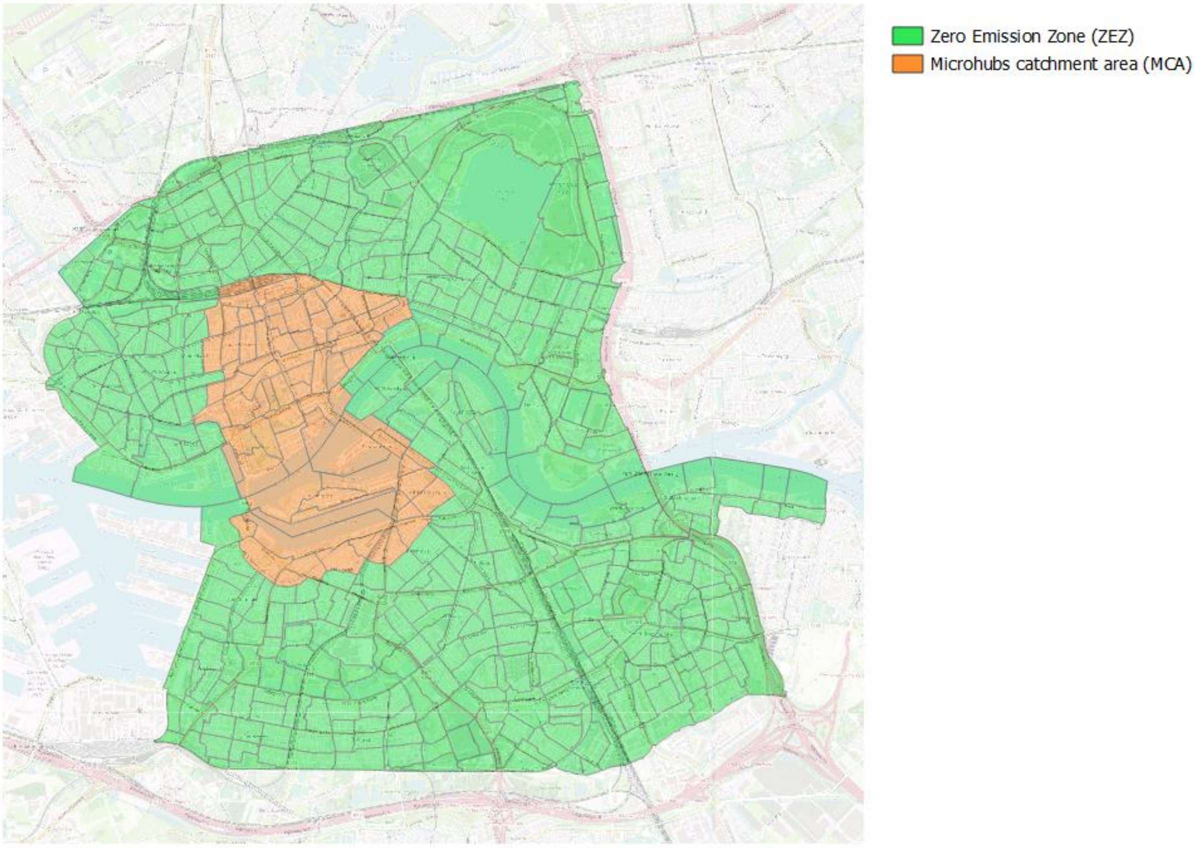

Figure 3-2 Geographical boundaries of the study area

3.2 Methodology

The implementation of the use case includes the following five steps:

1. Identification of candidate microhub locations
2. Determination of the zero-emission vehicles' specifications
3. Description of the business models
4. Development of the scenarios to be simulated in the TFS
5. Selection of the key performance indicators

In the following sections, each of the five steps is going to be elaborated upon.

3.2.1 Identification of candidate microhub locations

The framework depicted in Table 3-2 was inspired by the transferability framework of established micro-consolidation initiatives developed by Janjevic & Ndiaye (2014) and is followed in this use case to identify candidate microhub locations in the Rotterdam city centre. The identified microhub locations do not have specific coordinates, but rather represent the TAZ (Transport Analysis Zone) in which they are located, as the TFS is operating on the tactical level of planning. It must be specified, nevertheless, that the TAZ each microhub is located in does not represent its catchment area, meaning every TAZ can be visited by any vehicle serving any microhub. To arrive at the final TAZs, the QGIS application was used as will be explained below.

Table 3-2 Relevant dimensions, attributes and indicators for microhub location selection

DIMENSIONS	ATTRIBUTES	INDICATORS
Relevance	Demand	Zonal number of Business Units
		Zonal number of Households
		Zonal number of parcels
Suitability	Area accessibility	Average speed of traffic
		Road Hierarchy
	Access restrictions	Environmental standards
	Loading/Unloading infrastructure	Parking spaces

All the indicators presented in the framework are derived from the following four attributes: (1) demand, (2) area accessibility, (3) access restriction and (4) loading/unloading infrastructure. The Urban Freight Lab (2020) and Kim et al. (2019) underline that demand is of great importance to justify the need for change in the urban freight system, as well as to keep microhubs sustainable and efficient during their operation. To this end, the indicators associated with zonal demand are the number of business units (measuered in employment), the number of household units and the generated number of parcels. As microhubs should be placed in locations where demand is the highest, for each of the three indicators the TAZs with the ten highest values were identified and saved as separate layers in QGIS.

Concerning the accessibility attribute, it is assumed that a truck will be delivering the consolidated parcel demand from the outskirt depots to the microhubs. It is critical for the efficiency of these tours to be able to reach the microhubs as quickly and effortlessly as possible. For this reason, the microhubs should be located in areas nearby high-level hierarchy roads and roads with high urban speeds. In QGIS two different layers were created with selections of links to the road network that met either of the two criteria. For each layer, a buffer of 100m was applied to trace suitable locations for the microhubs placement. The overlap of the two buffered layers revealed the most accessible areas for the microhubs placement.

The access restrictions attribute corresponds to the ZEZ policy, therefore it was followed to set the boundaries of the study area. Due to the unavailability of loading/unloading infrastructure data, it was decided that parking places in the city that could accommodate microhubs operations could be used instead. The parking places and garages were traced through Google maps, and were subsequently drawn in a separate layer in QGIS.

By combining all the QGIS layers corresponding to the relevant indicators mentioned above (see Figure 3-3-a), we identified not only the most accessible areas but also the ones which require the operation of microhubs the most, as depicted in Figure 3-3-b. Even though the microhubs appear to be located in exact positions, they represent the centroids of their allocated TAZs in the simulation model as previously explained.

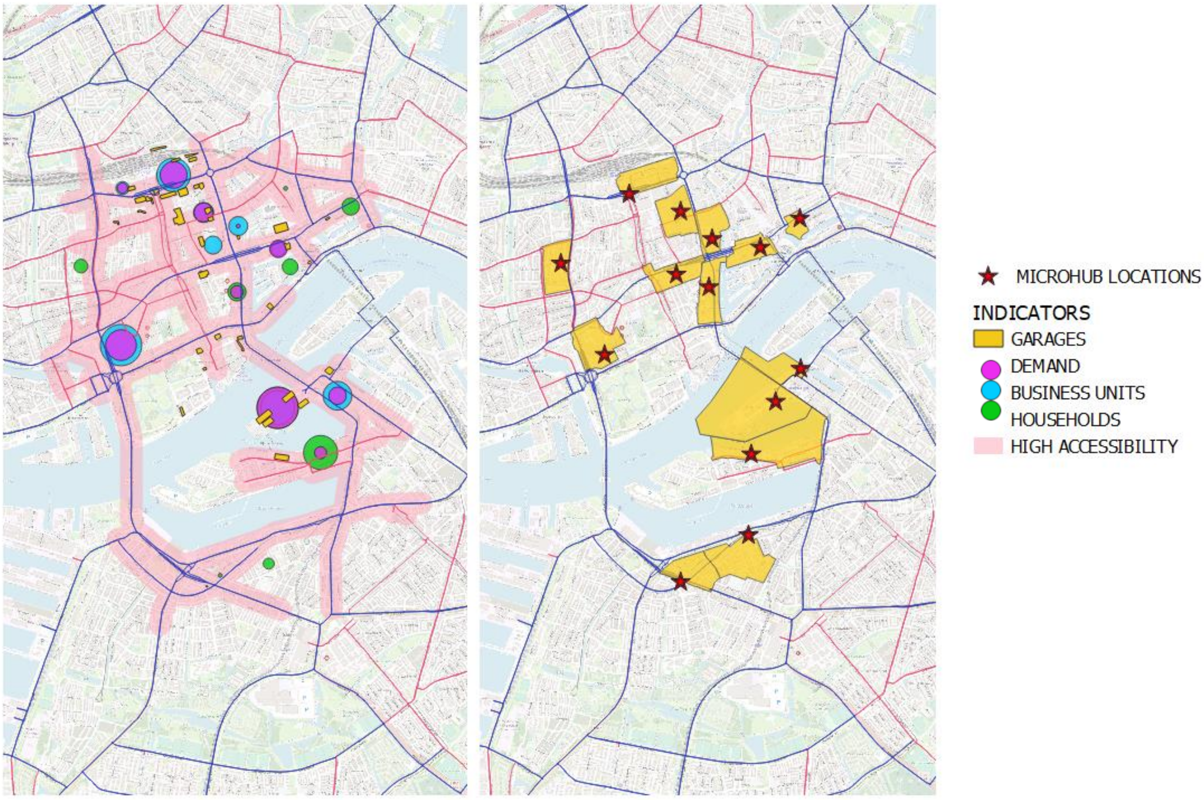

Figure 3-3-a: combined QGIS layers (left), Figure 3-3-b: candidate microhub locations (right)

3.2.2 Determination of the zero-emission vehicles' specifications

The zero-emission vehicles types considered for this use case are autonomous robot, electric bicycle, and light electric vehicle (LEV), some examples of which are presented in Figure 3-4. These vehicles differ greatly in range, speed, and capacity which allows us to investigate which is most beneficial for the operation of microhubs. For the TFS only one type of parcel is considered, meaning it has no specified weight or size. To compensate for this simplification, the capacity of each vehicle was deduced from studies conducted in relative literature. Where this information was unavailable estimations were made.

Manufacturers generally provide both the average and maximum values of the speed of the vehicles they produce. To approximate urban traffic conditions in the TFS, only the average values of range and speed were considered. For the vehicles where this information was unavailable, the corresponding maximum values were multiplied by a factor of 0.7. This factor indicates that 30% of the time in transit the vehicles are stopped due to congestion, waiting at traffic lights, pedestrian crossings etc. Table 3-3 summarizes the resulting values of average speed and maximum capacity of each vehicle that was considered in the simulation.

Figure 3-4 The green vehicles considered for this use case

Table 3-3 Specifications of the selected green vehicles

Modes	Av. speed (km/h)	Capacity (nr parcels)
Autonomous robot	4.5	5
Electric bicycle	17.5	13
Light electric van (LEV)	18	180
Truck	Av. road network speeds	1800
Van	Av. road network speeds	180

The average speeds of each examined zero-emission mode were used to calculate their respective skim time matrices. A skim time matrix is a matrix that provides the time impedance between zones, and is used in the simulator to calculate the duration of tours. Even though these modes use the same network for their operations (bicycle and pedestrian lane), taking their average speeds into consideration for this purpose is important due to their relatively small capacities. The skim time matrices of the diesel vehicles (van and truck) are the same, as they are both constructed based on the average speeds on each link of the road network on which they operate. The average road network speeds were retrieved by the MRDH model operated by the Rotterdam Municipality.

The skim distance matrices were used to construct the shortest path routes for each mode, meaning only distance was considered as a disutility as no information was available on the monetary cost of the zero-emission modes in comparison to the diesel ones. A potential future improvement would be to include cost unit prices of the new zero-emission modes. The skim matrices, nevertheless, were not constructed for each mode rather for each tour type as per their definition in section 3.1.1. This is because certain road hindrances were taken into consideration that apply only to specific tour types. More precisely, for the last yard delivery (tour type 2), no hindrances were considered as it is assumed that zero-emission vehicles can move in their designated MCA uninterrupted. In contrast, for the last mile delivery (tour type 1) for which trucks are employed, a penalty was imposed on links that are located in the ZEZ such that their usage is averted as much as possible. For tour type 0 this was not considered as it refers to the current situation, meaning no ZEZ policy is in effect. Lastly, for the last mile delivery (tour types 0 and 1) a penalty is additionally imposed to not use roads for which freight transportation is forbidden.

3.2.3 Description of the business models

As previously mentioned in section 3.1.2, the objective of this use case is to compare various microhubs configurations with the current state of last-mile delivery. Figure 3-5 illustrates in a simple diagram how the current last-mile delivery is taking place in the MCA between different CEPs. It can be seen that the parcels are delivered directly from the depots of each CEP to their respective customers with vans. As the tours are not coordinated, this results in relatively many vehicle kilometres travelled by delivery vans inside the MCA.

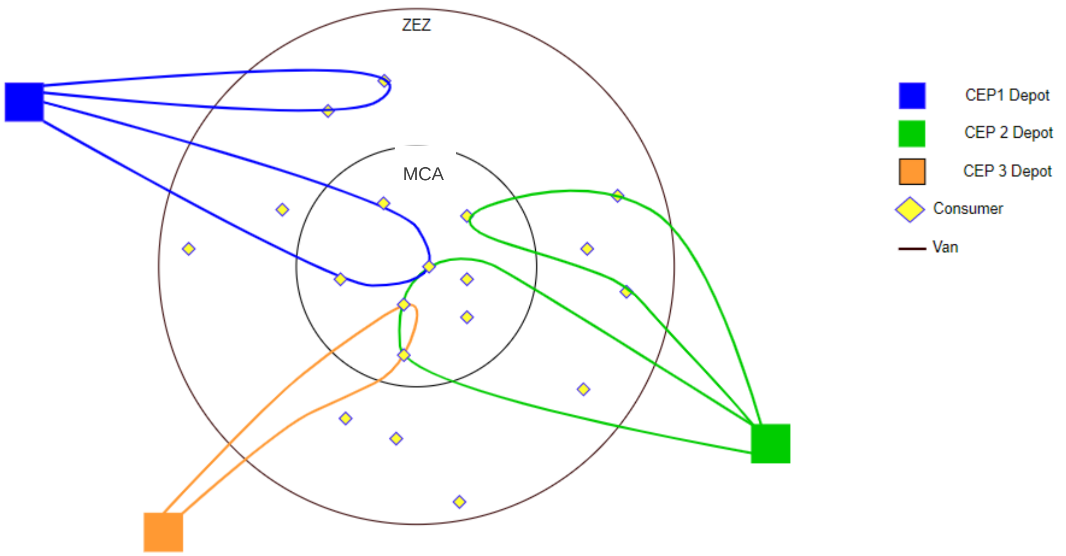

Figure 3-5 Current state of the last-mile delivery

Figure 3-6 and Figure 3-7 illustrate in a respective manner the Individual CEP and full-collaboration (and hybrid) business models described briefly in section 3.1.1. In both of these business models, the consolidated flows of goods toward the microhubs are served by trucks, while every other TAZ outside the MCA is explicitly served by vans. Trucks have a higher capacity than vans, which can lead to a lower number of vehicle kilometres as a lower number of delivery tours is required. The last-yard delivery in the MCA is performed by green vehicles for both business models. If the business model is individual CEP, then each CEP has its own assigned microhubs and is the responsible company for performing the last leg of the delivery. If the business model is full-collaboration then each CEP has the advantage of using any of the microhubs located in the area, and a neutral company is responsible for the last-yard delivery. If the business model is hybrid, some microhubs are operated independently by their assigned CEPs while the rest are shared among the rest of the CEPs.

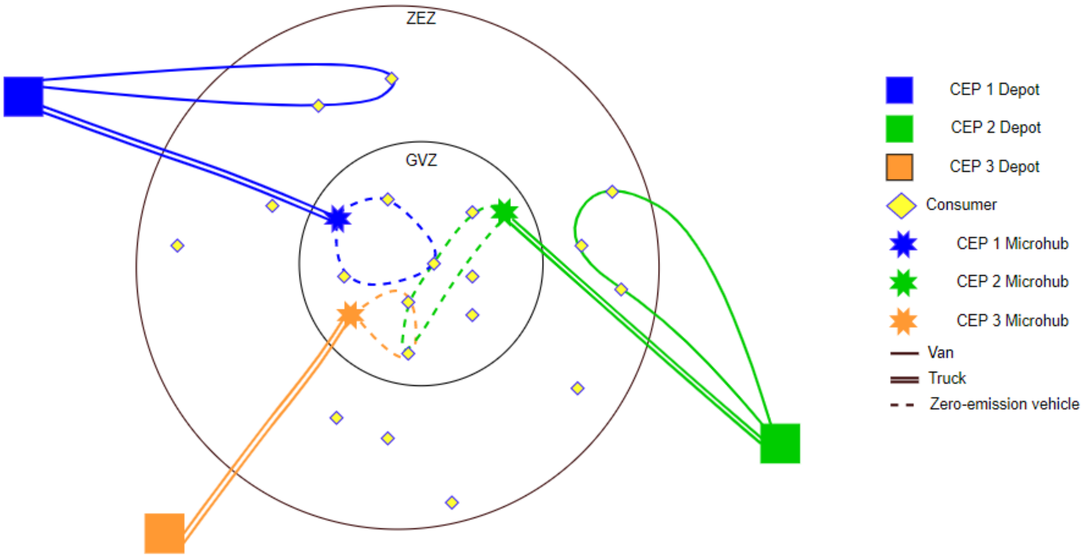

Figure 3-6 Individual CEP model

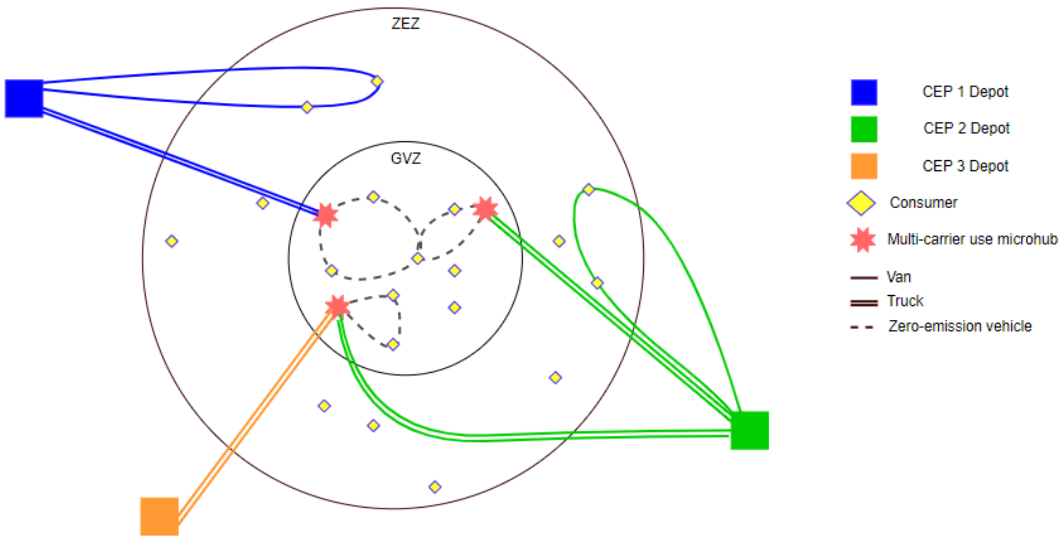

Figure 3-7 Full-collaboration (and hybrid) business model

3.2.4 Scenarios development

A multitude of scenarios of distinctive microhub configurations was designed to investigate how microhubs can affect the transportation system, which is presented in Table 3-4. Three key aspects were considered, the business model adopted for their operation, the number of microhubs, and the type of green vehicles used for the last-yard delivery.

The fourteen (14) microhub locations identified in section 3.1.2 represent the whole set of microhubs. From this set, subsets of microhubs are selected based on logical assumptions for the scenario design. More specifically, scenarios 1,2, and 3 examine the Individual CEP business model using the full set of microhubs. Scenarios 4,5 and 6 examine the hybrid business model combining single- and multi-carrier operations using a practical subset of eight 8 microhubs, while scenarios 7,8 and 9 use the same subset to examine the full-collaboration setup. It must be noted that the subset of 8 microhub locations selected for the second and third scenarios represent the TAZs with the highest parcel demand among the whole set of 14 microhub locations.

Every business model is examined against every green vehicle presented in section 3.2.2 to help us understand the usefulness of each under different types of microhubs. It is assumed that autonomous robot operations are complemented by electric cargo bicycles as they are expected to not be able to operate independently in such a large area due to capacity, speed, and range limitations. This solution restricts the operation of autonomous robots into a 500m radius around the microhubs and allocates the orders out of this radius to the services of electric cargo bicycles.

Overall, nine (9) configurations were developed to be compared with the reference scenario which represents the current state of the last-mile delivery.

Table 3-4 Scenarios simulated in the TFS

Scenario	Business model	Nr. microhubs	Mode	Mode Abb.
0	Reference		Van	
1	Individual CEP model	14	Autonomous robot + Electric bicycle	AR
2			Electric bicycle	EB
3			Light Electric vehicle	LEV
4	Hybrid model	6 + 2	Autonomous robot + Electric bicycle	AR
5			Electric bicycle	EB
6			Light Electric vehicle	LEV
7	Full collaboration model	8	Autonomous robot + Electric bicycle	AR
8			Electric bicycle	EB
9			Light Electric vehicle	LEV

The current local shares of the CEPs and the parcel demand per zone were taken into account when deciding the number of microhubs to be allocated to each CEP. For the “Individual CEP” model, the CEPs with market shares of less than 5% were assigned only one microhub each (GLS, UPS, DPD, FedEx), while the rest of the 14 microhubs were assigned to the rest CEPs according to their relative shares, that is 6 microhubs to PostNL and 4 microhubs to DHL.

For the “Hybrid” scenario, 2 of the 8 microhubs were decided to be shared among the CEPs with market shares of less than 5%, while the remaining 6 microhubs were to be assigned to the rest of the CEPs in a similar manner to the first scenario, resulting in 4 microhubs assigned to PostNL and 2 microhubs assigned to DHL. For the “Full-collaboration” model every microhub of the selected 8 is shared among every CEP.

To decide exactly which microhub locations (zones) should be assigned to each CEP, their market shares, their depot locations, and the parcel demand per zone were taken into account. More precisely, the assignment process started from the CEPs with the largest market shares which were then assigned the microhub locations with the largest parcel demand. The CEPs with market shares of less than 5% were consequentially assigned the microhub locations with the lowest parcel demand, but the location of their depot was taken into consideration to place them in the most efficient location possible. The resulting microhub configurations for all three models are presented in Figure 3-8, Figure 3-9, and Figure 3-10.

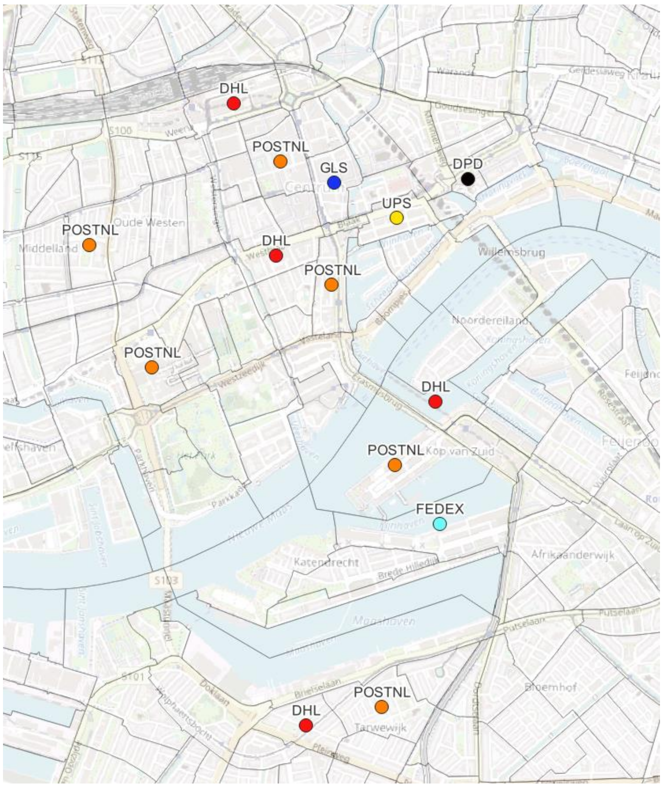

Figure 3-8 Microhubs configuration – Individual CEP model

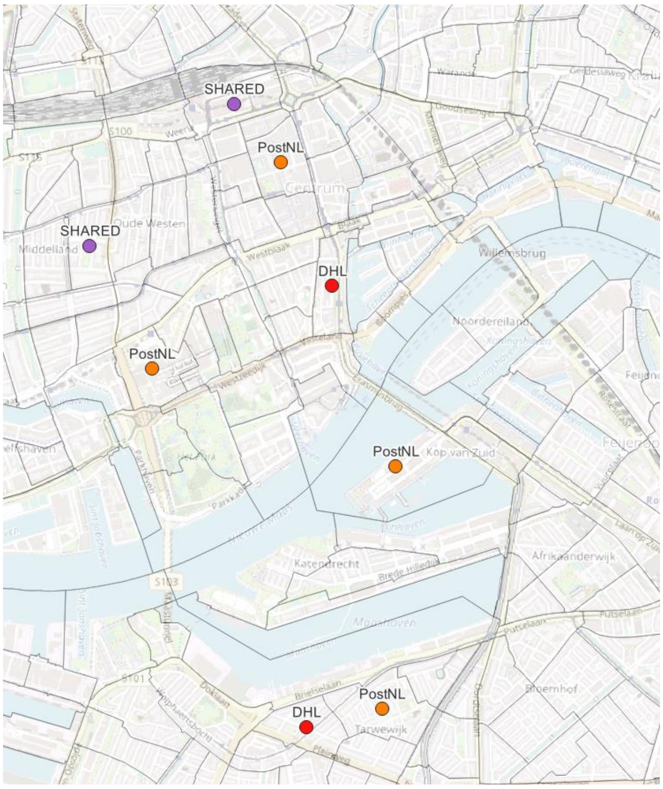

Figure 3-9 Microhubs configuration - Scenario 2: Hybrid model

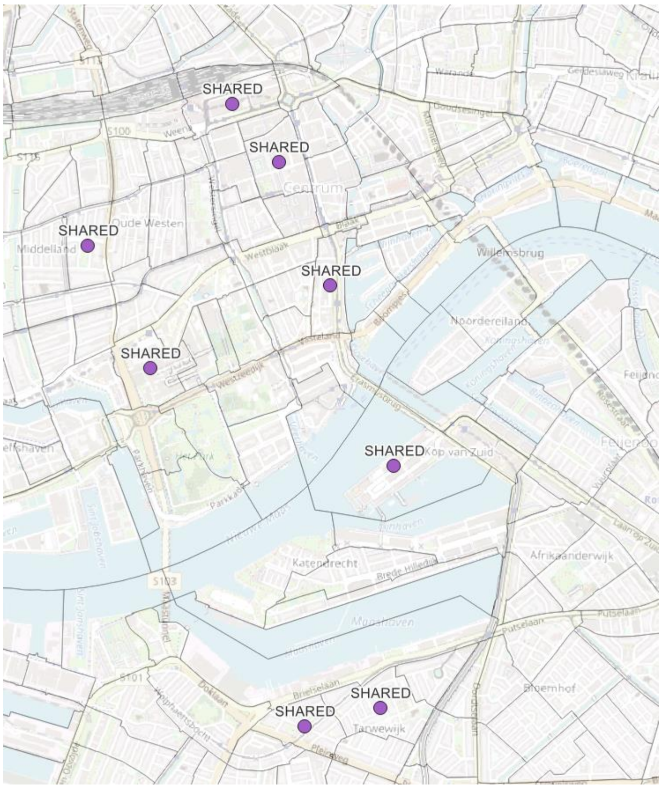

Figure 3-10 Microhubs configuration - Scenario 3: Full-collaboration model

3.2.5 TFS modules

The TFS modules used for the simulation of the designed scenarios are presented below, along with the assumptions made for their implementation.

Skim Module: to calculate the time and distance skim matrices

Parcel Demand Module: to generate the demand of parcels per CEP in the study area

- 75% first-delivery success: implies that 25% of the original number of parcels that will be redelivered, increased by the total number of synthesized parcels to account for the increased number of trips
- One-size parcels with no specified weight or size are considered to reduce the model complexity

Parcel Scheduling Module: to construct the tour matrices of all parcel deliveries

Traffic Assignment Module: to assign the trip flows on the road network and calculate the selected KPIs

3.3 Results

The impacts from the 9 microhub scenarios are evaluated using a variety of indicators. For each scenario, the same freight delivery performance has to be delivered. The following key performance indicators (KPIs) were selected to compare the performance of each examined scenario:

- Number of tours per vehicle
- Capacity usage of vehicles:
  - Number of tours using full capacity per vehicle
  - Average capacity utilization per tour per vehicle
  - Total number of kilometres travelled when capacity utilization is 0% per vehicle
- Vehicle kilometers:
  - Average tour distance per vehicle
  - Total number of kilometres travelled in/out of the ZEZ per vehicle

3.3.1 Number of tours

Every CEP has multiple depots spread around the region which can act as the supply chains' origins. Multiple depots from the same CEP can serve the same study area as they are assigned to microhubs based on their proximity. At the same time, every selected depot is responsible for its last-mile delivery, meaning that a truck does not visit other selected depots to collect parcels before arriving at the assigned microhubs. This indicates that, regardless of the number of parcels that need to be transported, a minimum of one tour is guaranteed per selected depot. It can be understood then that the higher the number of microhubs per CEP, the higher the possibility that a larger number of different depots is selected, which indirectly translates to a larger number of truck tours, for example in the individual CEP and full-collaboration models (see Table 3-5). In contrast, a lower number of microhubs per CEP, as in the hybrid model, can lead to a higher consolidation potential of parcels which can sequentially affect the final number of constructed tours.

Table 3-5 Number of tours per vehicle

Scenario	Business model	Mode Abb.	TRUCK	VAN	AR	EB	LEV
0	Reference scenario	VAN	-	44	-	-	-
1	Individual CEP model	AR	9	-	176	494	-
2		EB	9	-	-	559	-
3		LEV	9	-	-	-	47
4	Hybrid model	AR	8	-	120	511	-
5		EB	8	-	-	556	-
6		LEV	8	-	-	-	44
7	Full-collaboration model	AR	9	-	324	430	-
8		EB	9	-	-	556	-
9		LEV	9	-	-	-	44

Looking at Table 3-5, the full-collaboration model appears to favour the usage of autonomous robots (AR), which should be reminded to operate only on a 500m radius around each microhub. This can be explained as the flexibility to operate every available microhub means that the parcels are already delivered to their closest microhub by truck. This consequentially leads to microhubs attracting a higher number of parcels which have as a final destination the zones around it. Considering the 500m radius rule, it is clear in this case that the AR usage for the last-yard delivery will be increased. Considering the low capacity of the AR, it is understandable why the number of tours is so high in comparison to other modes.

At the same time, the AR usage for the individual CEP model is higher than for the hybrid business model even though no facility sharing takes place, which can be explained by the fact that the number of considered microhubs is almost double. A higher number of microhubs indicates that they occupy more urban space, and in this case, CEPs like PostNL or DHL are assigned the majority of microhubs (10 out of 14) as they are the largest market shareholders. This factor in combination with the above reasoning of microhubs attracting more local demand, explains the increased AR usage. Nevertheless, this mode’s usage for the individual CEP model is almost half of that in the full-collaboration model due to the decreased degrees of freedom.

It is straightforward that the higher the AR usage is, the lower the electric bicycle (EB) usage becomes when they operate simultaneously. For this reason, when the main mode is AR, the full-collaboration model presents the least number of EB tours, but simultaneously the largest number of zero-emission vehicle movements. In contrast, the hybrid model presents the largest number of EB tours but at the same time the lowest total number of green vehicle movements.

As regards the number of tours per EB when the main mode is EB, all the models seem to perform similarly. Only the Individual CEP model constructs three additional routes for this mode which may be attributed to the fact that the bicycles carry only parcels from the CEP they are assigned to. Therefore, parcels assigned to the same destination but originating from different CEPs cannot be transported by the same bicycle, as could be witnessed partially in the hybrid model and to its full extent in the full-collaboration model. This indicates that the micro-consolidation potential for the last-yard delivery is lost, hence requiring the construction of additional routes. The fact that the biggest shareholders are assigned to the majority of the microhubs in the Individual CEP model, meaning they have a large proportion of the clients and sequentially carry the majority of the parcels, compensates for the loss of the micro-consolidation potential.

Similarly to the EB, the LEV usage per examined model is similar as the number of constructed tours is almost the same for every examined model. It is important to recognize nevertheless that the number of tours with the LEV is almost twelve times less than the number of tours with the EB, which may provide considerable operational advantages.

3.3.2 Capacity usage of vehicles

Table 3-6 Number of tours using full capacity per vehicle; please also provide a table with the percentages of the total number of trips

Scenario	Business model	Mode Abb.	TRUCK	VAN	AR	EB	LEV
0	Reference scenario	VAN	-	38	-	-	-
1	Individual CEP model	AR	1	-	165	480	-
2		EB	1	-	-	545	-
3		LEV	1	-	-	-	33
4	Hybrid model	AR	0	-	114	503	-
5		EB	0	-	-	548	-
6		LEV	0	-	-	-	36
7	Full-collaboration model	AR	1	-	320	424	-
8		EB	1	-	-	549	-
9		LEV	1	-	-	-	36

The truck utilized for the last-mile delivery has the largest capacity among the examined modes at 1800 parcels. Due to this reason, it is logical that its capacity will not be easily fully utilized, especially for CEPs which don't occupy large shares in the market. From Table 3-6 it can be seen that for the hybrid model not even one tour utilizes the full vehicle capacity, while one tour does so for the rest of the models. Nevertheless, looking back at Table 3-5 it can be seen that the hybrid model constructs one lesser tour than the rest of the models. This may indicate that the parcel demand is more evenly distributed among tours, which limits the necessity for that additional tour. Evidence of this is provided in Table 3-7**Error! Reference source not found.**, where the average truck capacity u tilization per tour for the hybrid model is at 50%, while for the rest of the models is at 44%.

Table 3-7 Average capacity utilization per tour per vehicle

Scenario	Business model	Mode Abb.	TRUCK	VAN	AR	EB	LEV
0	Reference scenario	VAN	-	91%	-	-	-
1	Individual CEP model	AR	44%	-	97%	98%	-
2		EB	44%	-	-	99%	-
3		LEV	44%	-	-	-	85%
4	Hybrid model	AR	50%	-	99%	99%	-
5		EB	50%	-	-	99%	-
6		LEV	50%	-	-	-	91%
7	Full-collaboration model	AR	44%	-	99%	100%	-
8		EB	44%	-	-	99%	-
9		LEV	44%	-	-	-	91%

For the scenarios where the main mode for last-yard delivery is the light electric vehicle (LEV), it can be observed that the hybrid and full-collaboration models perform better than the individual CEP model. More specifically, they both construct 44 tours of which 36 start their first trip utilizing the full vehicle capacity, while the individual CEP model constructs 47 tours of which only 33 use their full capacity (see Table 3-5 and Table 3-6). Looking at Table 3-7, we can also observe that the average LEV capacity utilization for the hybrid and full-collaboration models stands at 91%, while for the individual CEP model at 85%. Considering the fact that the parcel demand is distributed differently in each business model, it is important to acknowledge the gains that can be achieved with the hybrid and full-collaboration models when a lower number of tours can transport the same number of parcels by utilizing their capacity better. Of course, this can be attributed to the micro-consolidation that takes place in the aforementioned models. Similar results can be observed for the scenarios where the main mode for last-yard delivery is the electric bicycle, fact which enhances the above observation.

Regarding the scenarios that have as a main mode the AR, the above observation cannot hold as each business model affects this mode's usage very differently. It can be observed, nevertheless, that the full-collaboration model provides the best results in terms of capacity utilization as 320 out of the 324 AR tours and 424 out of the 430 EB tours are fully utilized (see Table 3-6). Table 3-7 supports this observation as the average capacity utilization for both these vehicles stands respectively at 99% and 100%. This concludes that the full-collaboration model, even though constructing the highest number of tours in the scenarios where the main mode is AR, and similar number of tours for the rest of the vehicles, still promotes a higher vehicle capacity utilization than the rest of the business models.

3.3.3 Vehicle kilometers

Table 3-8 shows for every examined scenario the total number of kilometres travelled in and out of the ZEZ per vehicle. If we set aside the zero-emission vehicles', it is easy to see that by implementing the concept of microhubs, the total number of movements with large vehicles in the ZEZ can be reduced. This is very important if we consider the fact that those movements are currently performed with diesel vehicles. To be more specific, the total number of kilometres travelled in the ZEZ with vans for the reference scenario is 776, while the corresponding number of kilometres travelled with a truck in the worst performing model, which is the full-collaboration model, is around 140. If we compare the scenarios where the LEV is used as the last-yard mode, as it is equivalent to the van in terms of capacity, we can still see that the total travelled kilometres in the ZEZ are reduced. More specifically, the combined total number of kilometres of trucks and LEVs for the worst performing model (the Individual CEP model), is 416, which is still almost half of the reference scenario.

As previously observed in Table 3-5, 9 truck tours are constructed for both the individual CEP model and the full-collaboration model, with their total number of travelled kilometres almost matching, if we look at Table 3-8. Nevertheless, it is clear that the road network usage for each of these models is very different when we compare their activity in and out of the ZEZ. The full-collaboration model makes more use of the road network inside of the ZEZ zone (see Figure 3-14), which can be explained by the fact that the trucks have to travel to all 8 microhubs to deliver their assigned parcels. It is interesting to point out that for this model, the trucks visit the closest microhub to their origin depot first, thus decreasing the number of kilometres travelled outside of the ZEZ. In contrast, the individual CEP model makes more use of the network outside of the ZEZ zone (see Figure 3-15) as the trucks must visit first only one of their closest *assigned* CEP microhubs, therefore they lack the flexibility of the full-collaboration model.

The hybrid model exhibits characteristics of the Individual CEP model but proves that the number of microhubs can be of trivial importance in the travelled kilometres inside or outside the ZEZ. From Table 3-8 it can be seen on one hand, that they hybrid model leads to almost the same number of truck kilometres outside of the ZEZ as the individual CEP model, even though the latter has 6 additional microhubs. On the other hand, even though they hybrid model has the same number of microhubs as the full-collaboration model, it can be seen that it leads to almost half of the number of kilometres travelled inside the ZEZ. In comparison to the Individual CEP model, it leads to just 13 lesser kilometres which again indicates that the number of microhubs is not an important factor.

Scenario	**Business model**	**Mode Abb.**	**TRUCK**			**VAN**			**AR**			**EB**			**LEV**		
			TOTAL KM	IN ZEZ	OUT ZEZ	TOTAL KM	IN ZEZ	OUT ZEZ	TOTAL KM	IN ZEZ	OUT ZEZ	TOTAL KM	IN ZEZ	OUT ZEZ	TOTAL KM	IN ZEZ	OUT ZEZ
0	Reference scenario	VAN	-	-	-	958.4	776.0	182.4	-	-	-	-	-	-	-	-	-
1	Individual CEP model	AR	284.8	82.9	201.9	-	-	-	94.1	94.1	-	1623.2	1623.2	-	-	-	-
2		EB	284.8	82.9	201.9	-	-	-	-	-	-	1663.1	1663.1	-	-	-	-
3		LEV	284.8	82.9	201.9	-	-	-	-	-	-	-	-	-	333.0	333.0	-
4	Hybrid model	AR	270.3	69.7	200.6	-	-	-	59.6	59.6	-	1664.5	1664.5	-	-	-	-
5		EB	270.3	69.7	200.6	-	-	-	-	-	-	1689.6	1689.6	-	-	-	-
6		LEV	270.3	69.7	200.6	-	-	-	-	-	-	-	-	-	218.5	218.5	-
7	Full-collaboration model	AR	278.9	139.4	139.5	-	-	-	155.9	155.9	-	893.4	893.4	-	-	-	-
8		EB	278.9	139.4	139.5	-	-	-	-	-	-	953.4	953.4	-	-	-	-
9		LEV	278.9	139.4	139.5	-	-	-	-	-	-	-	-	-	101.3	101.3	-

Table 3-8 Total number of kilometres travelled in/out of the ZEZ per vehicle

Table 3-9 Average tour distance per vehicle

Scenario	Business model	Mode Abb.	TRUCK	VAN	AR	EB	LEV
0	Reference scenario	VAN	-	21.78	-	-	-
1	Individual CEP model	AR	31.64	-	0.53	3.29	-
2		EB	31.64	-	-	2.98	-
3		LEV	31.64	-	-	-	7.09
4	Hybrid model	AR	33.78	-	0.50	3.26	-
5		EB	33.78	-	-	3.04	-
6		LEV	33.78	-	-	-	4.97
7	Full-collaboration model	AR	30.98	-	0.48	2.08	-
8		EB	30.98	-	-	1.71	-
9		LEV	30.98	-	-	-	2.30

Table 3-10 Total number of kilometres travelled when capacity utilization is 0 % per vehicle[*]

Scenario	Business model	Mode Abb.	TRUCK	VAN	AR	EB	LEV
0	Reference scenario	VAN	-	366.8	-	-	-
1	Individual CEP model	AR	134.9	-	24.2	730.3	-
2		EB	134.9	-	-	744.0	-
3		LEV	134.9	-	-	-	63.2
4	Hybrid model	AR	134.6	-	7.9	792.8	-
5		EB	134.6	-	-	799.1	-
6		LEV	134.6	-	-	-	60.7
7	Full-collaboration model	AR	99.8	-	19.8	416.6	-
8		EB	99.8	-	-	425.0	-
9		LEV	99.8	-	-	-	35.2

[*] For parcel delivery vans, undelivered parcels were not counted for

As expected, for every green vehicle the total travelled kilometres match the kilometres travelled in the ZEZ, as they only operate in that designated area (seeTable 3-8). Combining Table 3-5 and Table 3-8 shows that the total kilometres travelled with the AR are relative to the number of tours performed for each by almost a factor of 2, a fact which can also be supported by Table 3-9 as the average tour distance with an AR fluctuates at around 0.5 km for every examined scenario. This can be explained as they only deliver parcels which fall into a 500m radius around each microhub. The hybrid model seems to lead to the least total travelled kilometres for this mode, but also to the least kilometres when it travels completely empty (see Table 3-10).

In regards to the EB that complement the AR operations, it is interesting to notice that for the full-collaboration model 430 tours are constructed, in comparison to the 494 of the Individual CEP model, which result in a total of 894 kilometres which is almost half of the corresponding kilometres travelled in the Individual CEP model (see Table 3-5 and Table 3-8). This of course is affected by the increased usage of the AR (almost 90 additional AR kilometres), but it nevertheless proves that micro-consolidation even in such a small scale can still lead to significant gains.

The full-collaboration model seems to be the most beneficial in terms of least total travelled kilometres and least total travelled kilometres when vehicle is empty as observed for both the EB and LEV operations. Operating with the LEVs under this business model, proves to be the most optimal scenario as also the least number of vehicle tours is constructed, with the majority of them starting under full capacity. Looking at Figure 3-17, it is obvious that the frequencies of use of the roads in the MCA by the LEVs are much smaller than the respective frequencies observed in Figure 3-15 and Figure 3-16, which indicates that the tours overlap is reduced. By comparing Figure 3-15 and Figure3-16, it can be seen that for the hybrid model only the roads close to the microhubs are mostly active, due to the overlap of the tours, while in the Individual CEP model, even though majority of the roads are used due to the spatial spread of the microhubs they still present of the highest frequencies of use. Table 3-8 proves this as the number of kilometres travelled by the LEVs for the Individual CEP is almost double the kilometres travelled for the hybrid model, and almost triple the kilometres travelled for the full-collaboration model. This explains why the average tour distance for the LEVs presents a similar pattern under each examined model (seeTable 3-9).

Apart from the full-collaboration model, it has been observed that the individual CEP model favours more the EB, while the hybrid model favours more the LEV. More specifically, the EB for the individual CEP model constructs 559 tours, in comparison to the 556 tours of the hybrid model, which still lead to 26.5 less total kilometres, almost 55 less kilometres travelled when the vehicle is empty and simultaneously a shorter average tour distance of around 3 kilometres. The LEV for the hybrid model constructs 44 tours, in comparison to the 47 tours of the individual CEP model, which lead to 114.5 less total kilometres, 2.5 less kilometres travelled when the vehicle is empty which is trivial, and a shorter average tour distance of around 5 kilometres. It appears then that when the parcel concentration at microhubs is high, as in the case of the full-collaboration model (parcel micro-consolidation as all CEPs share the same vehicle) or the hybrid model (lesser number of microhubs attract higher number of parcels) the LEV performs better due to its higher capacity, but in the opposite case modes with smaller capacity such as the EB present an advantage.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815269

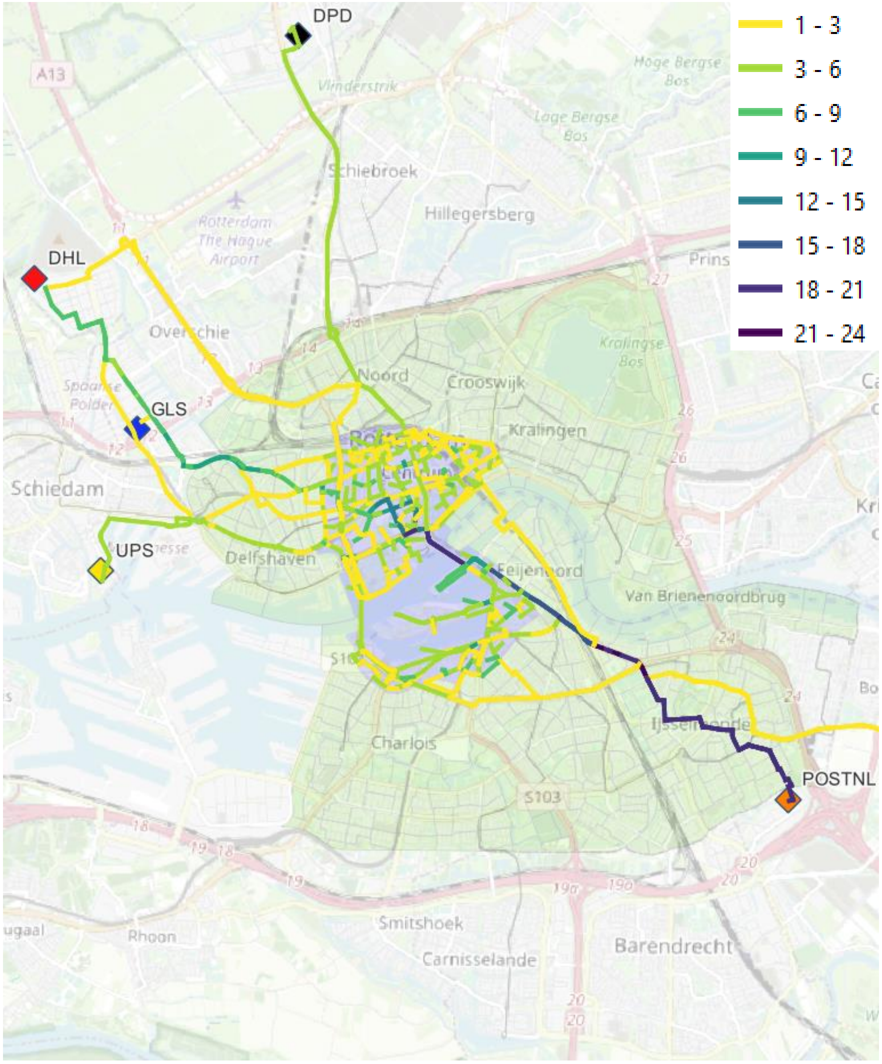

Figure 3-11 Reference scenario – Van road network usage

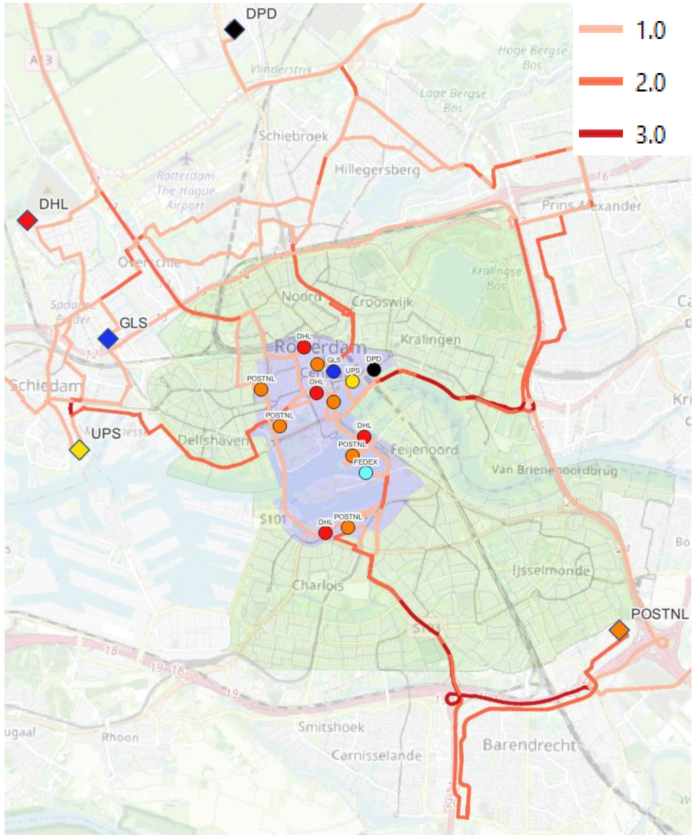

Figure 3-12 Individual CEP model: truck road network usage

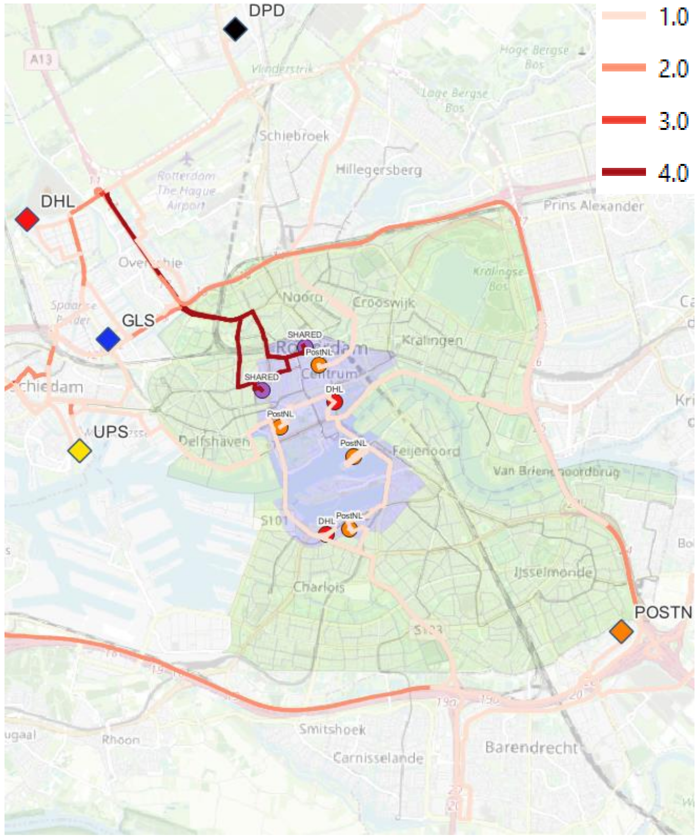

Figure 3-13 Hybrid model: truck road network usage

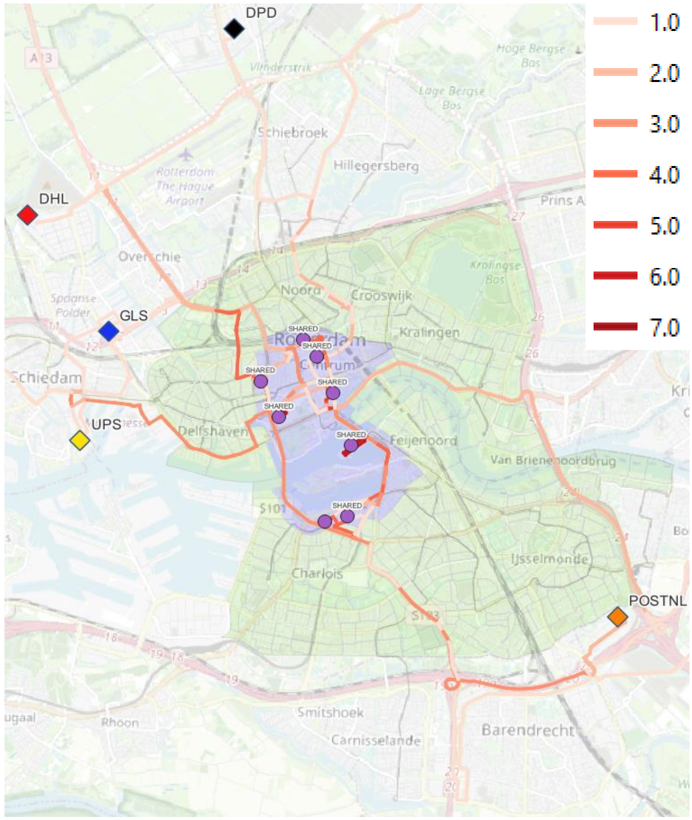

Figure 3-14 Full-collaboration model: truck road network usage

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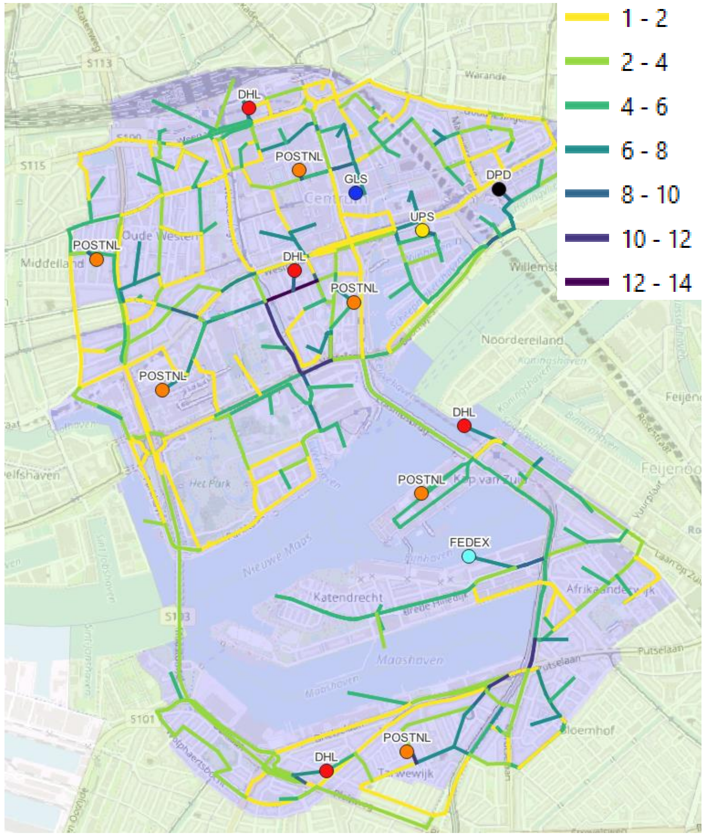

Figure 3-15 Individual CEP model - LEV road network usage

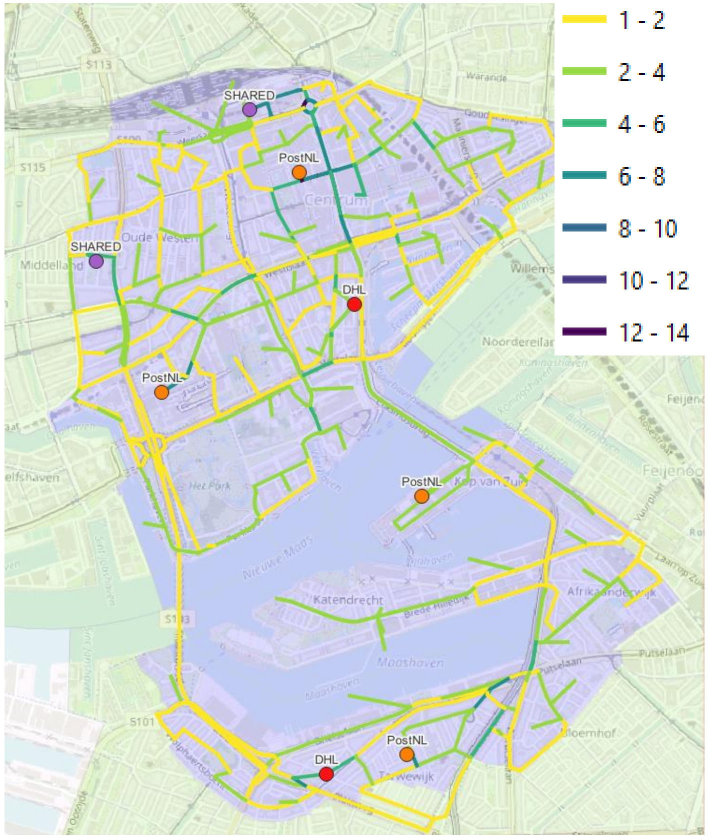

Figure 3-16 Hybrid model - LEV road network usage

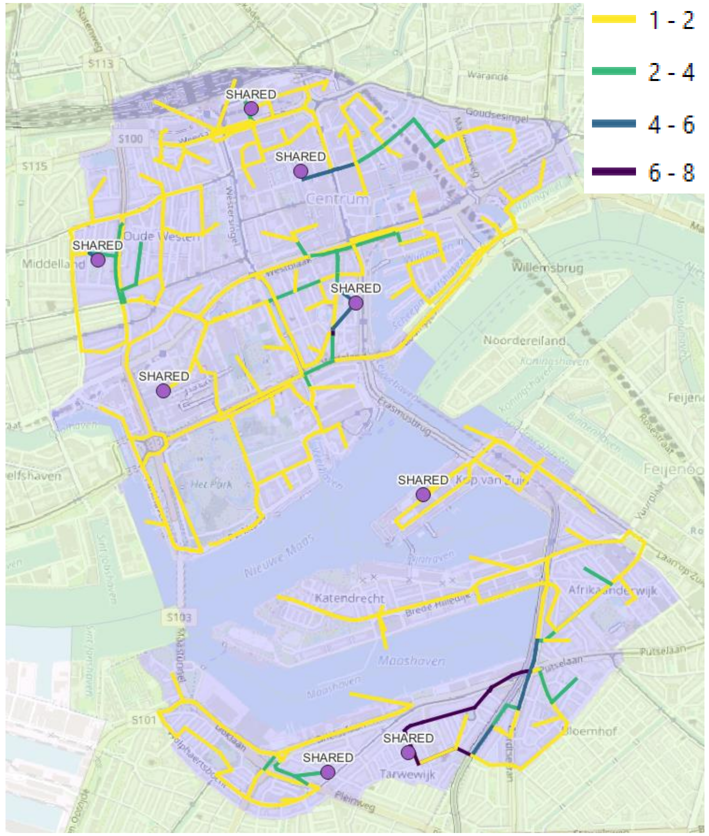

Figure 3-17 Full-collaboration model - LEV road network usage

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815269

4 Use Case 2: Zero Emissions Zones

4.1 Description of scenario

4.1.1 Background:

With the current municipal coalition agreement, in line with the national coalition agreement, the Mayor and Executive Board of Rotterdam have committed to achieving the goal of reducing CO2 emissions by 49% by 2030 [3]. For city logistics Rotterdam is working to achieve a transition to a system that is as efficient as possible (reducing vehicle kilometers) and deploys zero emission (ZE) vehicles. For this purpose, Rotterdam plans to introduce a zero-emission zone [3]. This zero-emission zone is part of a broader vision for emission-free city logistics that involves supporting measures such as consolidation hubs at the outskirts of the city and generating a shift to zero-emission vehicles. Part of this solution is the deployment of electric light goods vehicles (LEVVs) such as cargo bikes or small vehicles with an electric engine, or vehicles with no emissions, such as electric, hydrogen or hybrid drivelines.

The last decade has shown the emergence of measures to reduce emissions in city logistics throughout Europe. An important tool for local administrators is the introduction of low (or ultra-low) emission zones [1],[2]. These low emission zones impose access restrictions for commercial vehicles or emission-based access fees. Systems have been put in place in Prague, Gothenburg, London, Rome, Ljubljana, and different cities in The Netherlands and Germany. The measures vary in stringency of access restriction, , size of the area and method of enforcement [1]. Sometimes high emission vehicles are completely banned or pay a fee to enter. In Ljubljana vehicles exceeding 7.5 tons are not allowed within the inner ring road at peak times. Prague has two zones with weight restrictions for HGVs (since 1999). To improve air quality Gothenburg introduced a LEZ in 1997, which was then extended to cover a larger area in 2007. In London access restrictions are in place for vehicles from different weight or emission classes in the London Lorry Control Scheme. Findings from monitoring suggest that trucks use less direct routes, which can lead to an increase in heavy goods vehicle (HGV) kilometers and environmental emissions. As of 2019, London has introduced the Ultra-Low Emissions Zone and only diesel trucks with minimum Euro standard VI are allowed. The reported impacts of low emission zones vary, according with the type of implementation [1]. The environmental vehicle ban in around 60 German Cities is reported to reduce emissions by 0-15% [1]. However, it is not possible to attribute this to the LEZ introduction or autonomous trend of HGVs moving towards cleaner Euro standards. Over-all it can be concluded that in most cases the impacts of LEZ were found to be insignificant, maybe except for the LEZs in Germany.

The introduction of a zero-emission zone is part of the Green Deal Zero Emission City Logistics (GDZECL) that aims at reducing CO2 emissions and improving both air quality and accessibility in the city. Figure 2 shows the location of the ZE-zone in the study area. The zero-emission zone implies restricted access to the city center only with zero-emission vehicles and consolidation of shipments in urban consolidation hubs (UCCs) at the outskirt of the city. The use of UCCs effectively means adding a stage to existing supply chains [33]. Each logistic segment has its own specific characteristics and will use different solutions. Parcel delivery services are more likely to shift from vans to emission free electric light goods vehicles (LEVVs), while construction logistics will change the driveline of tractors used from diesel to electric or hybrid drivelines. [33] found evidence that some sectors are more likely to use the consolidation potential of UCCs: retail stores are more receptive because they have lower delivery frequencies and are less time critical. Food shops and restaurants have higher delivery frequencies and are more time critical and, therefore, less likely to accept an additional transportation leg in their supply chain.

The Road Map zero-emissions City Logistics presents an expert-based description of likely shifts to zero-emission city logistics for each logistic segment [3]. These transition scenarios consist of two types of shifts (see Figure 4-1). The first is a shift from the conventional vehicle to vehicles with a zero-emission driveline, the second is a shift to a new zero-emission last-mile solution via UCCs. Distribution from these UCCs takes pace using LEVVs, such as cargo bikes or small vehicles with an electric engine, or electric vans.

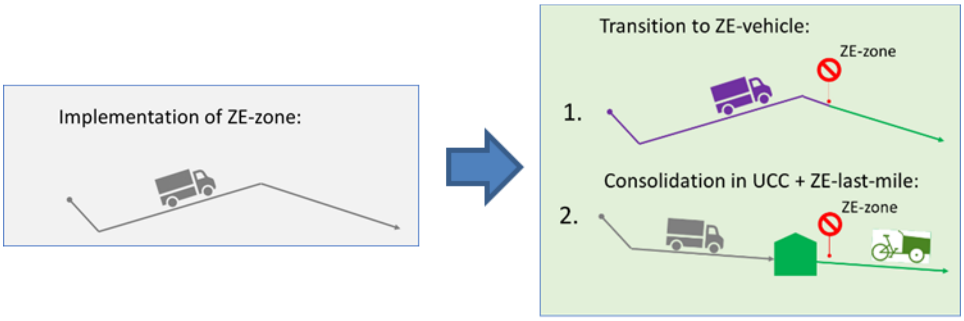

Figure 4-1:Implementation of transition scenarios

4.2 Methodology

In this case study we will use the presented simulation model and make a scenario-based case study of the impacts of the transition scenarios presented in the roadmap. This means that the expected transitions for each logistic stakeholder/segment are interpreted from the expert-based scenarios from the road map. Strategic research questions for the implementation of the policy concern the dimensions of the zero-emission zone, the location of consolidation hubs, and the impacts on freight demand patterns, vehicle use and network impacts (emissions).

The most likely boundaries of the zero-emission zone are just the inside of the highway ring around the city of Rotterdam. UCCs are planned at the edge of the zero-emission zone: seven possible locations for consolidation centers for last mile deliveries were identified (see Figure 4-2). We reformulate the general definition of a UCC [34] to our specific case study as: a logistics facility that is situated in relatively close proximity to the zero-emission zone, from which consolidated deliveries are carried out within that area. The UCC receives the deliveries from a larger number of suppliers. We also assume that horizontal collaboration exists, and shipments are assigned to the UCC based on their proximity. The propensity to use the UCC as an alternative depends on the logistic segment [33]. Table 4-1 presents the UCC propensity that is assumed in the transition scenario. Rotterdam has conducted a survey in which the logistics community is asked to reflect on their preferences to choose UCCs once they have to deliver or pick up within the ZEZ. together with the expert's description of the propensity in the road map, we have an upper bound and lower bound of the probabilities.

Table 4-1: UCC propensities by logistic segment

Logistic segments	UCC propensity Road Map	UCC propensity Rotterdam survey
1. Temperature controlled	15%	33%
2. Fresh Food(General Cargo)	20%	19%
3. Miscellaneous (General Cargo)	20%	14%
4. Waste	0%	0%
5. Express and parcels	50%	25%
6. Facility	20%	27%
7. Construction	30%	10%
8. Dangerous	0%	0%

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From the Rotterdam survey, we also realized the UCC propensities have a positive correlation with the size of the carriers. A linear regression model can represent this correlation. Please note that the relatively small sample size and uneven distribution of respondents among logistic segments do not allow us to derive a separate equation for each segment hence we are assuming the same regression model holds on average for all logistic segments. However, TFS provides the option of using separate equations for different logistic segments if one can calibrate them based on more comprehensive data.

UCC propensity= 0.0992× Firm_size + 0.0639

The result of this regression model is bounded between the Road map UCC propensity and the UCC propensity derived from the Rotterdam survey (see Table 4-1). For example, in the temperature controlled segment, we use the above equation to calculate the UCC propensity. If the UCC propensity calculated is less than 15%, we consider it to be 15% and if it is more than 33% we consider it to be 33%. For the UCC calculated between 15% and 33% using the above regression equation, we use the calculated number. In this way, the simulation of the ZEZ scenario is more inclined to reality and is validated by the measurements from the practitioners.

The second shift in the scenario involves the transition from the conventional vehicle to a ZE-vehicle. One of the solutions is the usage of LEVVs (cargo bikes or small vehicles with an electric engine) or electric vans. These are effective solutions for many smaller volumes. But since the carrying capacity is insufficient for larger shipments, many shipments will be carried with conventional vehicle types but with alternative drivelines (electric, hybrid or hydrogen). In this scenario we assume that all transports that are not rerouted via a UCC but do (un)load in the Zero-Emission Zone (ZEZ) will make the switch to a hybrid driveline. Hybrid vehicles use an electric engine inside the zero-emission area, and switch to diesel power train outside the area: this way the vehicles still have a large operational range. Geofencing can be used to force the vehicles to use their electric engine inside the ZEZ. The most likely shift to alternative vehicle or driveline depends on the logistic segment. Table 4-2 shows the assumed vehicle type shares for the transports between the UCCs and ZEZ (and within the ZEZ) in the ZE-scenario (source reference for the assumption).

Table 4-2: ZE vehicle type shares per logistics segment

Vehicle type + combustion	**Logistics Segment**						
	Fresh food (General Cargo)	**Misc. (General Cargo)**	**Temp. Control-led**	**Facility**	**Construc-tion**	**Waste**	**Express and parcels**
LEVVs (e.g. cargo bike)	6%	6%	41%	20%	0%	22%	50%
Van-Electric	35%	35%	27%	60%	17%	0%	50%
Van-Hybrid	0%	0%	0%	0%	4%	0%	0%
Truck-Electric	25%	25%	16%	12%	24%	13%	0%
Truck-Hydrogen	0%	0%	0%	0%	2%	0%	0%
Truck-Hybrid	16%	16%	11%	8%	15%	9%	0%
Tractor Trailer-Electric	4%	4%	1%	0%	6%	0%	0%
Tractor Trailer-Hydrogen	4%	4%	1%	0%	6%	0%	0%
Tractor Trailer-Hybrid	11%	11%	3%	0%	17%	0%	0%
Waste Collection-Electric	0%	0%	0%	0%	0%	11%	0%
Waste Collection-Hydrogen	0%	0%	0%	0%	0%	11%	0%
Waste Collection-Hybrid	0%	0%	0%	0%	0%	33%	0%
Special Construction-Hydrogen	0%	0%	0%	0%	2%	0%	0%
Special Construction-Biofuel	0%	0%	0%	0%	8%	0%	0%

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4.3 Results

The scenario is applied on the simulated shipments from the Shipment Synthesizer, the first module in the TFS. Next, the Scheduling module is run. Results are compared to a reference run of the situation before introduction of the zero-emission zone. In the Reference scenario 12 thousand shipments and 61 thousand parcels are transported per day to/from the area of the planned ZE-zone. Part of the shipments are rerouted through the seven UCCs (in blue) and distributed/collected inside the ZE-zone (in red). The other shipments are carried in the original tour, but using a ZE-vehicle. This leads to a small increase of 0.25% in the total Vehicle Kilometers (VKT) in the study area compared to the reference scenario. This is an unexpected, but realistic finding and can be explained by the extra leg that was added to the deliveries that are routed through the UCCs.

The transitions change the composition of vehicle movements in the ZEZ. Figure 4-2 shows the evolution of the fleet kilometers by vehicle type before and after the scenario application. New smaller vehicles such as e-scooters and electric cargo bikes travel around 10% more vehicle kilometers. These types of vehicles are introduced more frequently because they are the predominant vehicle used for last mile deliveries from the UCCs. The results also show that the composition of vehicles driving in the city center do not change dramatically. Of course, this is the result of the scenario assumptions: the Roadmap outlines how many shipments will be delivered using heavy goods vehicles (HGVs) but with alternative driveline type. This assumption is conditional to the availability of ZE- or hybrid vehicles. The outputs of these case studies can also be used as a prediction for the number of vehicles required to see if these numbers can be met by the truck manufacturers. We assume that carriers will use the available ZE- and hybrid HGVs in city logistics.

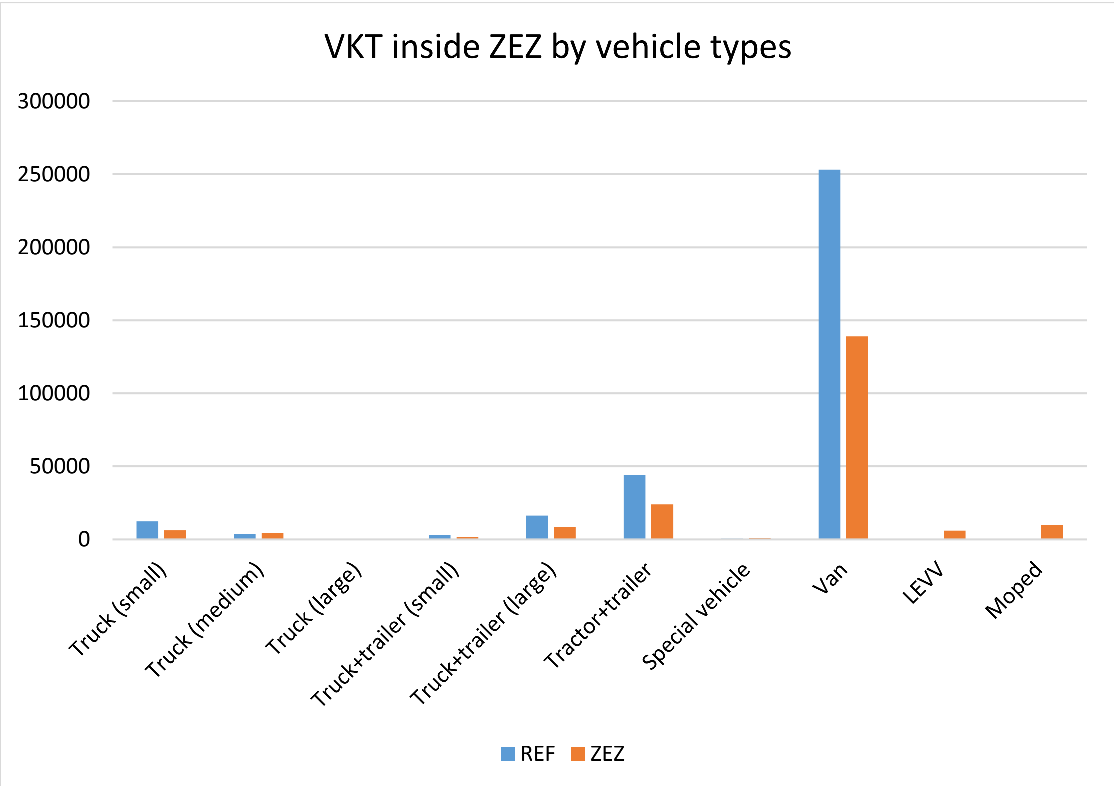

Figure 4-2: Vehicle kilometers by vehicle type before and after introduction of the zero-emission zone

Emissions are calculated from the route of each freight trip: this means that the calculation can take into account the vehicle type and load, but the route as well (location, link type, congestion)

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[29]. This is necessary for an accurate calculation of emission of hybrid trucks that have zero-emissions driveline based on their location. As expected, the implementation of the ZEZ led to a significant decrease in emissions in the ZEZ as it can be seen in Figure 4-4 and the totals presented in Table 4-3. All Greenhouse Gases (GHG) had a 90% decrease inside the ZEZ and were reduced by almost 10% in the rest of Rotterdam area. Results also show that the reduction of impacts is very small at regional (or national) level. Most of the freight traffic in this study area is unaffected by the zero-emission zone. In the area of Rotterdam most freight related traffic is generated by the port and involves long haul HGV transports that do not enter the city center: these transports remain unaffected. This case study shows that zero-emission zones are not the silver bullet in reducing greenhouse gasses. Additional measures are required to reach more ambitious climate goals. Future case studies with the presented simulation model will address the effectiveness of a combination of measures, both at local and national scale.

Table 4-3: Reduction in emissions at different scale levels

Type	In the ZEZ	Rotterdam	Study area (prov. South Holland)
CO2	-91%	-4%	-1%
SO2	-91%	-4%	-1%
PM	-86%	-6%	-1%
NOX	-93%	-5%	-1%

The implementation of the ZEZ in Tactical freight simulator provides an insight into the magnitude of the impact of the ZEZ in the study area and the local network: see Figure 4-3. This case study shows that the impact of UCCs is not trivial: emissions within the ZEZ are reduced (because all transport takes place with ZE-vehicles) but we can see a small increase in vehicle kilometers travelled (VKT) outside the ZEZ: +0.25% which can be attributed to the rerouting of shipments through the UCCs. Calculations confirm that emissions are reduced dramatically, by 91%, inside the ZEZ. At the city scale this corresponds to a reduction of 4%, as most freight related traffic is generated by the port and involves long haul HGV transport that do not enter the city center. At a regional level the reduction of impacts is very small, but emissions are reduced in particular in the high density urban area, which has a positive impact of the liveability in these important neighbourhoods. The impacts on city level are significant and a good step towards the ambition from the current municipal coalition agreement to reduce CO2 emissions by 49% by 2030. However, to achieve this policy objective more measures are needed for instance measures to decarbonize long-haul freight transportation, that make up for a large part of the emissions in the study area.

We also present the effectiveness and possibilities of the HARMONY Tactical Freight Simulator to address a complex zero emission city logistics scenario, with UCCs and vehicle type transitions. The level of detail in the multi-agent model also permits the assessment of different transition paths to ZE –vehicles for each logistics segment, to better account for heterogeneity in preferences of different actors. This provides a better empirical basis for informed decision making, e.g. on the planned size of the zero-emission zone, and to plan to support UCCs to provide accessibility for all stakeholders.

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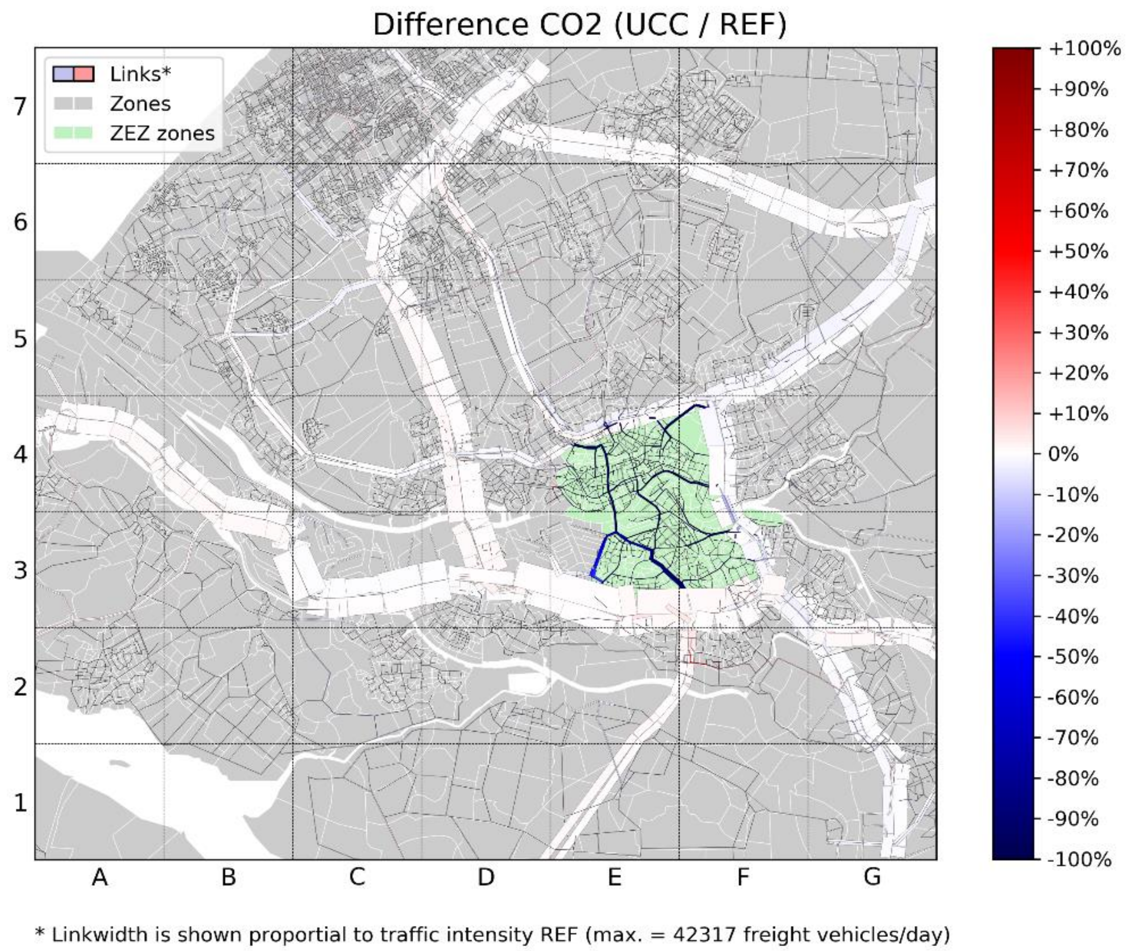

Figure 4-3: Change in emissions as a result of the zero-emission zone in Rotterdam

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5 Use Case 3: Crowdshipping

5.1 Introduction

5.1.1 Background

Digitalization and technological innovations has changed the logistics and freight transport system in recent years. These innovations, for example, have led to an exponential increase in e-commerce. PostNL as the largest Dutch parcel delivery service providers noted 29.6% increase volume of parcel deliveries in the last quarter of 2021 (PostNL, 2021), which was also fuelled by the Covid-19 lockdowns. The increase in demand on one hand and competition between logistic service providers to satisfy e-commerce customer's expectations on the other, has opened new opportunities and business models for last mile logistics. Crowdshipping is one of the new concepts that it's applicability in the city logistics has been eased by advancements in digital platforms. Crowdshipping is counted as an innovative solution to make use of the capacity of passenger transport in delivering parcels to customers. This solution could work in parallel to the traditional delivery methods (conventional carriers) to make the last-mile delivery more sustainable and efficient (Punel et al.,2018 & Rai et al., 2017).

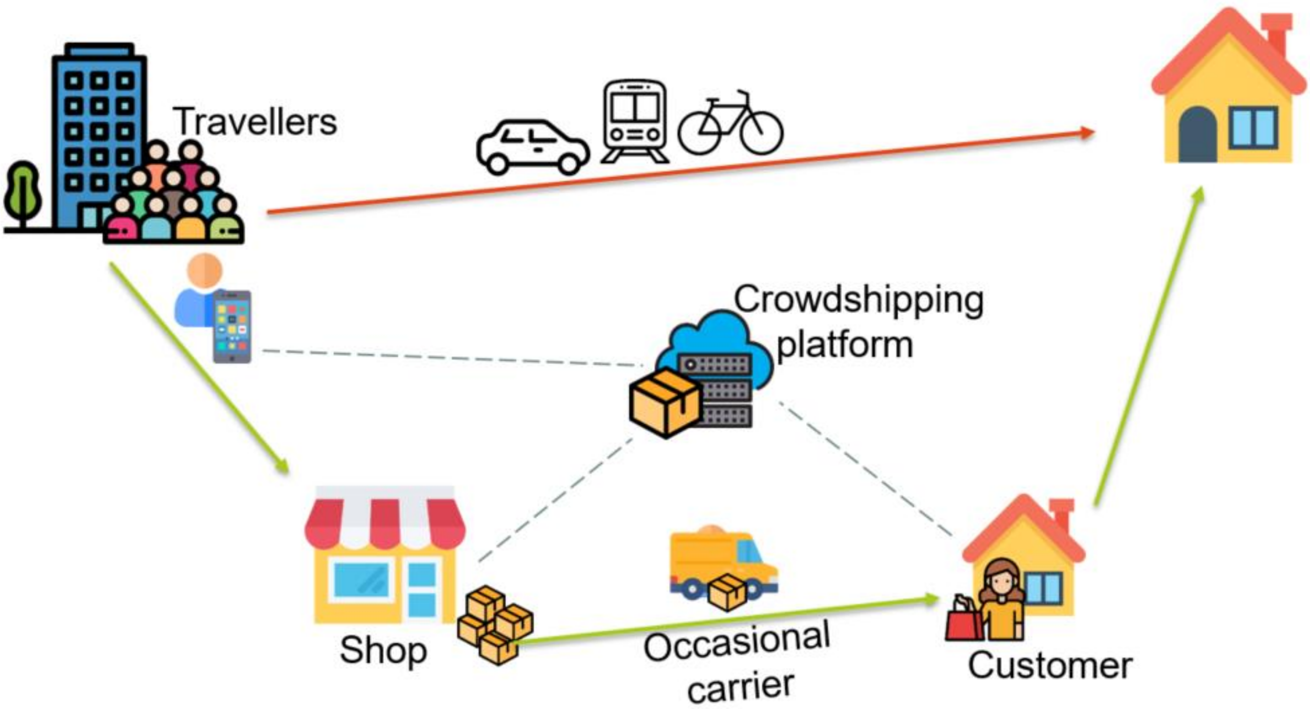

Figure 5.1: crowdshipping scheme

5.1.2 Objective of the use case

Although crowdshipping seems to be beneficial in terms of capacity utilization in transport systems, its pros and cons have not yet been explored thoroughly due to its complexity. This is therefore worthwhile for large metropolitan areas to study the impact of crowdshipping on the transport systems. In this usecase, we will use the TFS module of HARMONY MS to simulate the impacts of the implementation of different implementation scenarios for crowdshipping in the province of Zuid Holland in the Netherland. With this simulation experiment, we will explore and evaluate the viability of crowdshipping by assessing its positive and negative impacts on both the freight and the passenger transport system.

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5.2 Methodology

5.2.1 System Identification

The complexity of crowdshipping arises from the fact that it has to coordinate multiple actors in two systems using the same infrastructure. We, hence require an agent-based simulation with which we can study the interaction between these actors. Identifying agents and their interaction in a system is a prerequisite to agent-based modelling. In a crowdshipping ecosystem, four agents can be identified. These agents are customers, travellers, occasional carriers, and the crowdshipping platform.

The interactions between these actors can best be understood through a conceptualization of the crowdshipping ecosystem. This conceptual framework (see figure 5-2) has been developed by Maarten Berendschot (2021) specifically for this usecase and mainly relies on reviews in the literature like Rai et al. (2017), Savelsbergh and Van Woensel (2016).

In order to build a conceptual framework for the crowdshipping system, we first need to outline how this system works. A crowdshipping system needs to be managed by a digital platform that sets the conditions and communicates the possibilities to the retailers. The retailer (consignor) is now able to offer crowdshipping as a delivery option and the customer can place an order with crowdshipping as a delivery method. Once the order is made, the retailer redirect the order to the platform which then the delivery tasks will be assigned to traveller. This assignment takes place through communication between the platform and travellers. First, travellers communicate their trip to the platform after which the platform proposes suitable shipment possibilities to the traveller. Traveller now can decide whether and which offers to accept. Once a shipment is accepted, the traveller role becomes occasional carrier. The platform receives the accepted offer and notifies the consignor. Finally, the occasional carrier collects the parcel at the consignor and delivers it to the customer.

Base on the above explanation, figure 5.2 Shows the conceptual framework through which we modelled and simulate agents and their interactions in the simulation experiment.

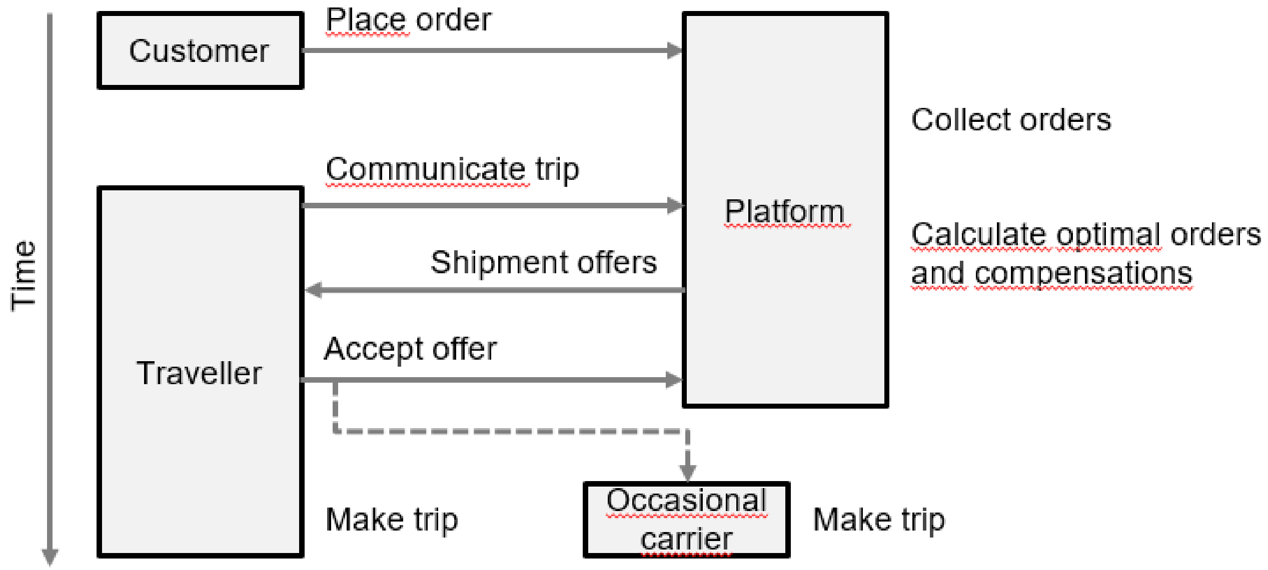

Figure 5-2. The conceptual framework of the crowdshipping system (Source: Berendschot, 2021)

As we can see from Figure 5-2, Each of these agents has goals, states, actions, and interactions with other agents and the environment. In the next section, we explain how the characteristics of each of these agents can be modeled for a simulation experiment.

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5.2.1.1 Crowdshipping platform

The crowdshipping platform assigns the demand for parcels to the supply of travellers. The platform agent has three actions to take: order administrations, parcel assignment and optimization, and compensation calculation.

Orders administration

The platform provides an overview of all ordered parcels by the customers. This includes the parcel's origin and destination, shipment distance, a status of the orders. Furthermore, it generates some statistics and indicators for the evaluation of the platform's performance. The platform also takes care of orders with crowdshipping status which no proper match with travellers is available or travellers did not accept to deliver them. in such cases the platform assigns these parcels to the conventional delivery services.

Optimization strategy

In this model, the orders are static over the day meaning that the platform collects all the orders from customers (origins and destination of parcels) and also all the travellers' trips (origin and destination of travelers). Being that the case, we assume that all the customers placed their order and also travellers reported their trips on the platform at least one day before the operation day. By looking at the origin and destination of parcels and travellers, the platform decides on the most suitable parcels for each traveller. This decision is based on minimizing the relative detour that a traveller has to make to deliver a parcel. the platform calculates the relative detour as follows

$$rd(p,t) = \frac{d^t_{i\to m\to n\to j} - d^p_{m\to n}}{d^p_{m\to n}}$$

Where:

- $rd(p,t)$ is a relative detour of traveller t for delivering parcel p,
- $d^t_{i\to m\to n\to j}$ denotes the detour (km) that a traveller with origin i and destination j has to make to deliver parcel p from location m to n,
- $d^t_{m\to n}$ is the distance(km) between locations m and n

The platform offers each traveller three parcels with the lowest relative detour. The platform agents also apply a relative detour treshold. If no traveler is found for which the relative detour is smaller than this treshold value, the parcel is filtered out and delivered by regular transportation. For this case study, a treshold value of 0 has been applied for the relative detour. Hence, a parcel was not offered for crowdshipping if every available traveler has to make a detour which is longer than the shipment distance for that parcel. . $rd(p,t) < detour\ threshold$.

Compensation calculation

The platform has to compensate for the detour to increase the acceptance of the traveller. Higher remuneration will lead to more accepted orders. However, crowdshipping must be economically viable and so the payment to the traveller should be less than the payment by the consignor. In 2020, the average price of parcel delivery in the business-to-consumer market was €3,35 in the Netherlands (Authoriteit Consument & Markt, 2020). To be competitive with these conventional services, this is the maximum price for the crowdshipping service as well. The minimum desired compensation for travellers is set to €1,50. Given the minimum and maximum remuneration, we used the following compensation scheme relative to the traveller detour distance where smaller trip lengths are compensated better per kilometre as compared to the longer trips.

$$compensation\ (€) = \log\left(d^t_{i\to m\to n\to j} + 5\right)\ )$$

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5.2.1.2 Customer

The customers behind parcel demand and their characteristics and decisions have a direct impact on the crowdshipping. Customers order parcels and choose the delivery method. We modelled their choice of the delivery method based on their willingness to crowdshipping. The willingness of customers to use crowdshipping as their delivery method is studied in the literature (Punel and Stathopoulos, 2017 and Gatta et al. (2019)). Based on these studies, we choose to use 30% adaptation rate. However, not all the retailers and consignors can provide crowd shipping options. It is expected that 20% of the parcels have this option. This would result in 6% (0.3*0.2)of the parcels being eligible for being picked up and shipped by travellers.

5.2.1.3 Travellers

Travellers are the main operating actors in the system that can act as potential carriers of the parcels. These agents should take two important decisions and their decision should be modelled in this simulation study. First, they have to decide whether they are willing to detour and ship a parcel. This only can take place after the platform provided three suitable parcels for the travellers. In this study, A rough estimate of 30% is used for the traveller's willingness to ship based on the literature. No distinction could be made in different modalities due to the lack of data and studies in the literature. However, the option to fine-tune this parameter is implemented in the simulation for future use.

The second decision that travellers have to make is choosing a parcel among the three alternatives that the platform provides for them. The traveller has two objectives when considering these delivery options. On the one hand, they will aim to maximize their compensation and are thus inclined to take the longest parcel trips. On the other hand, they would minimise their travel time and time spent to deliver this parcel. These two factors are both considered in the travellers' utility. The utility for a parcel (p) and a certain traveller (t) is calculated as follows.

$$U_{p,t}(€/h) = \frac{compensation(€)}{detour\ time_{p,t} + 2 \times parcel\ handling\ time_{p,t}}$$

Travellers would choose the parcel with the maximum utility only if the utility of this parcel is higher than the value of time (VOT) of the travellers

$$\begin{cases} accept\ to\ ship\ parcel\ p & if\ \ U_{p,t} > U_{p',t}\ \ and\ \ \ U_{p,t} > VOT \\ reject\ parcel\ p & otherwise \end{cases}$$

After accepting to ship a parcel in the system, the traveller commits to deliver the parcel and becomes an 'occasional carrier'. The Parcel handling time and value of time are used to calculate the utility that shipping a parcel may have for a traveller and to model travellers decision-making process. The parcel handling times refer to the times that occasional carriers should spend to pick up the parcel at the consignor and drop off it at the customer locations. This includes time for parking the vehicle, administrative tasks and possibly waiting.

5.2.1.4 Occasional carrier

The final agent that has to be modelled in this system is the occasional carrier. This agent type is assigned to the travellers who choose to ship a parcel in the system. The simulation platform limits each occasional carrier to ship only one parcel. The only decision that should be modelled for this agent type is making a trip. For this, the originally planned trip is combined with the origin and destination of the chosen parcel. It means that an occasional carrier starts his/her trip at the origin of the traveller and then goes to the origin of a parcel to pick it up. After visiting the destination of

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the parcel to deliver it to the customer, the occasional carrier ends his/her trip at the originally planned traveller's destination.

5.2.2 Simulation implementation

To simulate the crowdshipping system, the crowdshipping simulator uses the output of V-MRDH traffic model for acquiring travel patterns (bike and car) in the metropolitan area of Rotterdam and Den Haag. Additionally, it interacts with the HARMONY tactical freight simulator (TFS) . More specifically, it uses the parcel demand module and parcel scheduling module of TFS to distinguish parcels that are eligible for crowdshipping. The figure below shows an overall interaction between these simulator modules.

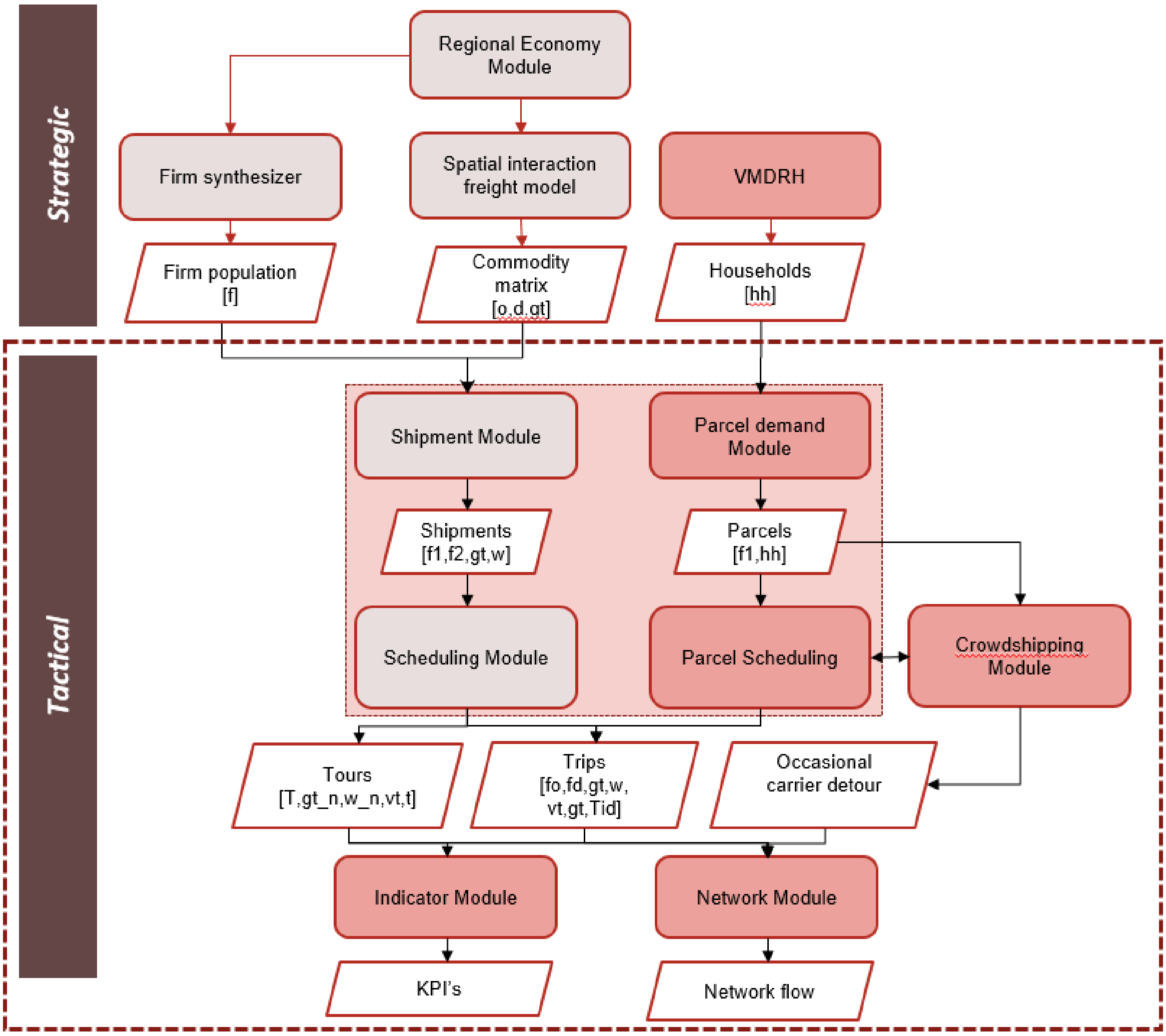

Figure 5-3: TFS interaction with crowdshipping module

To elaborate in detail on how the crowdshipping module works, the building blocks including the algorithm of this module are illustrated in figure 5.4.

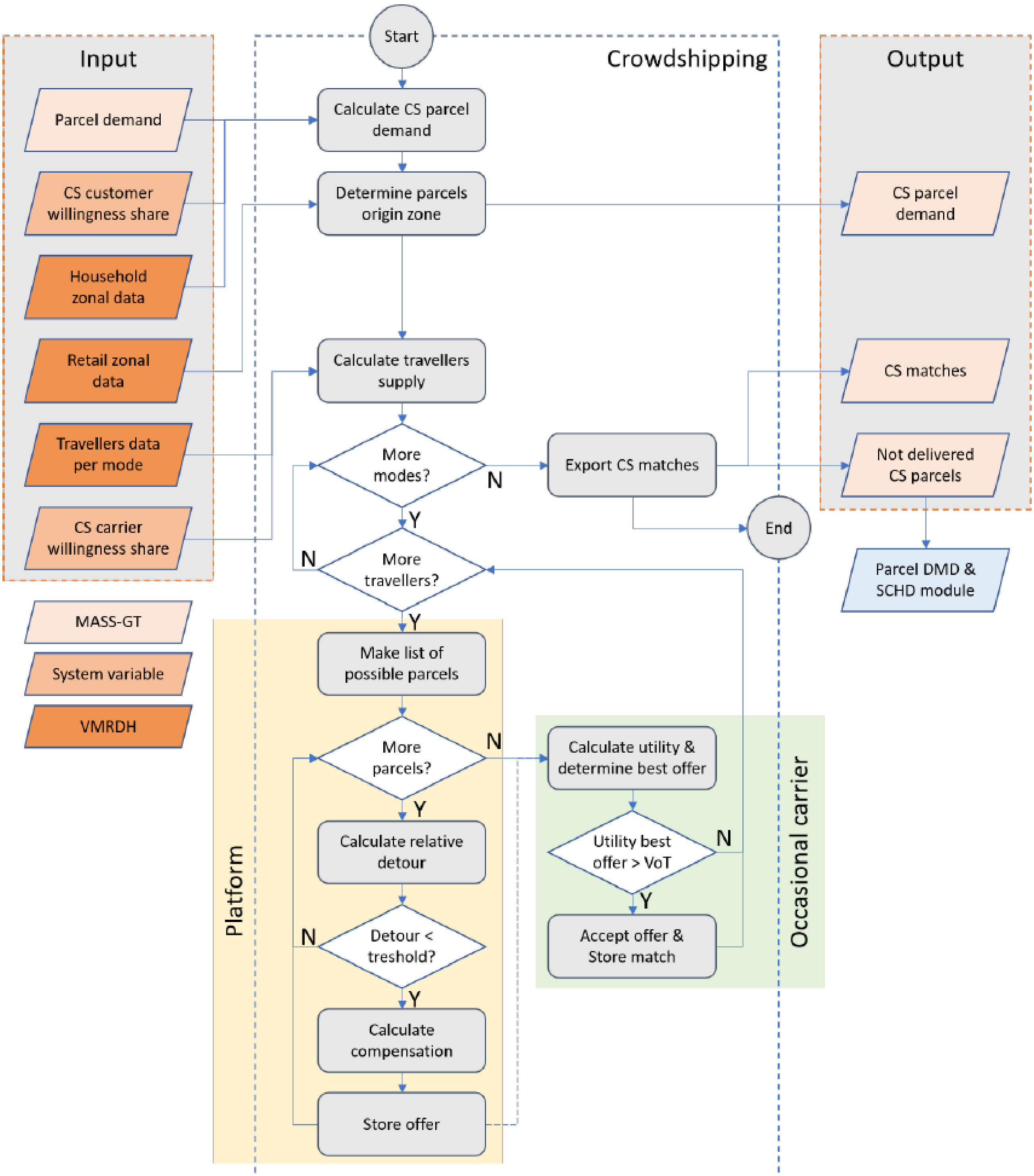

Figure 5-4: The simulation procedure of crowdshipping module

5.2.3 Specification of the crowdshipping simulation

As explained in the previous section, the parcel demand for crowdshipping simulation is generated by the parcel demand module in TFS. See for a description the deliverable 6.3. This module generates the B2B parcel demand to workplaces and B2C parcels to households. These demands

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are distributed over zones of the study area (South Holland, in the Netherlands, light pink polygons in figure 5-5) based on their socio-demographic characteristics. The origin of these parcels is assigned to the depots of the corresponding parcel carriers (in total 6 in the study area). The location of these depots is collected from Openstreetmap (see Figure 5-5). The crowdshipping module first of all calculates the proportion of parcel demand eligible for CS. For this demand, the module simulates the origin and destination of these parcels. Destinations of the parcels are the zones for which the parcels are generated. To identify the origin of the parcels, first the simulator assigns each parcel to one of the 6 parcel carriers based on the market share of these carriers. Then the origin of each parcel is assumed to be the closest depot of the corresponding parcel carrier.

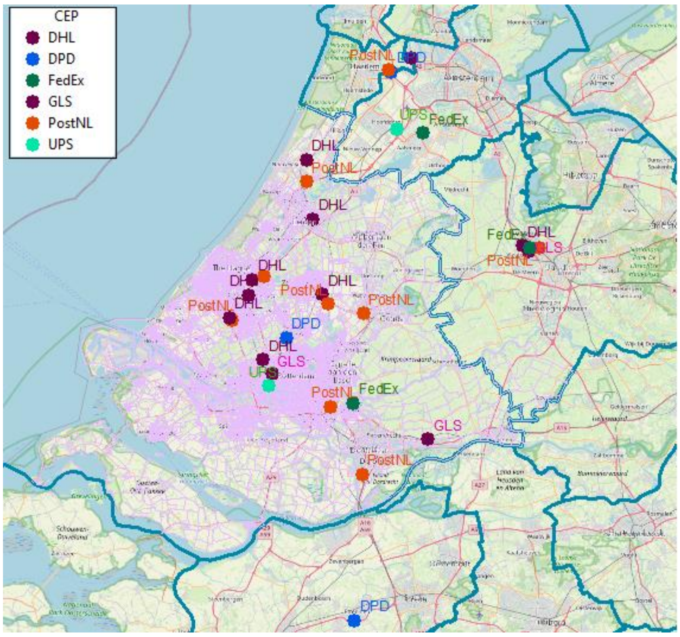

Figure 5-5: pickup location of parcels

To calculate the supply of travellers, the simulated trip patterns from the traffic model V-MRDH for the study area is used. Within the study area, 2.3 million car trips are made, over 450,000 public transport users and just below 1.8 million cycle trips each day. For these modes, an origin-destination matrix for all 5925 zones is available. The travel times for car trips is known using the skim matrix. The time skims matrix for cycling trips could easily be computed by dividing the distance by the average cycling speed of 12 km/h (Molnár, 2002). For public transport, however, no travel time skim matrix is available and for this reason, public transport travellers are not taken into account in this research. Please note that the traveller supply is considered to be a static input: no feedback loop is simulated from the changing travel patterns evoked by crowdshipping, back into the traffic model. It is expected that the impacts of the changes in travel patterns will be marginal on the traffic flow conditions.

The TFS with an enabled crowdshipping setting requires a set of specifications for running each scenario. A list of specifications of the TFS for crowdshipping scenario is listed in the table below. These specifications are parameters that control either demand or supply side of the crowdshipping platform.

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Table 5-1 Model specifications

Specification	Side of the system	Crowdshipping (Base)
Parcel per employee	Demand	0.041
B2B success rate	Demand	0.95
B2C success rate	Demand	0.75
Crowdshipping willingness	Demand	0.06 (6%)
Van max parcel load	Supply	180 (parcels)
Bike max parcel load	Supply	1 (parcel)
Car max parcel load	Supply	1 (parcel)
Bike willingness to ship	Supply	0.3 (30%)
Car willingness to ship	Supply	0.3 (30%)
Bike value of time	Supply	8.75 euro/h
Car value of time	Supply	9 euro/h
Bike idling time	Supply	0.0167 (60 seconds)
Car idling time	Supply	0.033 (120 seconds)
Van idling time	Supply	0.033 (120 seconds)
Bike Detour threshold	Supply	0
Car Detour threshold	Supply	0
Compensation scheme	Supply	Log(parcel distance+5)

Based on a study by McLeod et al. (2020), the drop-off time for delivery vans is about 2 minutes per parcel on average. This figure is half for bicycles, mostly because of less time spent parking the vehicle. It is assumed that the parcel handling at the pickup location also takes as long as its drop-off.

For The Netherlands, the value of time for car drivers is €9.00 per hour and €7.50 for public transport users (Kouwenhoven et al. (2014)). No specific outcomes are given for cyclists, so the total average of €8.75 is used for this mode. The VoT for cyclists is likely to vary, and cyclists with lower VOT are more likely to crowdship. If a distribution is known it could be a good direction fo research to further distinguish cyclists by VOT or socio demographic characteristics.

In crowdshipping case, 6% of the parcels are assumed to be eligible for crowdshipping. The willingness of the travellers to accept to join the crowdshipping system is assumed to be 30% for both bikes and cars (based on literature). In order to fine-tune the detour threshold and compensation scheme presented in table 5-1, we have run the simulation multiple times with various settings.

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5.3 Results

To assess the impact of the crowdshipping scenario on passenger and freight system, we run the TFS, first without (REF), and then with crowdshipping settings.

In addition, we have run several crowdshipping scenarios for sensitivity analysis of the parameters and assumptions made for crowdshipping simulation setups. Within these scenarios we could explore the impact of detour threshold on freight and passenger transport systems. We also could test the compensation policies. In the next sections we elaborate on crowdshipping simulation experiment and compare it with the reference and base-case scenarios.

5.3.1 Parcel delivery without crowdshipping (Reference case)

In the REF case, all the parcels are scheduled and delivered by conventional carriers (using Van vehicle type). In the passenger transport system on one hand, 4.1 million trips are simulated by V-MRDH model, of which 57% are made by car and the other 43% by bike. Travellers have driven a total distance of 15.5 million kilometres (6.6 km/trip) by car while the total driven distance of bike travellers is 7 million kilometres (3.9 km/trip). In the freight system on the other hand, 243000 parcels are delivered by customers on a daily basis. The total distance traveled by vans to deliver these parcels in the study area is 90 thousand km. Table 5.2 summarizes the indicators of both passenger and freight transport system in the reference case resulting from simulation of the study area without crowdshipping.

Table 5.2: Simulation result of parcel delivery without crowdshipping for the study area

Indicator	Freight system	Passenger system
Total number of parcels	242866	-
Vans' number of tours	1362	-
Vans' number of trips	33259	-
Vans' VTK (km)	89718.05	-
Bikes' number of trips	-	1763000
Bikes VTK (km)	-	6,917,000 (3.92 km/trip)
Cars' number of trips	-	2337000
Cars' VTK (km)	-	15,468,000 (6.6 km/trip)

In the reference case (see Table 5.2). All the 242866 parcels are delivered by conventional carriers which resulted in 89718.05 km travelled by van. The kilometer per parcel ratio in this case is 0.37.

5.3.2 Parcel delivery with Crowdshipping

The TFS demand module generates the parcel demand for 6625 zones in south holland. However, we could only simulate the crowdshipping in 5925 zones in the study area within which the travellers' origins and destinations are available from V- MRDH model. That means that from 242866 parcel demand in the reference case, 148790 parcel demand is considered for the simulation. The result of simulation shows that from the total 148897 ordered parcels, 9569 parcels are eligible for crowdshipping of which 8311 parcels (86.85%) have been delivered by occasional travellers.

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From the delivered parcels by crowdshipping, 5163 parcels are delivered by bikes with the total of 8230 km extra travelled distance and 3148 parcels are delivered by passenger cars with the total of 12450 km extra travelled distance. A comparison between the reference and crowdshipping scenarios shows that the crowdshipping system can decrease vans' travelled distance by 1553.19 km. This, however, is at the cost of cars' extra 12450 km travelled distance that is imposed to the transportation system by occasional carriers. The kilometre per parcel ratio for the crowdshipping scenario is 2.16 ((12450+8230)/9569). This ratio is relatively high as compared to the reference case. This is due to the inefficiency of the occasional carriers as compared to the efficiency of professional parcel delivery companies. These inefficiencies mostly arise from the fact that professional delivery companies bundle parcels into one vehicle and hence can drive less to deliver the same number of parcels.

As Figure 5-6 shows, detour length is on average 3.95 km per parcel for cars and 1.59km per parcel for bikes. The distribution of detour length of bike users is denser around the average as compared the car users. This logically shows that car users are more flexible for larger detours as compared to the bike users. Regardless of their mode, occasional travellers have made 2.49 km detour on average to deliver these parcels.

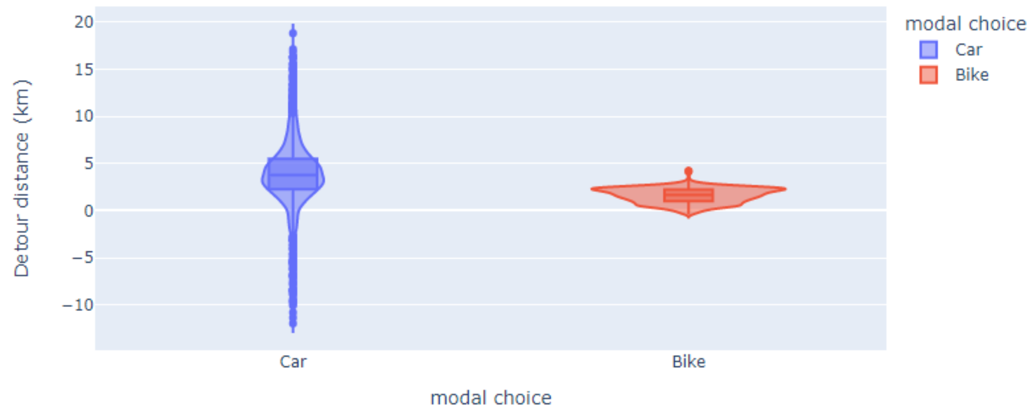

Figure 5-6: Distribution of detour distances per modes

Looking at the distribution of Cars' detours in figure above, we can observe some occasional carriers with negative detours (minimum detour is –11.95 km). That means less distance is travelled when a traveler delivers a parcel. This is because travelers usually use the fastest route in their trajectory not the shortest route. Therefore, when occasional carriers make a delivery, it might be a case that they travel shorter distance while the path will take longer. This leads to a negative detour. Figure 5-7 Shows a representation of this issue.

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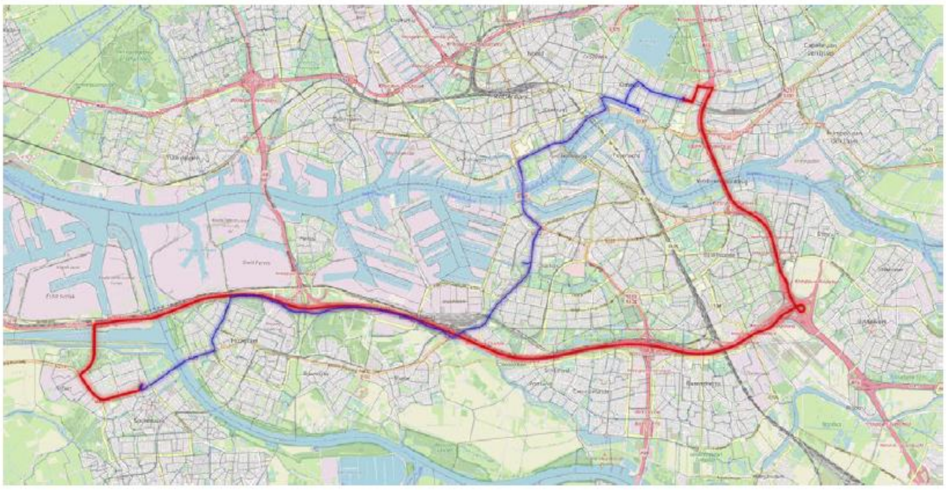

Figure 5-7: Representation of negative detours

In general, the average provided compensation for the occasional carriers is 2.32 euro. Figure 5-8 compares the distribution of compensation for car and bike users. The average compensation provided for bike users is 2.12 euro and for car users is 2.44 euro.

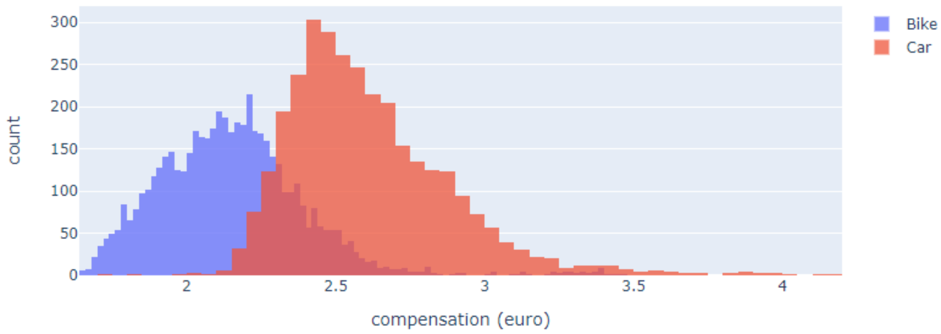

Figure 5-8: Distribution of compensation per modes

From the 9569 parcels that are eligible for crowdshipping, 8311 parcels are delivered by occasional carriers and 1258 parcels are delivered by conventional carriers because eighter the detour threshold or value of travel time constraints could not be satisfied for any travellers. Looking at the destinations of these parcels, it looks like that parcels that are carried by occasional carriers are more likely to belong to residential areas (B2C) while the crowdshipping parcels that are delivered by conventional carriers are more likely to belong to industrial areas (B2B).

From this analysis, we could conclude that the crowdshipping has a marginal positive impact on freight transport system reducing van's vehicle kilometres meaning that carriers can reduce their fleet size and yet being able to deliver their parcels, hence this would reduce fixed and variable cost of having larger fleet size. The crowdshipping, however, has a negative impact on transport system since a large share of crowdshipping parcels will be delivered by travellers using passenger cars and the extra detour cost imposes a surge of vehicles flows in the residential areas. Therefore, policy makers and municipalities in the metropolitan areas have to be aware of such side effects. Note that the initial assumption was that the introduction of crowdshipping would not significantly affect traffic flows as simulated in V-MRDH.5.3.3 fine tuning crowdshipping platform

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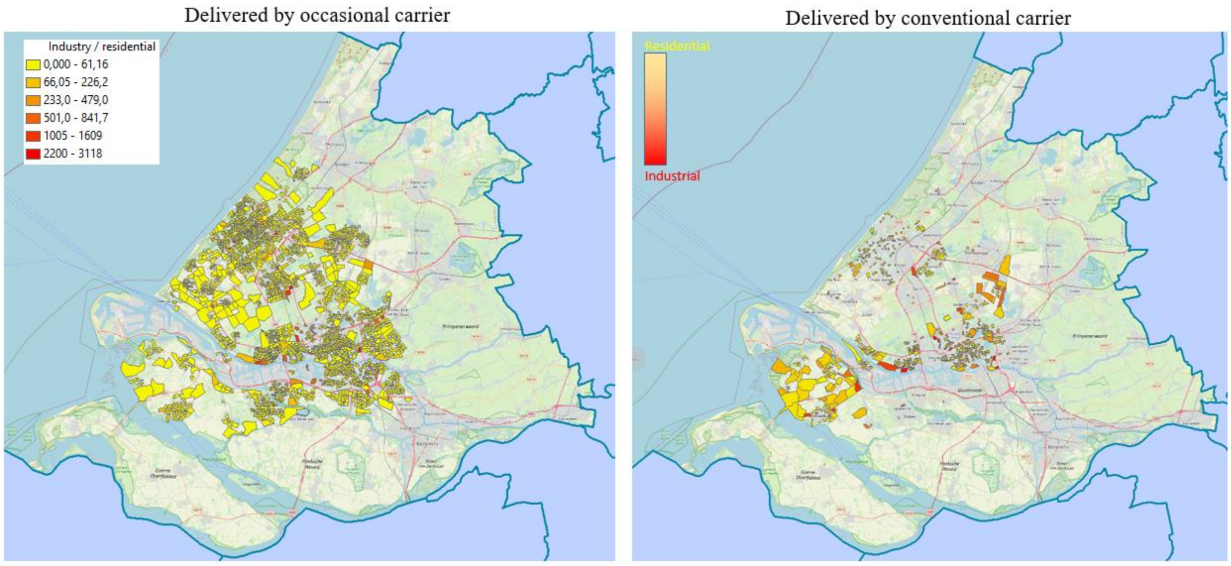

Figure 5-9: Comparison of the destinations' land use for occasional and conventional carriers

Given that the result of the crowdshipping simulation depends on the assumptions made to setup the simulation experiment, we could explore the possibilities to reduce these side effects and make crowdshipping more efficient. One of the important assumptions that could have a direct impact on these side effects is detour threshold value. We, therefore, have run several crowdshipping scenarios to assess the impact of various detour thresholds on the passenger and freight transport system. In each scenario, we decreased the detour threshold from 0 to –1 gradually. This means that the crowdshipping platform limits the occasional travellers to deliver a parcel with detours lower than shipment distance. Table 5-3 Shows that the percentage of crowdshipped parcels decreased accordingly. However, the efficiency of the crowdshipping increased, I.e. less kilometres per parcels were computed . We find out that the threshold –0.7 can the best setting for the crowdshipping platform since a large percentage of crowdshipping parcels (71.88%) are delivered by crowdshippers while the kilometre per parcel ratio is relatively very low (0.67 km) and closer to the conventional carriers (0.37 km).

Table 5-3: Percentage of crowdshipped parcels decreased according to detour threshold

Threshold	Crowdshipped (%)	Kilometre/parcel
0	86,85%	2,48
-0,2	85,63%	2,29
-0,5	82,86%	1,58
-0,7	71,88%	0,67
-1	38.25%	-1.09

In table 5-4 We report the output of crowdshipping scenario with –0.7 detour threshold. It can be seen from the Table 5-4 that the crowdshipping with –0.7 detour threshold functionality is more

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efficient and has less side effect on passenger system. With this setting, the crowdshipping system imposes 2190 km cars' vehicle kilometres to the passenger system while decreases 1583.02km vans' kilometre travelled distance from the freight system. This would be the maximum functionality of the crowdshipping system with minimum payoff in the study area.

Table 5-4: Output of the crowdshipping scenario with -0.7 detour threshold

Measurements	Crowdshipping parcels
No. parcels	9429
No. delivered parcels	6778
Parcel delivered by Bikes	3487
Parcel delivered by Cars	3291
Parcel delivered by vans	2651
average parcel distance	7.76 km
Total extra kilometre	4560 km
Bikes' total detour	2370 km
Cars' total detour	2190 km
Average detour	0.67 km
Average compensation	2.28 (euro)
Bike compensation	2,14 (euro)
Car compensation	2,43 (euro)
Decrease in vans' travelled distance	1583.02 km

In conclusion, The TFS of the HARMONY MS has shown its functionality in the impact assessment of the crowdshipping systems on freight and transport system. The result of this use-case showed that although crowdshipping could improve the efficiency of freight transport system in delivering parcels, it has marginal side effects on passenger system. These sides effects could be controlled by applying control policies on the crowdshipping platforms such as their parcel-to-traveller assignment policies (detour thresholds).

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6 Use Case 4: Spatial planning scenario of Logistic facilities

6.1 Introduction

The increasing competition for urban space has driven many logistic activities outside of the city centres into peripheral locations, also referred to as logistic sprawling (Dablanc et al., 2014). In addition, the size of logistic facilities is scaling up: almost half of the total logistic surface area is hosted by large distribution centres of >20.000 m2 (Onstein et al, 2021). The locations of these facilities have direct impact on accessibility, liveability, and sustainability, including visual intrusion of the landscape. Regional coordination in spatial planning of logistic facilities can be an effective tool to mitigate external impacts of new logistic facilities.

Currently, there is no national or regional spatial policy for the planning of logistic facilities. The allocation of demand for logistic real estate is a matter for local municipalities. Most often, any policy is lacking, and municipalities are often found in competition between their neighbours for the acquisition of new logistic businesses: they provide more jobs and increase the land value. This leads to pragmatic decision making and often uncontrolled and unsustainable planning of new logistic real estate. With the surging demand for logistic real estate this issue is requiring more substantial analysis to support sustainable planning. Therefore, in this use case, the Tactical freight Simulator is used to explore the impacts of alternative spatial planning scenarios for the study area Zuid Holland.

6.2 Methodology

The impacts of spatial planning scenarios are explored in a what-if-analysis. This means first scenarios are to be formulated in such a way that they can be analysed in the TFS. For the use case we develop two scenarios. The two main uncertainties in the spatial planning scenario are: economic growth and the type of spatial planning policy. For economic growth the WLO Low and High scenario are considered. The WLO Low scenario assumes 0.5% growth per year and high 4% per year. For each scenario a different spatial planning policy is assumed, differing in the degree of regulation in the allocation of logistic facilities.

This analysis consists of the following steps:

1. Estimate future demand
2. Allocate spatial demand
3. Impact assessment in the TFS

The first two steps are discussed in this section. The results from the impact assessment in the TFS are presented in the next section.

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6.2.1 Estimation of future demand

For future demand a high- and a low growth scenario are formulated. The Table below first of all shows the recent development of demand for logistic real estate in the study area, and the Netherlands over-all. The data are provided from a market report (NVM, 2021).

Table 6-1: Surface area of logistic real estate between 2012-2020.

	2012	2014	2016	2018	2020
South-Holland (M2)	4.420.000	4.687.500	4.883.000	5.538.000	6.944.500
The Netherlands (M2)	27.446.000	28.760.000	30.933.000	35.462.000	40.887.000
Growth SH (%)		+6,05	+4,17	+13,41	+25,40
Growth NL (%)		+4,79	+7,56	+14,64	+15,30

The increase in logistic real estate was substantial and dynamic over the recent years. The trend between 2012 and 2020 is considered to be representative for a strong growth scenario. Therefore, the recent trend is used to extrapolate the demand for 2030 in the high growth scenario. This implies a growth of 49% of the current floorspace.

For the low scenario a much more modest increase is expected. The relative variation is assumed to be consistent with the difference in macro-economic growth scenario. This corresponds to a factor 8: there the growth in Scenario 1 with low growth is assumed to be (0.5/4.0)x49% = 6%.

6.2.2 Location policy scenario

For each scenario, WLO Low and High, a different spatial planning policy is explored that are distinctive in the degree of regulation in the allocation of logistic facilities. For the low scenario we assume less regulations, and in the high scenario we are assuming stronger regulation.

In case of unrestricted policies, it is assumed that the current trend would continue: this means new logistic facilities will be planned in peripheral locations for lower land prices and near highways to lower transport costs. For the restricted scenario we assume that new logistic facilities will be planned on brownfield locations and existing industrial terrains and in urban areas.

A first step in the allocation of logistic facilities, is to define the search space. This is visualised in the following plots. In scenario 1 the DCs can be planned unrestricted. New locations are mostly considered to be placed beside the well-used highways. This is done for good accessibility and efficient transport costs. The red dots indicate the search area with potential new locations. The total demand of new logistic facilities (35 in total) is allocated to these dots.

For the second scenario, the new DCs are restricted to settle on already used industry areas. In this scenario, the DCs are more centralized because the new DCs are located in the already existing industrial area. Because there are already many DCs in these industrial areas, they are assumed to be attractive locations for logistic facilities and these areas are easily accessible because of the already existing infrastructure.

The following maps show the allocated floorspace of new DC's in both the unrestricted low growth scenario (1) and restricted high growth scenario (2).

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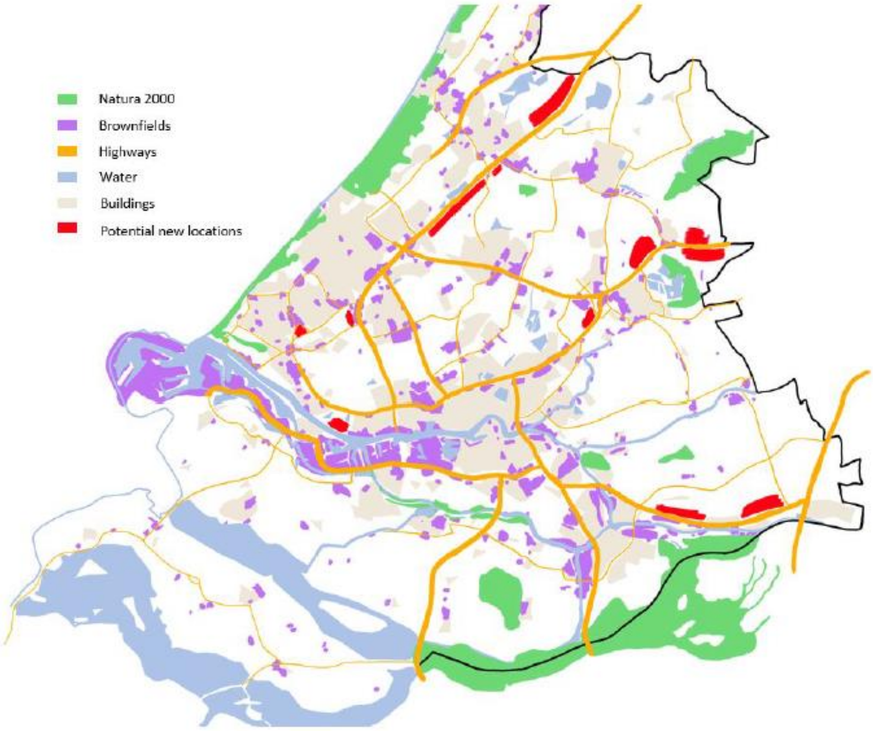

Figure 6-1: Search area for Scenario 1 with unrestricted development

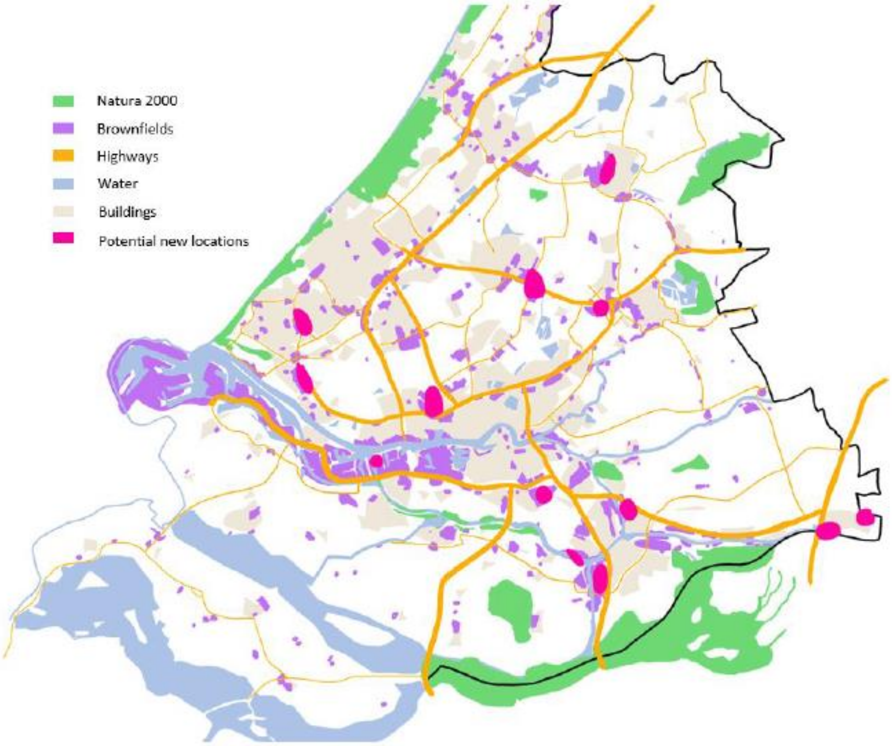

Figure 6-2: Search area for Scenario 2 with restricted development

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Figure 6-3: Allocated surface area of logistic facilities in Scenario 1 (unrestricted)

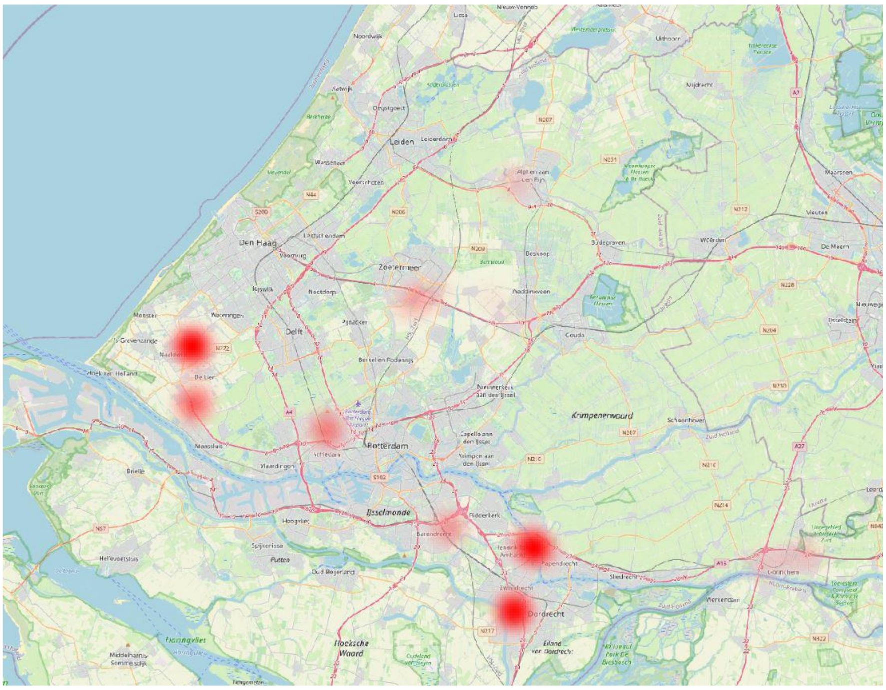

Figure 6-4: Allocated surface area of logistic facilities in Scenario 2 (brownfields)

Below an overview is provided of the assumptions in both scenarios. The impacts of the planned distribution centers in the scenarios are simulated by inserting the planned logistic real estate in the reference scenario for 2030. For both economic scenarios, the low and high scenario, a reference scenario is available for 2030 with the corresponding macro-economic growth of 0,5 % and 4 % annually. Scenarios 1 and 2 are developed as spatial alternatives in the WLO Low and High scenarios.

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Table 6-2: Overview of assumptions in the spatial planning scenarios

	Scenario 1	Scenario 2
Economic growth	Low economic growth of 0,5 %	High economic growth of 4 %
Location choice	Unrestricted	Only on brownfields
Growth rate	6,11 % (8 times lower than scenario 2)	48,9 %
Amount of new DCs	35	297

In the first scenario with low economic growth, 35 DCs are expected and in the second scenario with high economic growth 297 new facilities are planned. Next, these scenarios are used as input for the TFS, and the impacts are simulated on the transport system.

6.3 Results

The scope of the TFS is to simulate the impacts of policies on freight transport decisions, the freight demand patterns, and the generation of freight traffic. Doing so it provides information for the evaluation of impacts on accessibility and sustainability. The main KPI's it provides are vehicle kilometers and emissions.

The Table below summarises the global impacts. The WLO Low and High scenario show an toal increase of vehicle kilometers for 2030 of 6 and 15 % respectively . These scenarios include business as usual freight demand development, and no investments in new logistic facilities. In these scenarios it is assumed that all freight demand is handled through the existing logistic facilities, without capacity constraints. A direction for future research could be to constrain the flow through logistic centers. In the spatial scenario's the localization of new facilities have a redistributive impact on the pattern of freight shipments. The objective of scenario 1 and 2 is to explore what would be the impact of unrestricted allocation (peripheral and near highways) and restricted to brownfields (existing industrial terrains).

From the results of scenario 1 it shows that the unrestricted policy leads to a marginal increase in vehicle kilometers, even though the distribution centers are allocated near highways. The peripheral locations contribute to longer transport distances.

The restricted policy in scenario 2 shows that the planned locations for logistic facilities contribute to a modest reduction in vehicle kilometers. This is a positive outcome as it shows that the redistribution of logistic activities can help in reducing freight transport.

Table 6-3: Global impacts of Scenario 1 and 2.

Scenario	Baseyear 2018	Reference 2030 WLO abs	rel (%)	Spatial scenarios abs	rel. to 2030 REF (%)
Vehicle kilometers (vkms):					
Scenario 1: Low - unrestricted	18429993	19522354	5.9%	19550301	0.14%
Scenario 2: High – restricted	18429993	21219772	15.1%	21078784	-0.66%
CO2 emissions(kg):					
Scenario 1: Low - unrestricted	19418441	21716025	11.8%	21706821	-0.04%
Scenario 2: High – restricted	19418441	23816751	22.7%	23301287	-2.16%

The next figures show the local impacts of the spatial planning scenarios on traffic intensities and emissions.

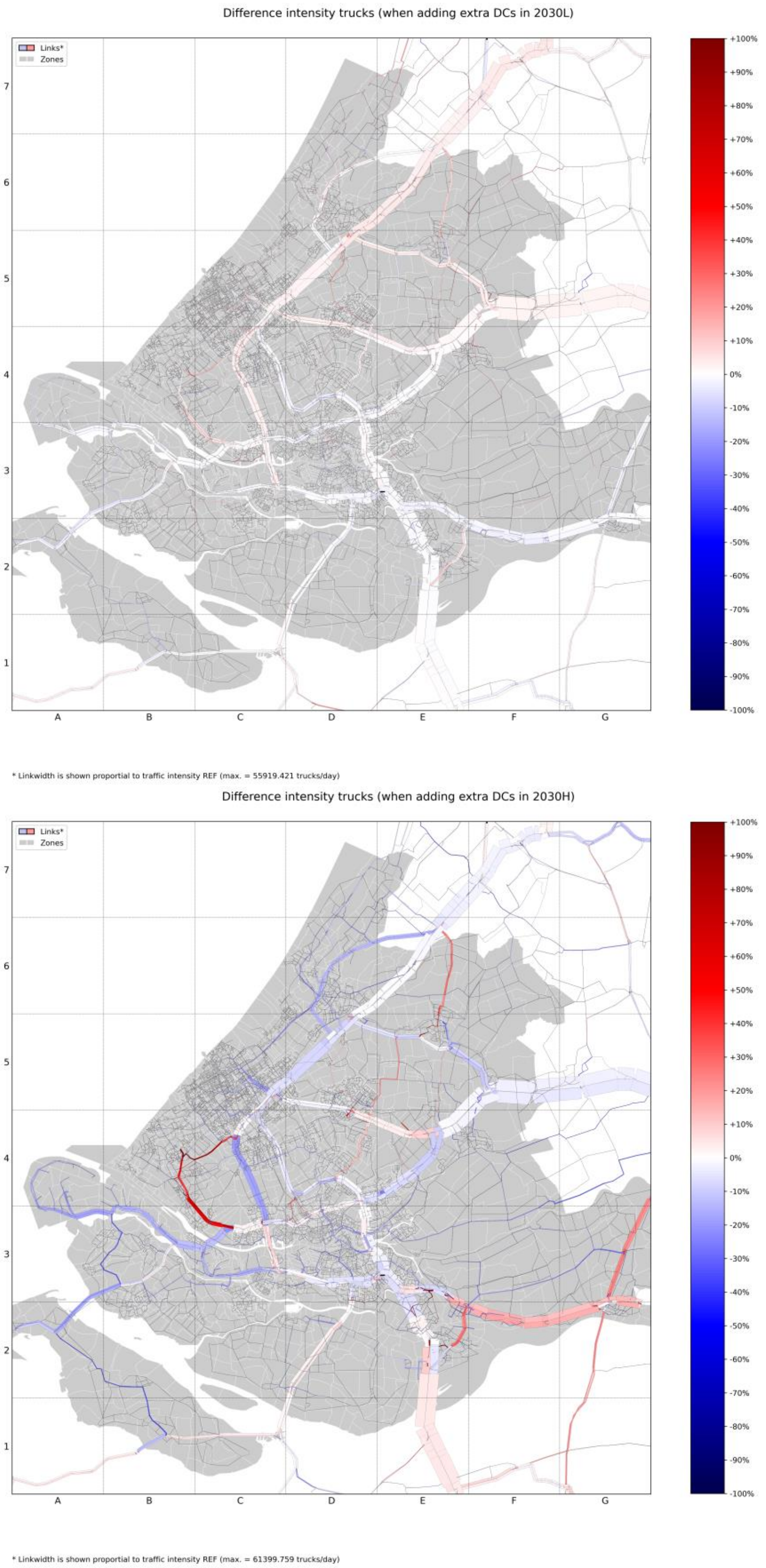

Figure 6-5: Traffic intensities in the Low scenario (Top) and High scenario (Below)

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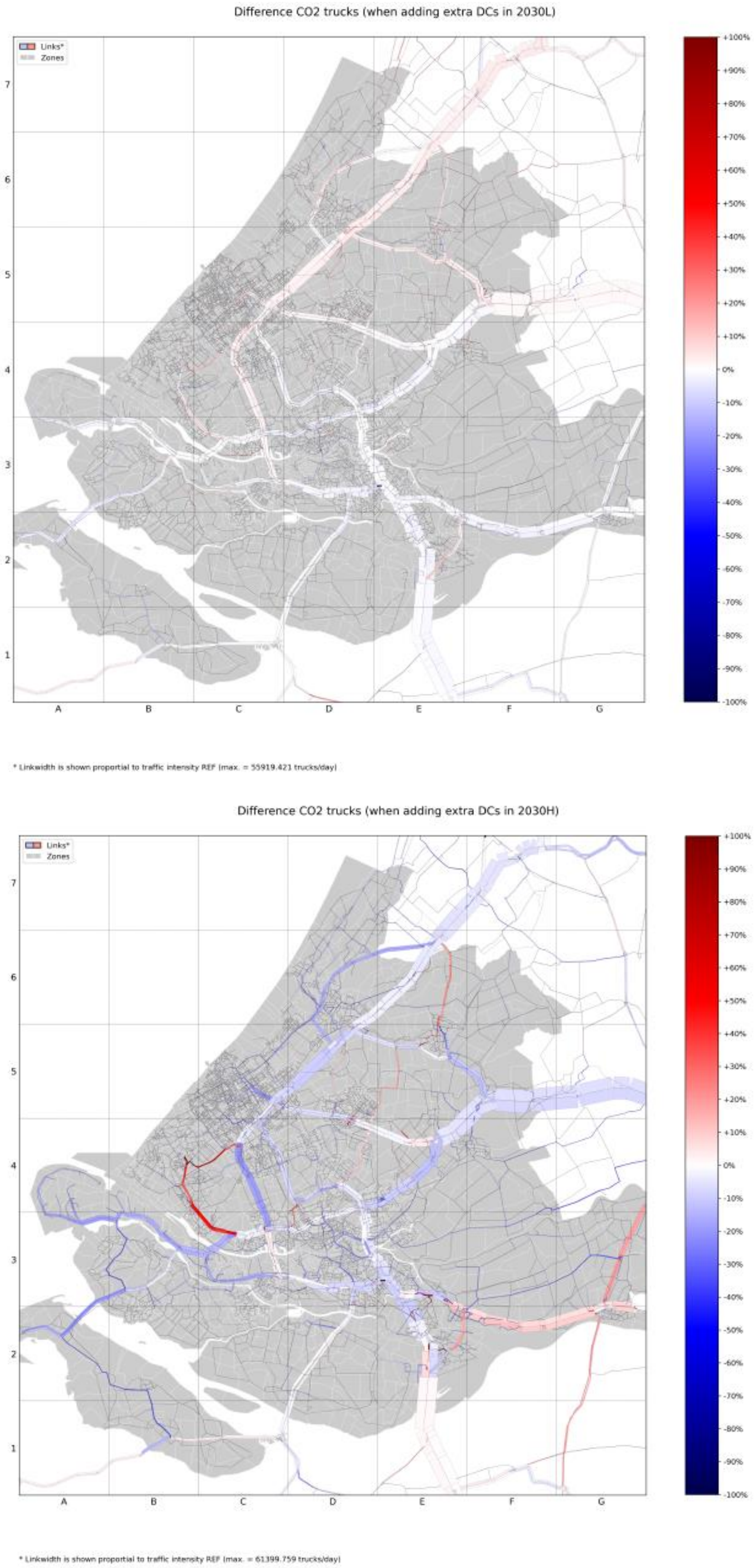

Figure 6-6: Emissions in the Low scenario (Top) and High scenario (Below)

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The impacts on CO2 emission shows that emissions increase stronger compared to the vehicle kilometers: in the High scenario the emissions increase by 23% while vehicle kilometers only increase by 15%. This can mostly be attributed to the higher congestion levels in the High reference scenario's which effectively lead to higher emissions per kilometer. This occurs in particular on the highway links. As a result, the impacts of the spatial planning scenario on emissions are also slightly stronger: a reduction of 2% in the high scenario. Scenario 1 showed a modest reduction of vehicle kilometers due to the favorable allocation near highways, but since freight vehicle have higher emissions per kilometer on the highway the net impact is a modest increase of CO2 emissions. Results show it is necessary to have location specific calculation of emissions (see Deliverable 6.3 for details). In addition, it is important to look into the local impacts.

The network intensity plots show much stronger local differences in Scenario 2 as a result of the spatial planning scenarios. Of course, this scenario allocates much more logistic real estate, that attract and generate local traffic. As one of the hotspots for real estate development was in the 'Westland', a district west of the A4 highway, a significant rerouting of freight movements can be observed: a significant shift can be observed of much freight movements now going from the Westland to Rotterdam via the A20 instead of A4. Strong local increases can also be observed on the A15 and A16 South-East of Rotterdam where two designated hotspots were localized.

A DC has an impact on a local level. As can be seen in the results the emission is increased at new locations of the DCs. When there are a lot of new DCs in one place the changes can be significant. This can be seen in scenario 2 where the emission difference can be up to 20 % in Westland. However, overall, the emission in South-Holland increases only slightly. This is because the scenario only assumes redistributive impacts: the new DC's take a market share of all freight transport handled through distribution channels. The total freight through distribution channels does not change in these spatial scenarios. For this the scenario should have to be increased with a logistical component: how does the opening of new distribution centers increase the use of distribution channels in the supply chain.

The scenarios that are developed here are a first sketch with the purpose to illustrate the use case of logistic facility planning. A general conclusion drawn from this analysis is that the growth of logistic real estate demand is above the trend and with a spatial planning policy for the allocation of logistic facilities, the freight transport demand and externalities on accessibility and emissions can be influenced. If the growth of the DCs is going in the same pace as now the demand for new DCs can be up to 300 in 2030. The arrival of these new DCs influences the local level and there is not enough space in South-Holland to continue this growth and for the DCs to build new industrial areas. However, it is seen that the centralization of the DCs has a positive influence on the vehicle kilometres.

The validity of the spatial scenarios can be improved by developing scenario in cooperation with the main stakeholders: regional authorities, local authorities, logistic service providers and carriers. The development of such policy scenarios can be used to encourage the logistic sector to work together and bundle the DCs at already existing industrial areas. This influences the vehicle kilometre but also the demand for new facilities. Cooperation on the planning of logistic facilities can also be used as a step towards more innovative collaborative concepts and asset sharing. This would also require an extension of the modelling with an explicit modelling of supply chains.

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7 Discussion

The use cases in this deliverable illustrate the applicability of the Tactical Freight Simulator to a variety of city logistic use cases. It is capable of making scenario forecast for demand in shipments and parcels and simulate the associated vehicle patterns. The simulator can be used to analyse the impacts of various spatial planning policies at different scales (e.g. regional distribution denters or micro hubs) or regulatory policies or new services or technologies.

This session highlights the most important findings from the use cases.

Microhub:

- The Tactical Freight Simulator (TFS) was used to simulate the impacts of a wider scale implementation across the city centre. Different design aspects are explored in 9 scenarios: location, type of vehicles (autonomous robot, electric bicycle, light electric van), and type of business model (Individual, Full-collaboration).
- The light electric vans have a higher capacity so on average have fewer tours from the micro hubs; this is considered an operational advantage.
- The hybrid and full-collaboration models show a better vehicle utilisation than the individual CEP model.
- The full collaboration model, with light electric vehicles lead to fewest vehicle kilometers in- and outside the study area.

Zero emission zone:

- The implementation of the ZEZ in Tactical freight simulator provides an empirical quantitative insight into the impact of the ZEZ in a study area.
- Using UCCs reduces emissions within the ZEZ areas but slightly increases the vehicle kilometers travelled (VKT) outside the ZEZ
- Calculations confirm that emissions are reduced dramatically, by 90%, inside the ZEZ.
- At the city scale this corresponds to a reduction of almost 10% of whole emissions produced by freight transport.
- At a regional level the reduction of impacts is very small.
- The impacts on city level are significant

Crowdshipping:

- The TFS of the HARMONY MS is successfully applied to assess the impact of the crowdshipping systems on freight and transport system. This demonstrates its capacity to assess innovative mobility solutions.
- Crowdshipping could improve the efficiency of freight transport system in delivering parcels,
- Crowdshipping has marginal side effects on passenger system. However, a large share of crowdshipping parcels will be delivered by travellers using personal cars and the extra detour cost imposes an increase in vehicles flows in the residential areas.
- The sides effects could be controlled by applying control policies on the crowdshipping platforms.

Spatial planning:

- TFS is successfully applied to simulate the impacts of spatial planning policies on freight transport and traffic.
- With this simulation we identified that the growth of logistic real estate demand is above the trend (I think this has not been be derived from the simulations; perhaps from the analysis). Moreover: a trend is derived from historic data, so unless the TFS predicts real estate demand or calculates the demand for it, which to my knowledge it does not, I think you should reformualte this conclusion or leave it out.

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- Spatial planning policy for the allocation of logistic facilities influences the freight transport demand, accessibility and emissions.
- Centraliziation of the DCs has a positive influence on the vehicle kilometres.
- Despite the increasing demand for the new DCs, there will not be enough space in South-Holland to to build new industrial areas.
- Cooperation with the main stakeholders such as regional authorities, local authorities, logistic service providers and carriers is required to develop policies like encouraging the logistic sectors to work together and bundle the DCs at already existing industrial areas.

Conclusions

The application of a new city logistic simulator shows the possibilities of using simulation to study the impacts of new technologies and services in city logistics at system level. The explorations have taught us that although the technology seems to be ready for innovative solutions, the logistical organisation or business models and policies are not yet well developed. Simulation tools such as TFS can contribute to this development by showing potential impacts of system-wide impacts by getting a common understanding of the pros and cons, and barriers, challenges and opportunities of new solutions. This can stimulate the relevant stakeholders in urban logistics to collaborate which becomes ever more relevant and necessary in the age of growing urbanization.

To create more value from the simulations with the TFS, future work can focus on the integration of the different use cases into broader logistic scenarios. These use cases are complementary as micro hubs can be considered in combination with a spatial planning scenario and extended in a scenario with a crowd-shipping service where the micro hubs also serve as a location for the pick-up or drop-off of parcels. By combining the use cases, a holistic logistic scenario is created with consistent assumptions across the use cases. The development of broad logistic scenarios requires regional coordination and the involvement of logistic stakeholders. The results from the individual use cases can be used to feed the discussion between these stakeholders.

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8 References

Aljohani, K., R Thompson (2016). "Impacts of logistics sprawl on the urban environment and logistics: Taxonomy and review of literature." Journal of Transport Geography 57: 255-263 DOI: 10.1016/j.jtrangeo.2016.08.009.

Anderluh, A., Hemmelmayr, V. C., & Rüdiger, D. (2020). Analytic hierarchy process for city hub location selection - The Viennese case. Transportation Research Procedia, 46(2352-1465), 77-84.

Dablanc, L., S Ogilvie, A Goodchild (2014). "Logistics Sprawl." Transportation Research Record: Journal of the Transportation Research Board 2410(1): 105-112 DOI: 10.3141/2410-12.

de Bok, M. & Tavasszy, L. (2018). An empirical agent-based simulation system for urban goods (MASS-GT). Procedia Computer Science, 130(8).

HARMONY (2022a). D6.3- The HARMONY Tactical freight Simulator: Model specification, calibration and validation.

HARMONY (2022b). D8.3 - Extended SUMP guidelines for metropolitan areas in the new mobility era.

Hunt, J. D., & Stefan, K. J. (2007) Tour-based microsimulation of urban commercial movements. Transportation Research Part B: Methodological, 41(9), 981–1013. https://doi.org/10.1016/j.trb.2007.04.009

Marcucci, E., Le Pira, M, Gatta, V, Inturri, G., Ignaccollo, M. & Pluchino, A. (2017) Simulating participatory urban freight transport policy-making: Accounting for heterogeneous stakeholders' preferences and interaction effects. Transportation Research Part E: Logistics and Transportation Review, 1(46-62), p. 17.

Mohammed, R., Nadi, A., de Bok, M. & Tavasszy, L., 2020 . Using data fusion to enrich truck diaries with firm databases, Delf, the Netherlands: Paper send for presentation at IEEE-Forum ISTS2020.

NVM (2021) Logistiek vastgoed in cijfers 2021. Nieuwegein: NVM Business.

Onstein, A., I Bharadwaj, L Tavasszy, D van Damme, A el Makhloufi (2021). "From XXS to XXL: Towards a typology of distribution centre facilities." Journal of Transport Geography 94 DOI: 10.1016/j.jtrangeo.2021.103128.

Rotterdam, C. o., 2019. Roadmap ZECL: Moving towards Zero Emissions City Logistics in Rotterdam in 2025, Rotterdam: City of Rotterdam.

Samimi, A., Mohammadian, A., Kawamura, K. & Pourabdollahi, Z., 2014. An activity-based freight mode choice microsimulation model. Transporation Letters, 6(3), pp. 142-151.

Tavasszy, L. & de Jong, G., 2014. Data Availability and Model Form . In: L. Tavasszy & G. de Jong, eds. Modelling Freight Transport . London: Elsevier Insight , pp. 231-244.

Thoen, S., Tavasszy, L., de Bok, M., Correia, G., & van Duin, R, 2020. Descriptive modeling of freight tour formation: A shipment-based approach. Transportation Research Part E:

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Logistics and Transportation Review, 140(June 2019), 101989. https://doi.org/10.1016/j.tre.2020.101989

Urban Freight Lab. (2020). Common MicroHub Research Project Research Scan. Washington: Supply Chain Transportation & Logistics Center.

van Duin, R., N van den Band, A de Vries, P Verschoor, M el Ouasghiri, P Warffemius, N Anand, H Quak (2022). Sharing Logistics in urban freight transport: a study in 5 sectors. 5th International Conference Green Cities, Szczecin, Poland.

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