Anthropolis Chair and Future Cities Lab

Joint Seminar Series 2021-2022

November 10th, 2021

Photo by Pierre Blanché, 2019 creative commons

Anthropolis Chair and Future Cities Lab Joint Seminar Series 2021-2022

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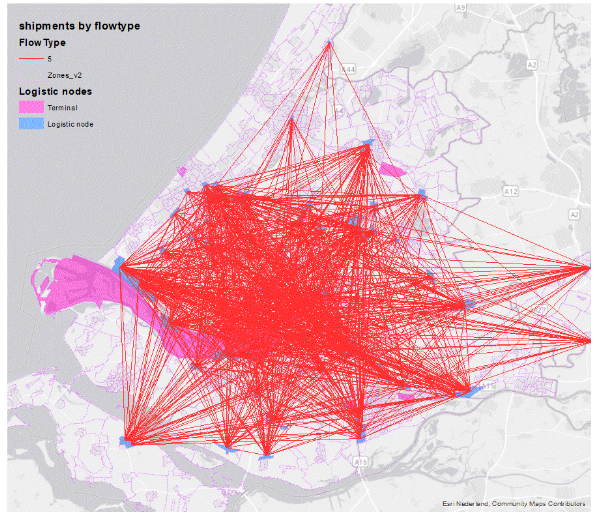
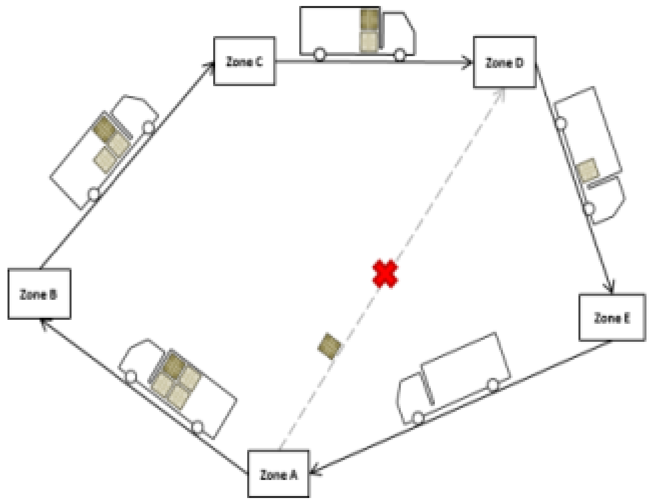


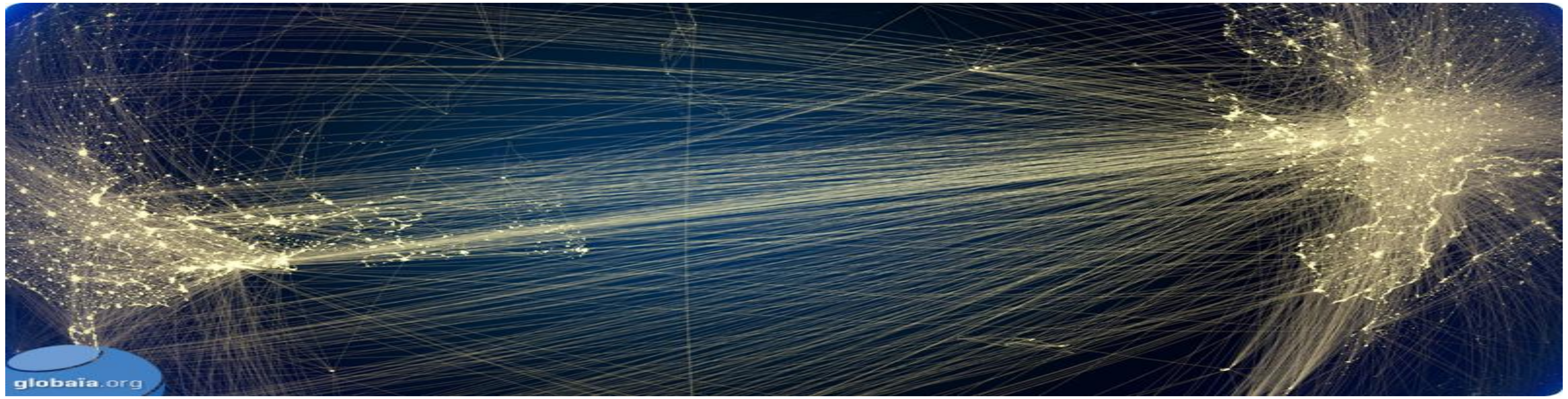


Multi-agent simulation of urban freight transport: MASS-GT model development and applications

Michiel de Bok

Delft University of Technology and Significance Quantitative Research

10-11-2021



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HUMAN CENTERED MOBILITY

Content

Background

Multi agent model for urban freight transport:
MASS-GT / HARMONY-TFS

Case studies:
- zero-emission city logistics
- decarbonization of Road Freight Transport

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Traffic and emissions in city centre of Rotterdam (2015)

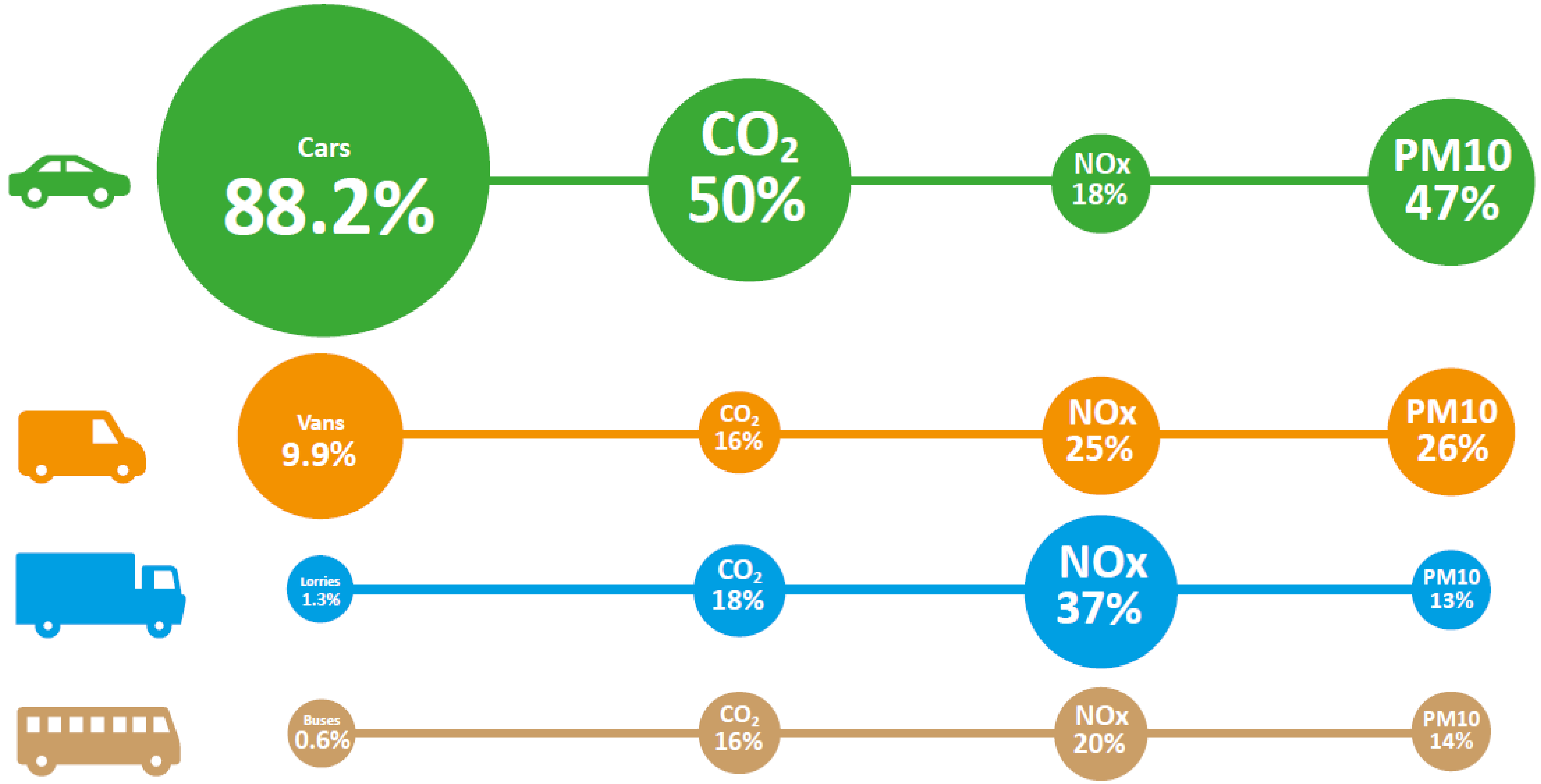

Image 2.7: Proportion of vehicles in traffic and emissions (Rotterdam city centre, 2015)[8]

[8] Please note: this image is based on measurements from 2015. Since that time, the fleet of lorries has been updated and many more Euro VI lorries are active in the city. Up-to-date data is currently lacking, but Euro VI lorries emit almost no NO_x. In the current situation, this suggests that the proportion of NO_x emissions from lorries will be substantially lower than in 2015. Professional road transport actors (including the market leaders in Logistics 010) have already been using Euro VI lorries to supply the city centre for some years.

- Lorries make up 1.3% of VKM's in the city but produce 18% of CO2 emissions
- This 'snapshot' for 2015 is difficult to update due to lack of reliable data
- And it is even more difficult to predict how this will develop in forecasts by policies and logistic developments

Source: Roadmap ZECL: Moving towards Zero Emission City Logistics (ZECL) in Rotterdam in 2025, June 2019:

https://www.rotterdam.nl/wonen-leven/stappenplan-zero-emissie/Roadmap-ZECL.pdf

The story of Jos..

E commerce

Road user charges

Globalisation

Internet of Things

Logistic developments

Logistic hub's

ZE vehicles

Truckplatooning

Emission zones

'Urban transport planner'

Keep the city accessible

Reduce CO2 emissions

Policy objectives

Keep the city livable

Use land efficiently

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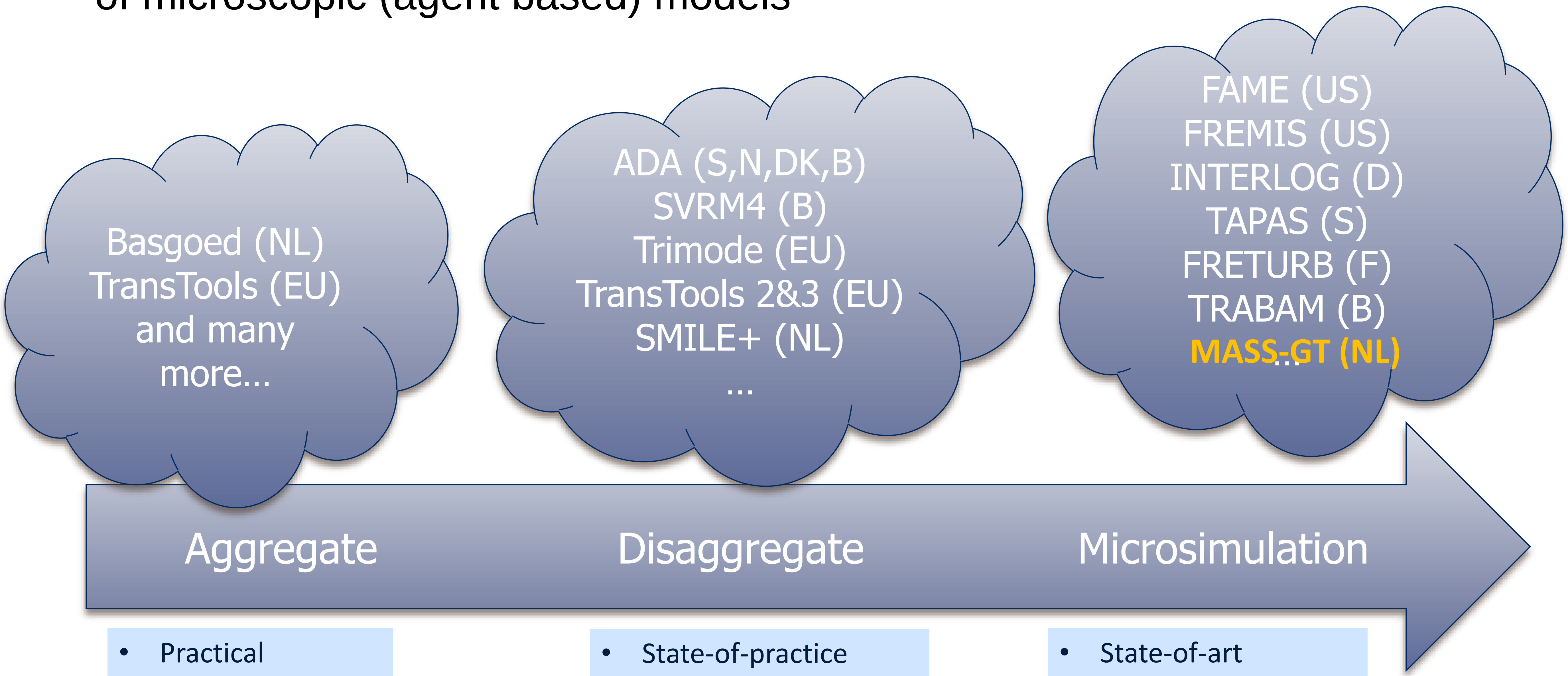
Evolution of strategic freight models

- Strategic large scale freight models are (slowly) evolving in the direction of microscopic (agent based) models



- Practical
- Regional
- Much applied

- State-of-practice
- Operational
- Zonal
- Logistic choice

- State-of-art
- Academic (no policy application)
- At firm level
- Logistic behavior

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Research objective of MASS-GT

The **MASS-GT** research project aims at developing a more comprehensive behavioral multi-agent microsimulation framework for strategic freight transport demand

Main assumptions:

1. Shipment- and behavioural: we build a micro-simulation framework of logistic decision making
2. Evidence based: to develop empirical simulation models for freight transport demand with logistic decision making. For this purpose we use high density freight transport data
3. Manage complexity during model development. For this purpose we follow an incremental development process

In H2020 project HARMONY the MASS-GT model is further developed as Tactical Freight Simulator

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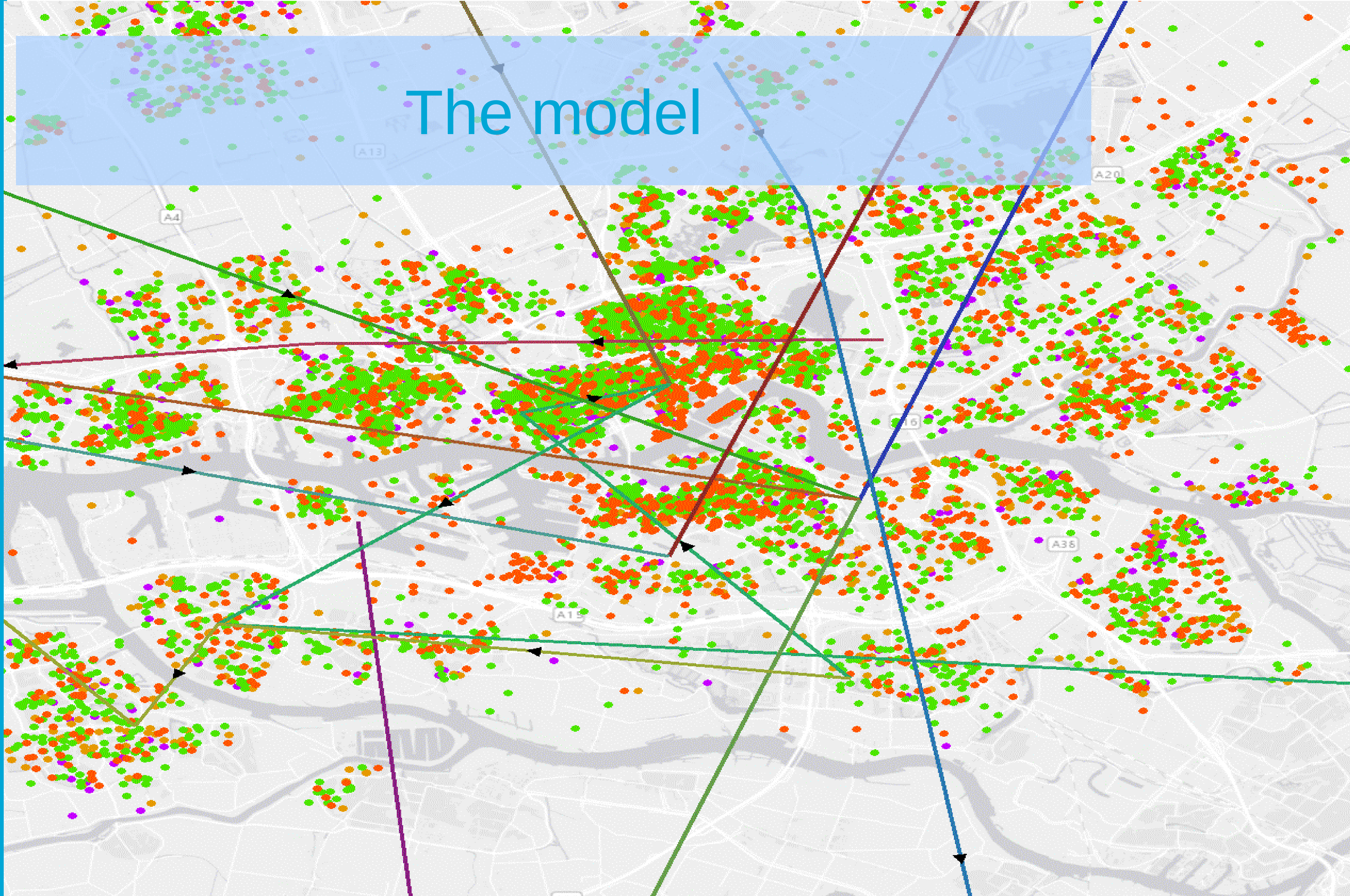
The model



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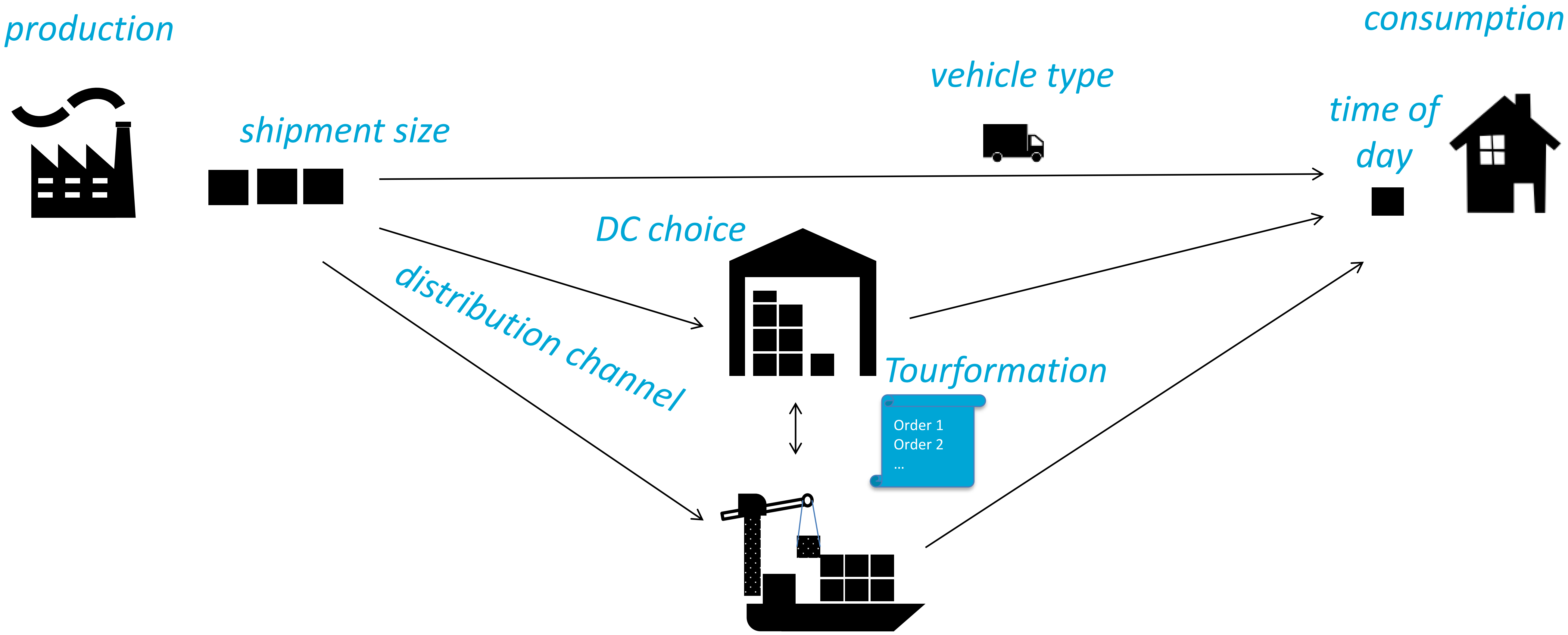
Conceptual model for MASS-GT

- Goods are transported as shipments between producer and consumer. Some transports are direct from P to C…..
- …but many goods are transported via distribution channels via one or more logistical node
- Different logistical choices are made, which we try to simulate as accurate as possible



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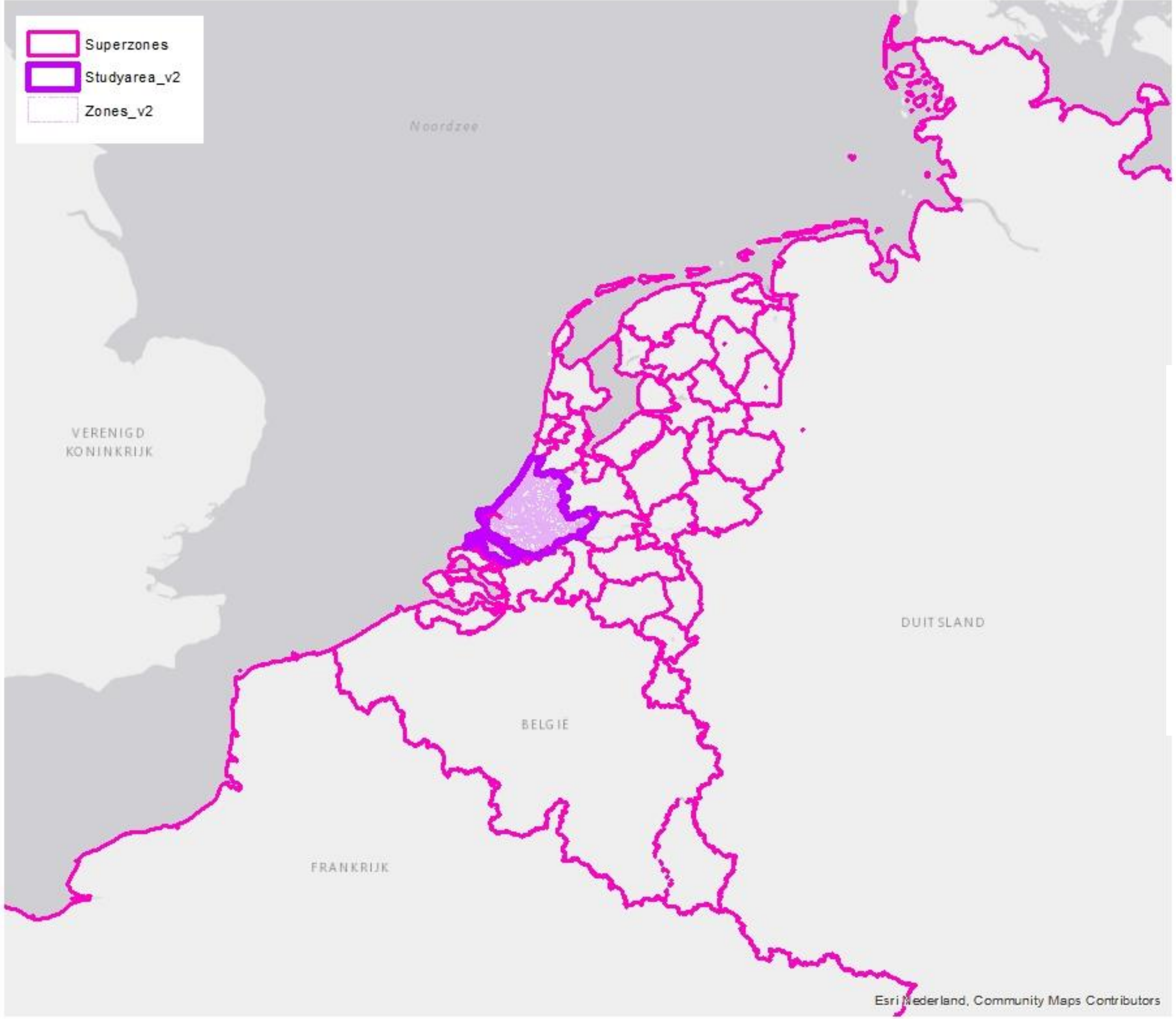
Study area



- South Holland
- Population: 3.5 M
- Area: 3k km2

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MASS-GT v4 in HARMONY

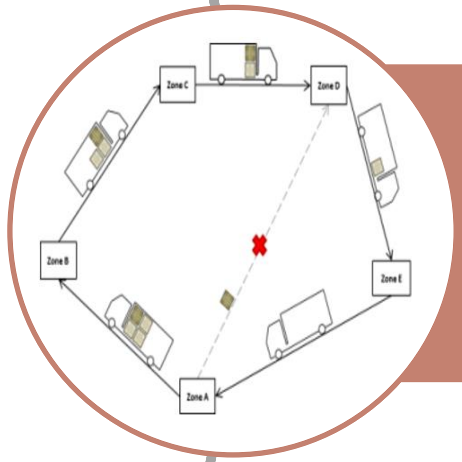
In the H2020 project HARMONY, MASS-GT is used as a basis for the Tactical Freight Simulator (TFS).

<u>Key design principles:</u>

- ❖ Evidence based (data!)
- ❖ Agent-based: to represent the heterogeneity in city logistics: producers, consumers, carriers, public administrators
- ❖ Shipment-based: more behavioural realism
- ❖ Modular: long-term and daily logistic decisions are simulated separately

Shipment & parcel demand module

- Producer/supplier choice
- Shipment size & vehicle type



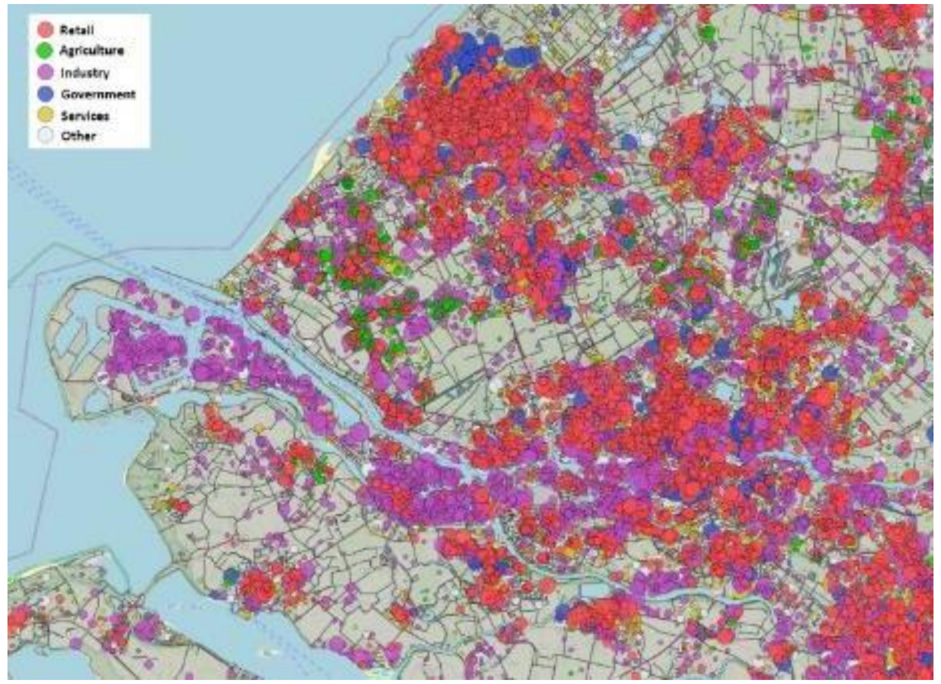
Scheduling module

- Tourformation
- Time-of-delivery choice

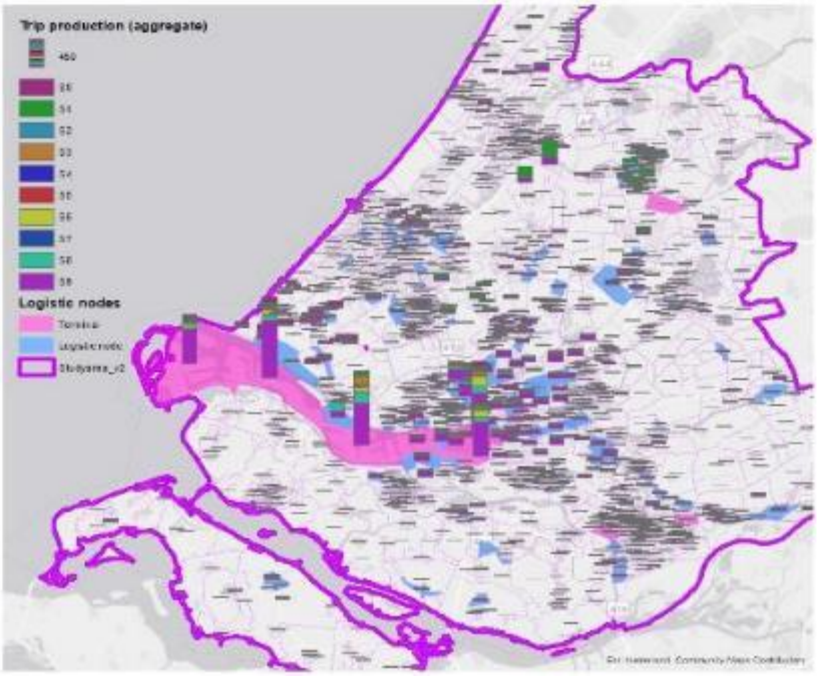
Networkmodule

- Routechoice
- Emissions

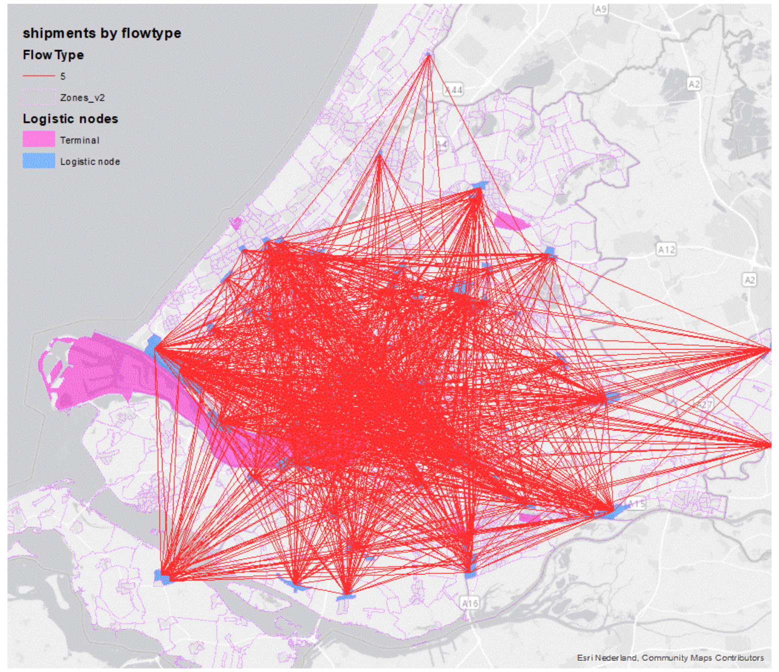
Tactical Freight Simulator in 6 figures



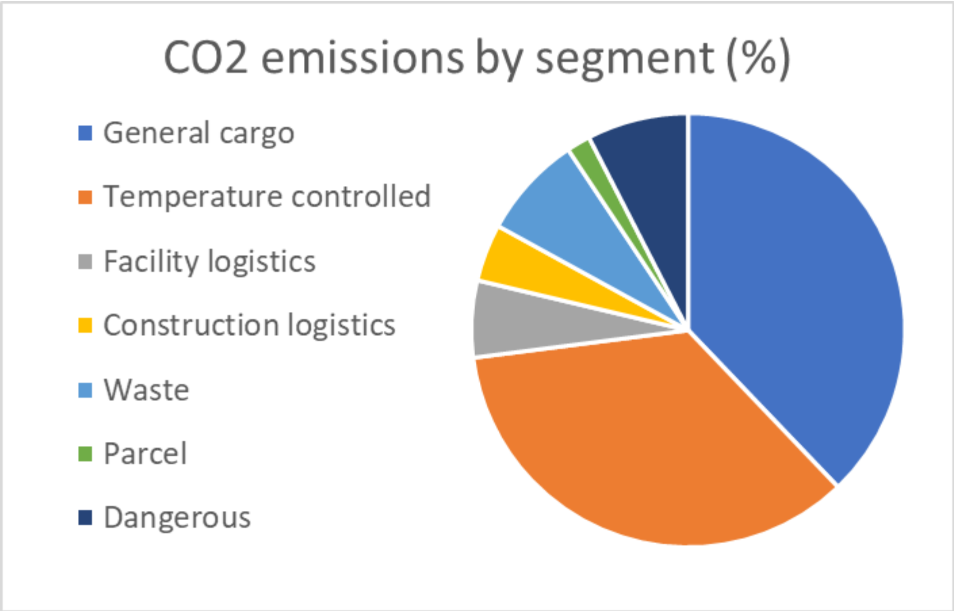
Firms (Synthetic)



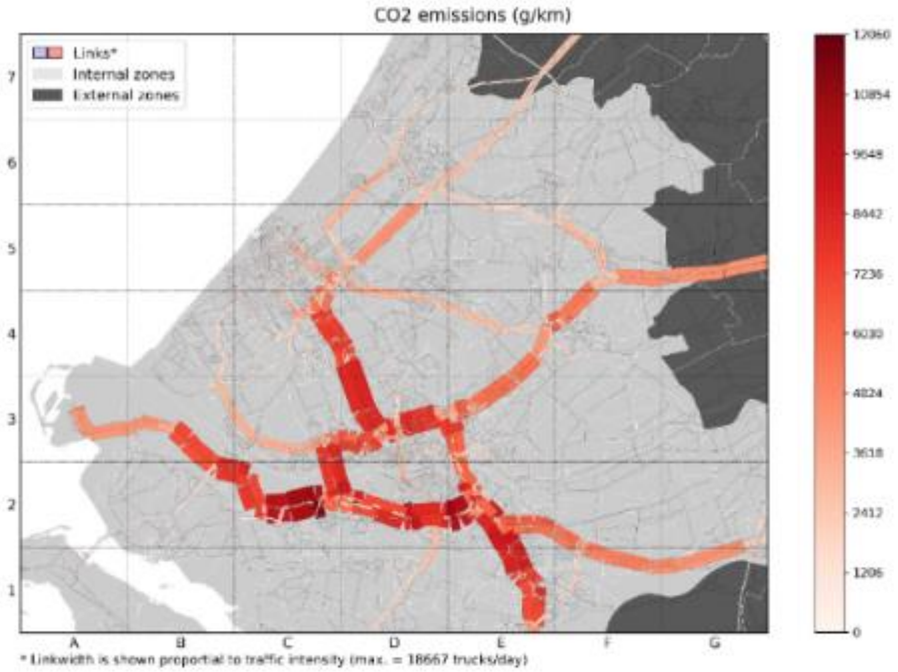
Shipment demand



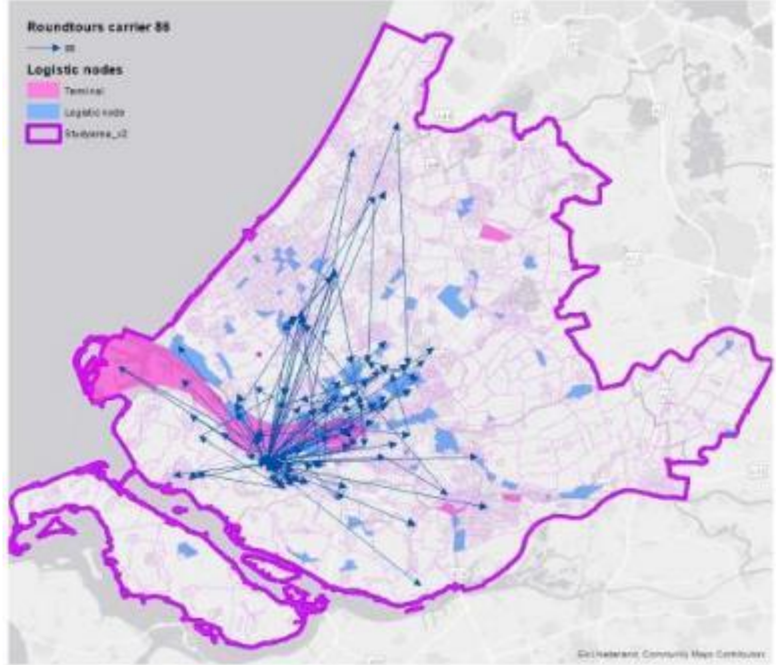
Demand via distribution channels



Aggregated output indicators (KPI's)



Emissions



Logistic planning of roundtours

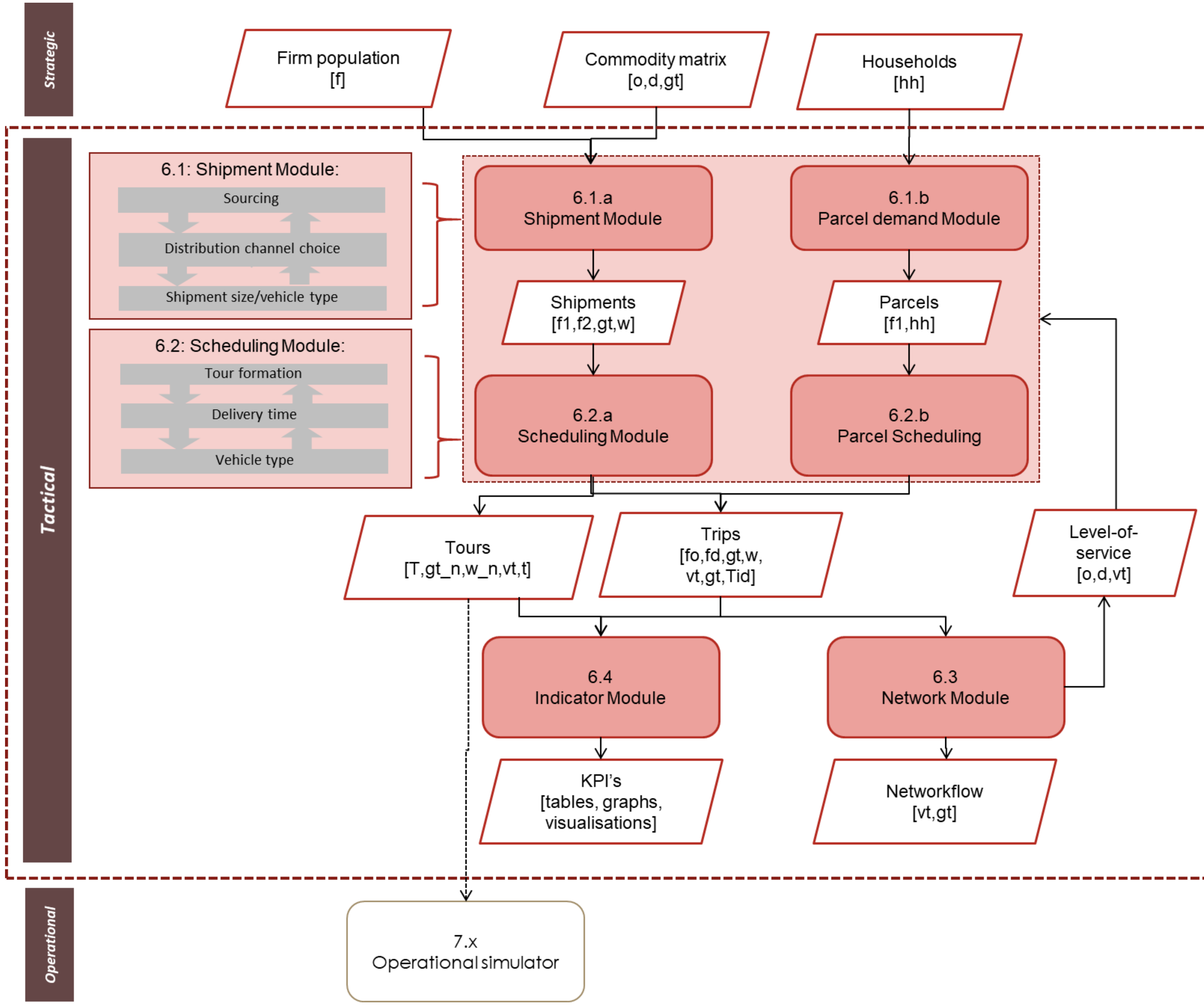
www.harmony-h2020.eu

Harmony-H2020

Harmony_H2020

HARMONY

Technical architecture



Shipment module: simulates long-term decisions:

- ❖ Sourcing/Producer choice
- ❖ Distribution channel choice
- ❖ Shipment size & vehicle type (simultaneous)

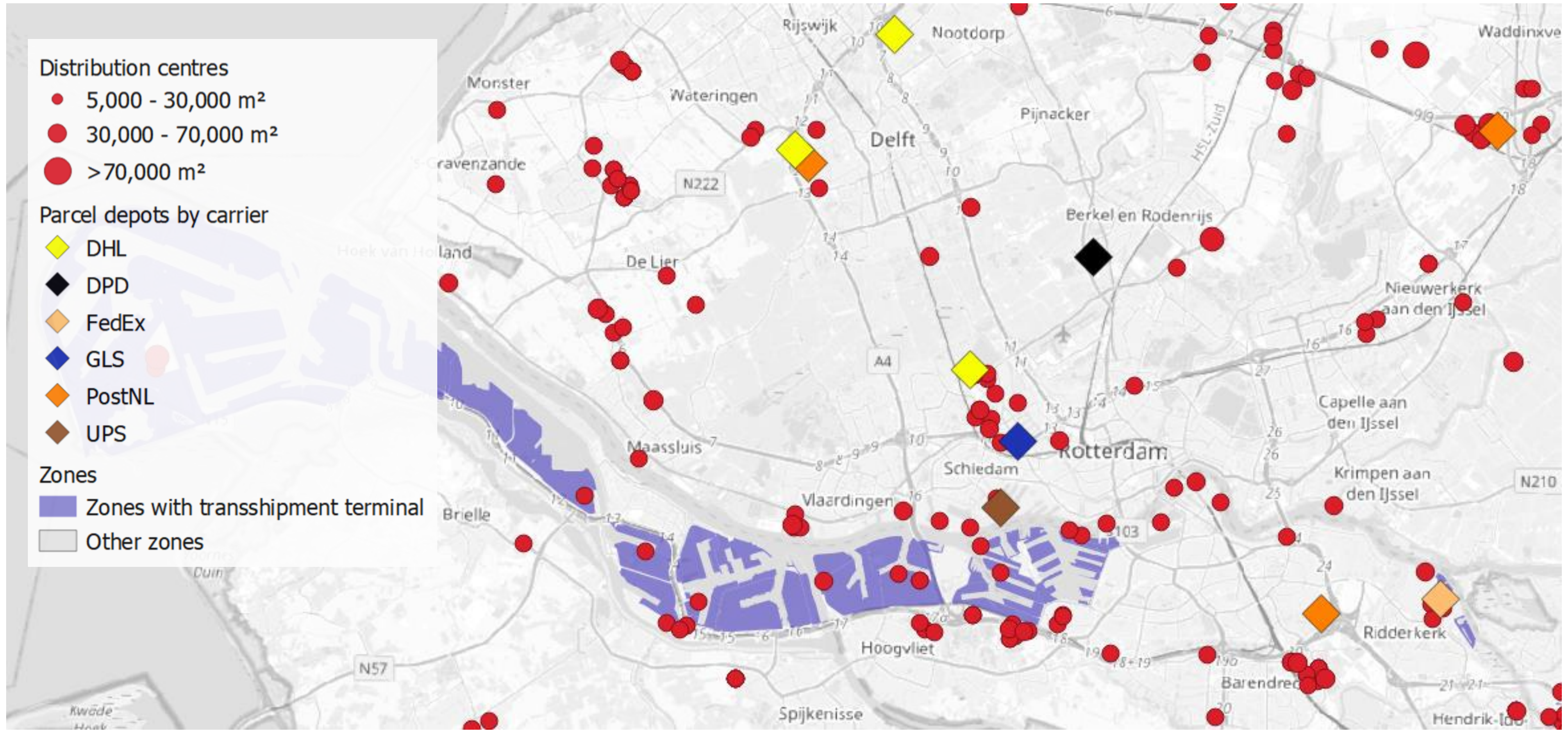
Scheduling module: simulates daily decisions:

- ❖ Tourformation
- ❖ Time-of-day

Two auxiliary modules:

- ❖ Network Module (skim & routechoice)
- ❖ Indicator Module

Population of freight agents



Logistic nodes (fixed/scenario):

- Multi modal **Transshipment Terminals**, e.g. in port basins. Important generators of Freight Transport
- **Distribution centers** operated by **Carriers**, origin and destination of freight demand,
- **Parcel depots by CEP carrier**, origin of delivery tours for parcel demand.

Firm Synthesizer (based on SEGS):

- Firms are simulated by discretizing the zonal employment. These are the **Consumers** and **Producers** of products

Shipment module

Objective of the shipment synthesizer:

To build a set of all shipments that are transported to/from/within the study area.

Top-down simulation of mid-term tactical decisions:

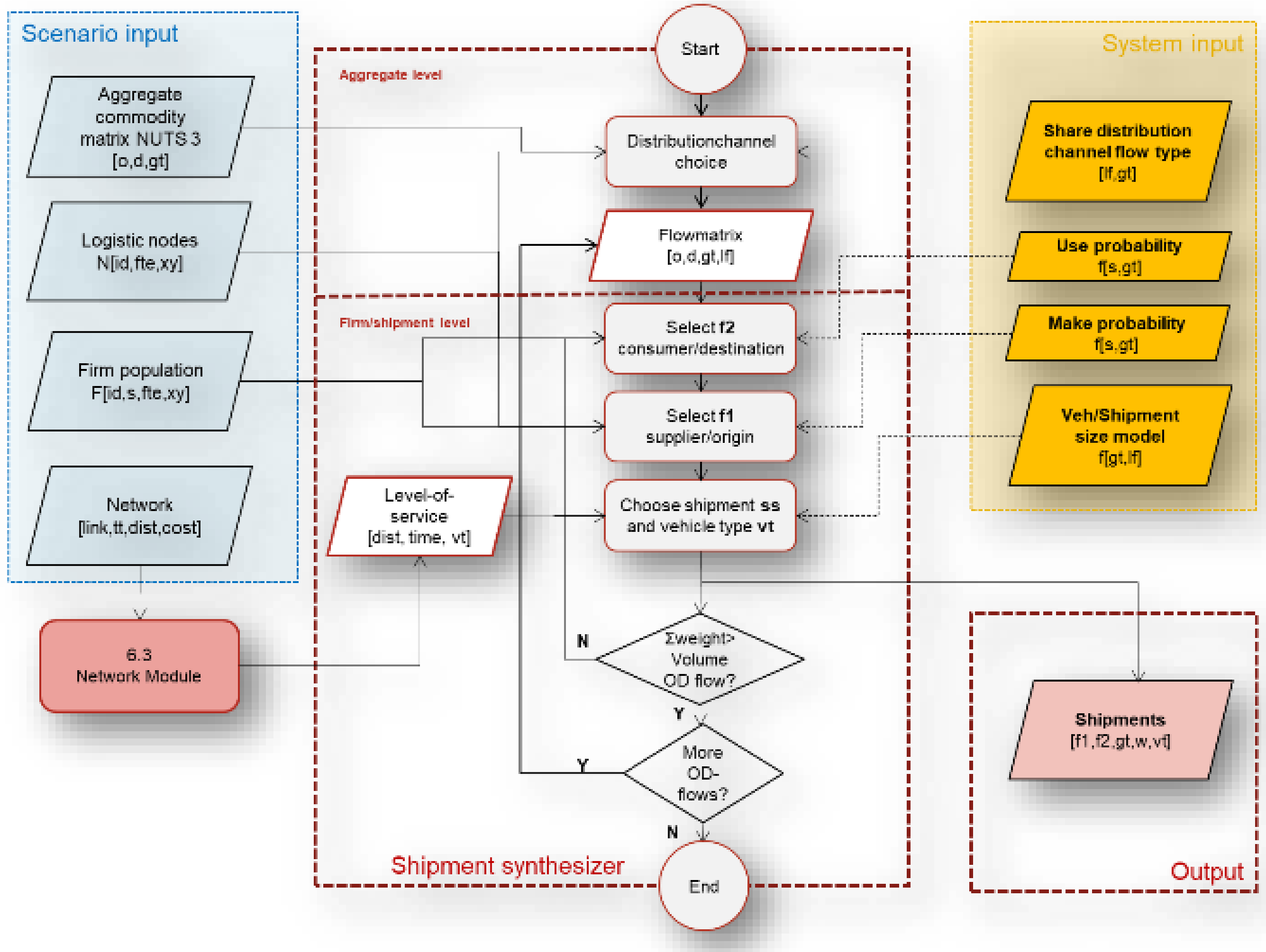
1. Allocation to distribution channel
2. Vehicle and shipment size choice
3. Selection of consumer and/or producer

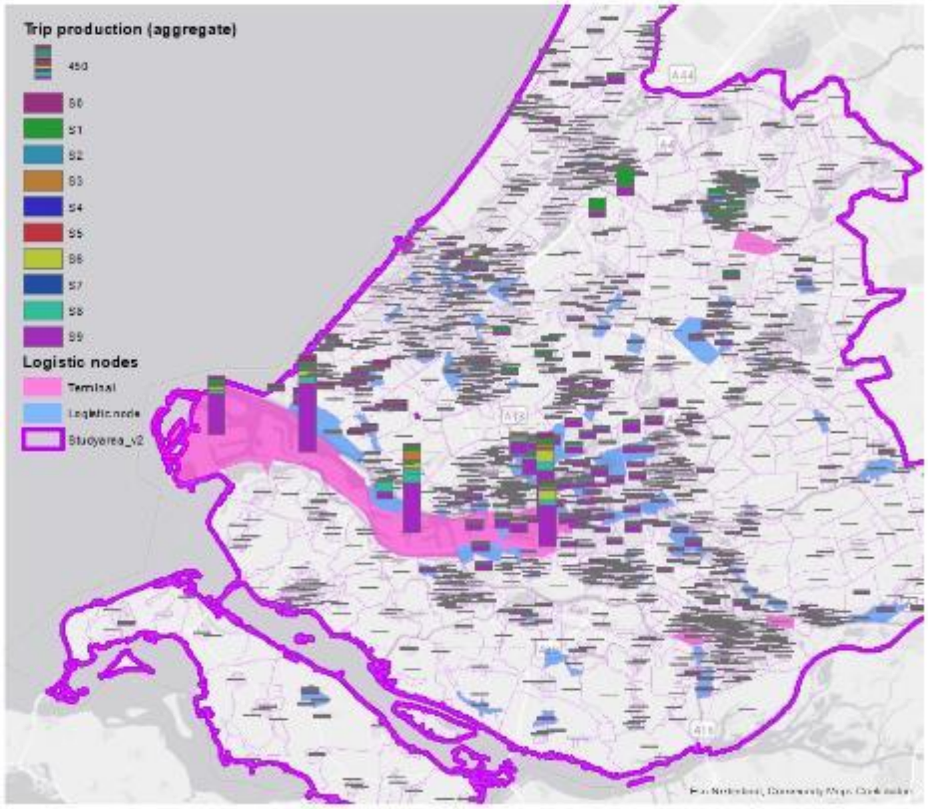
Output:

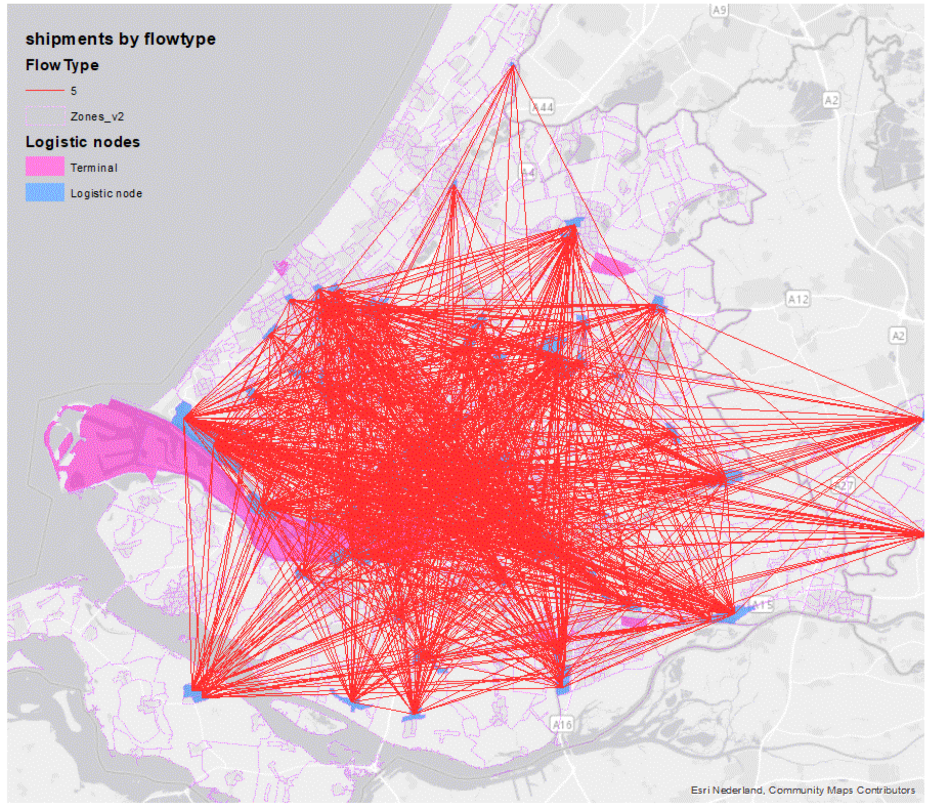
All shipments in the study area

Statistics and models based on transport data:

- ❑ Statistics Netherlands (XML microdata)
- ❑ Regional transport Model







Scheduling module

Objective of the Scheduling module:

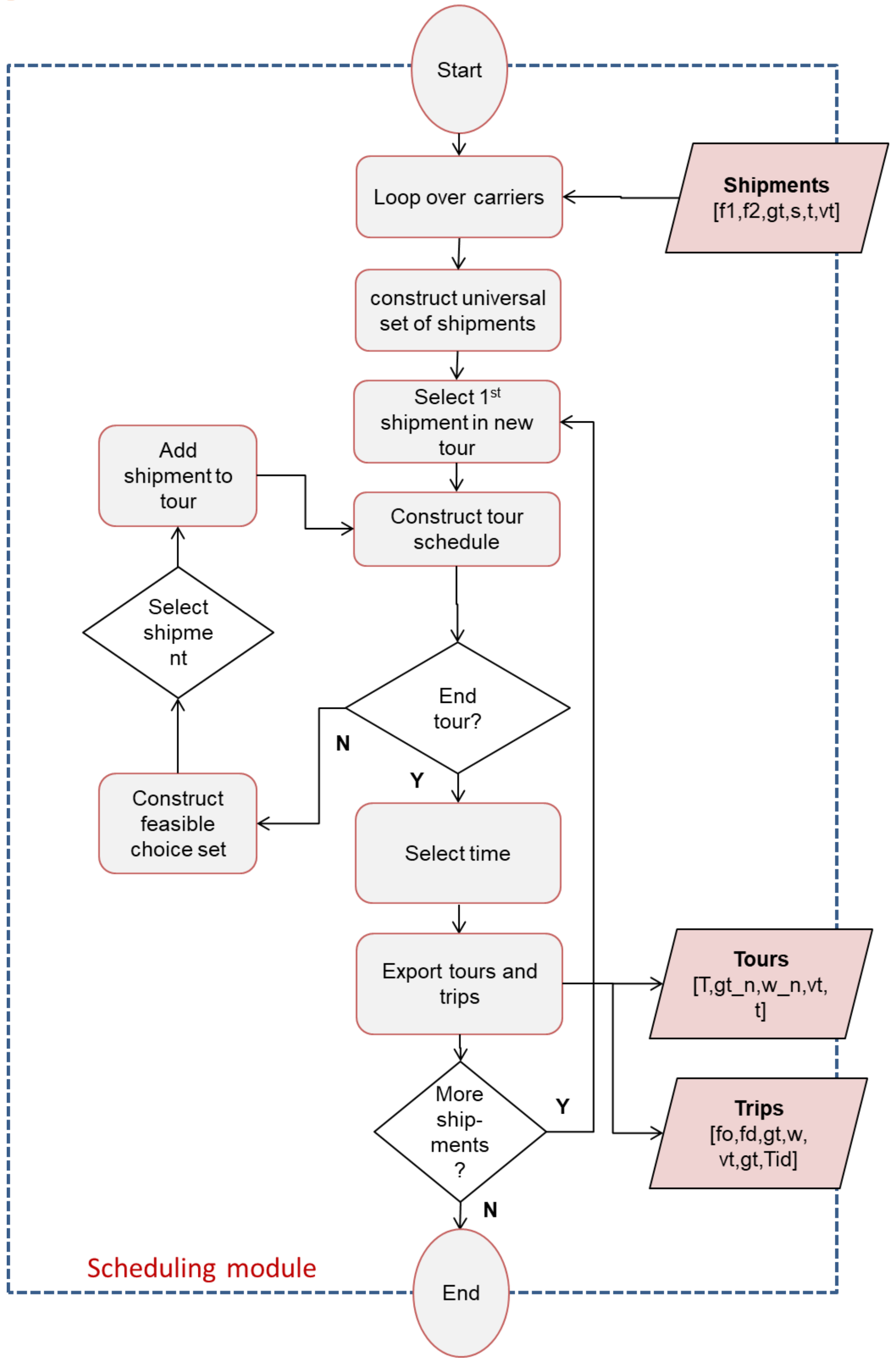
Simulate daily logistic decision making to schedule the delivery of all shipments that are transported to/from/within the study area.

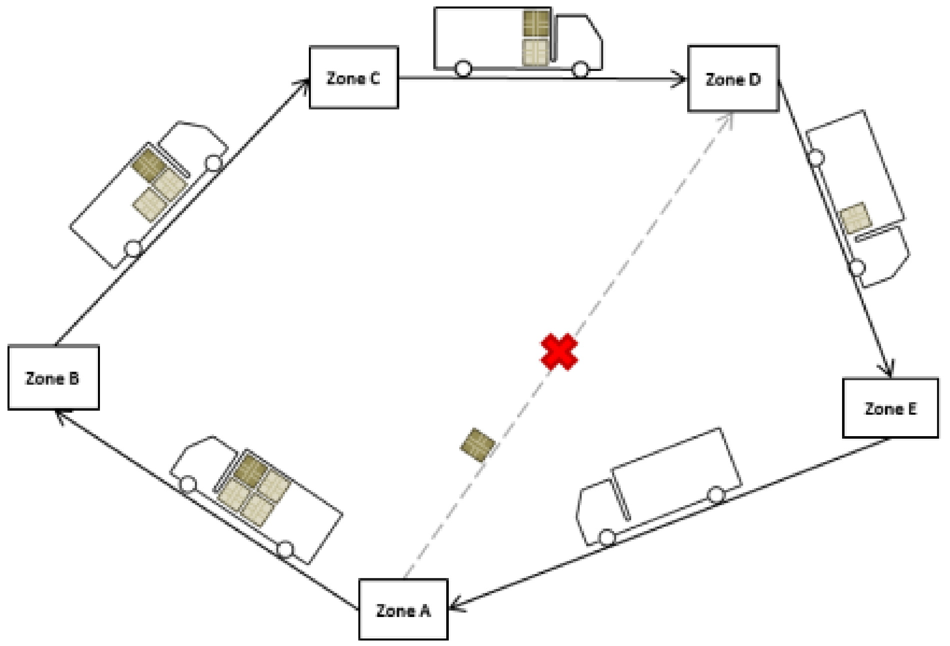
Builds tour patterns, in a step-wise procedure, simulating the following logistic processes:

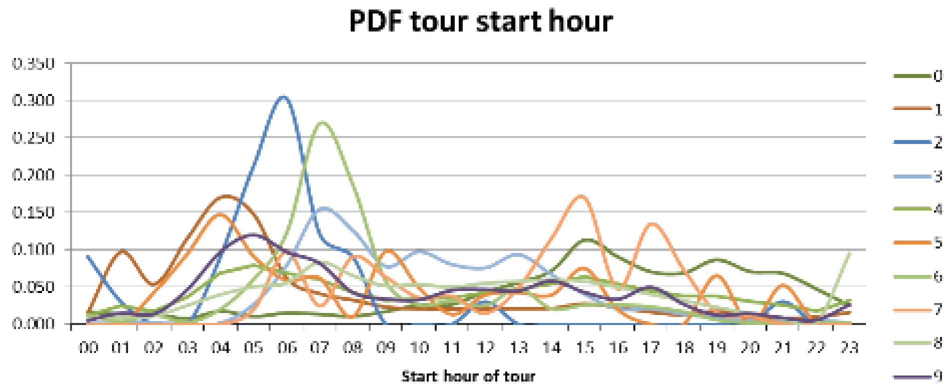
1. Tourformation
2. Delivery time

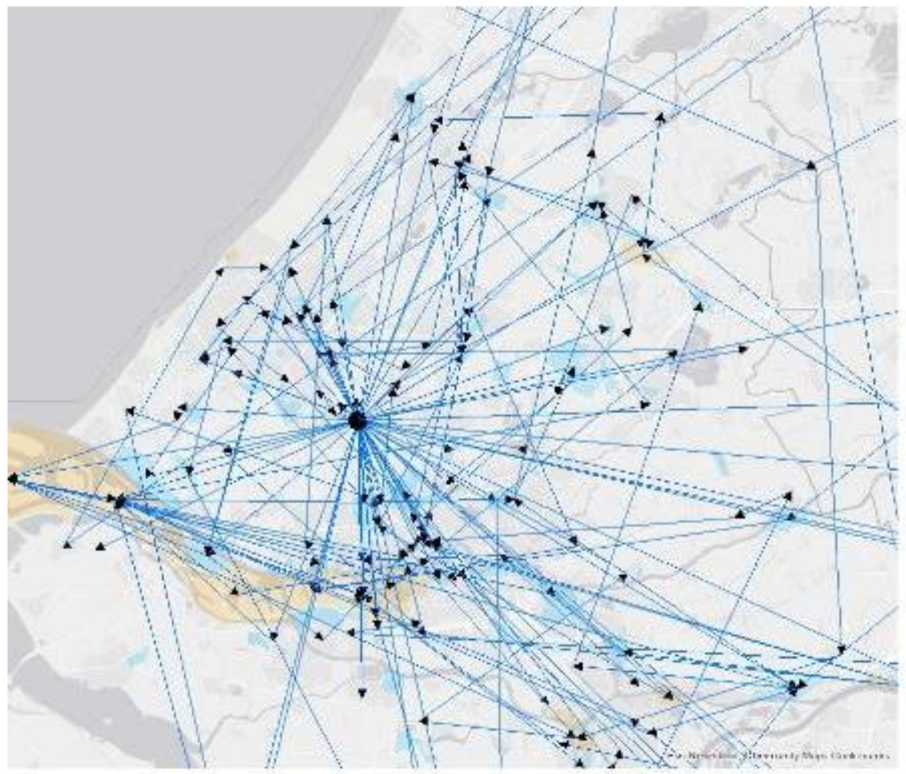
Output:

Truck round tours for the collection and delivery of all shipments in the study area





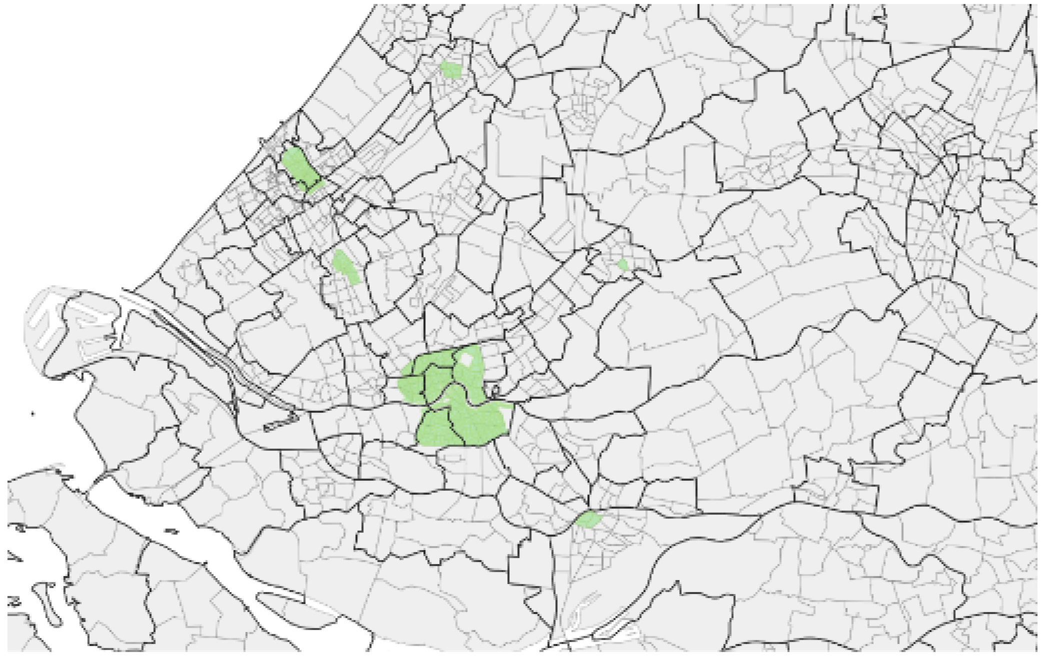


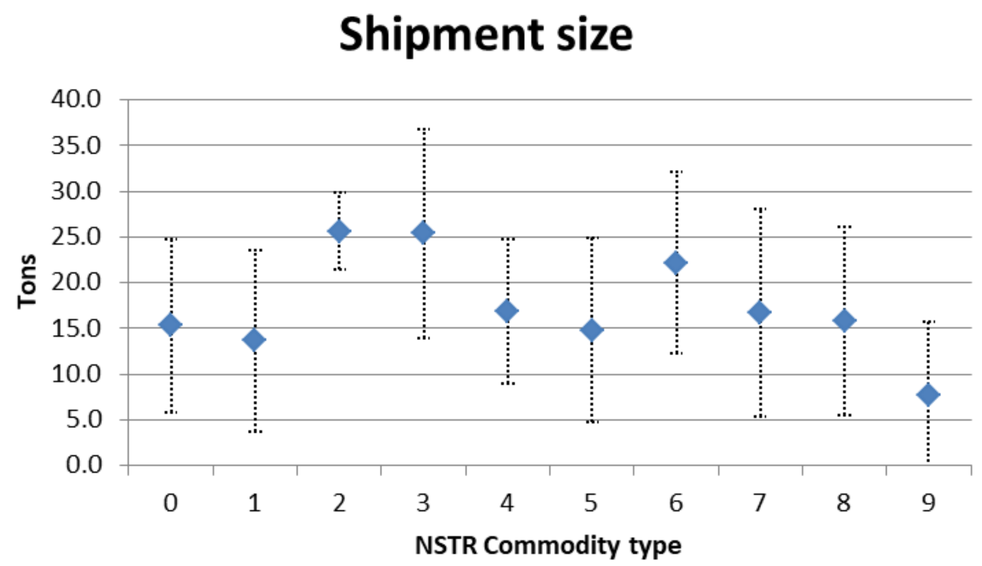


For details see:

Thoen, S, L Tavasszy, M de Bok, G Correia, R van Duin (2021) Descriptive modeling of freight tour formation: A shipment-based approach, *Transportation Research Part E*, Volume 140

Data requirements





The TFS has been designed in such a way that it uses generally available transport modelling data and statistics as primary inputs. Behavioural parameters can be calibrated, either validated, depending on local available data.

Summary of basis input data:

- ❖ Local transport model (networks, zones with socio economic data)
- ❖ Location of logistic nodes (distribution centers/transsphipment terminals)
- ❖ Global firm statistics (size distribution)
- ❖ Aggregate commodity demand

Optional data for calibration:

- ❖ Detailed freight trip diaries
- ❖ Establishment surveys
- ❖ Truck counts

XML data from Statistics Netherlands (CBS)

- Automated Truck Trip Diaries (big data)
- Collection from Transport Management System (TMS) of HGV users
- +2M individual trips in raw data !!!
- Offers huge potential for development of microscopic freight demand models

Privacy!

opgaveId (Truck)
License plate
Year & week
In BasGoed sample [yes/no]
Transporting company
Ownership type *Owned, hired, leased, or not owned anymore*
Fuel consumption [L per 100 km]
Home base *Country* *ZIP* *Town* *LatLon*
Carrying capacity [kg]
Vehicle type

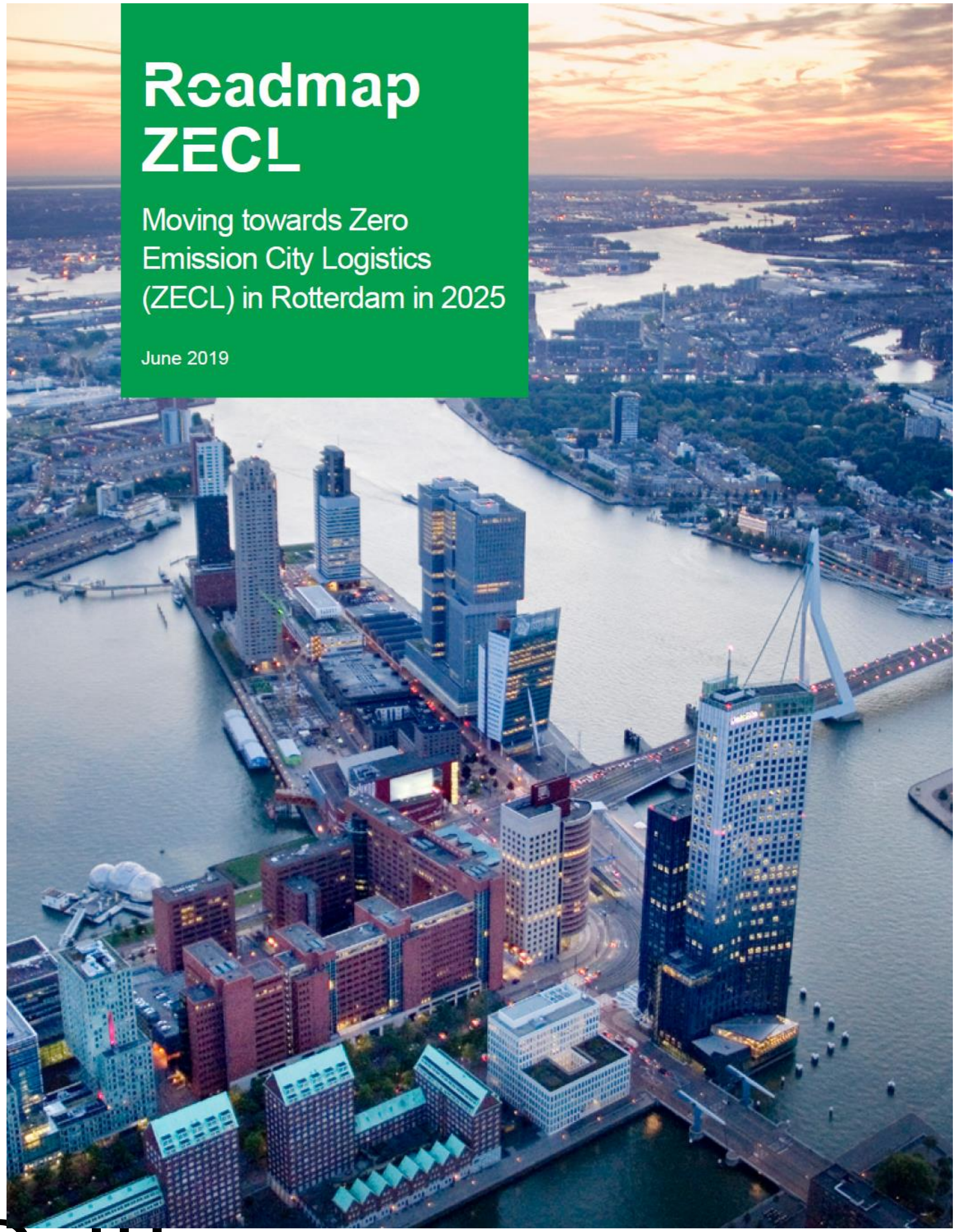
ritId (Tour)
Serial tour number *Describes order of tours for a truck*
Distance [km] *From origin to destination of tour*
Date & time *Start* *End*
Origin & destination *Country* *ZIP* *Town* *LatLon*
Operator type *Hired carrier or own-account*
Capacity utilization *% m2* *% m3*
Border crossing *Country* *LatLon*

zendingId (Shipment)
Serial shipment number *Describes order of shipments for a tour*
Distance [km] *From loading to unloading point*
Gross weight [kg]
Shape *Fluid, solid bulk, sea containers, other containers, pallets, hanging goods, goods in ropes, mobile units with own power, or other mobile units.*
Loading and unloading location *Country* *ZIP* *Town* *LatLon*
Loading and unloading location type *Production, consumption/processing, retail, seaport, inner port, rail terminal, airport, distribution/wholesale, or home base.*
Goods type *Description* *NSTR* *NST2007* *Hazardous [yes/no]*
Invoice value [€]
Volume [L or m3]

Impacts of a zero- emission zon

- Background
- Scenario
- Simulation results

Zero emission zone for Rotterdam



Jan Boeve, Director of TLN:

"As soon as possible, the City of Rotterdam must communicate where the zero emission zone for city logistics will be from 2025, so that transport business owners know where they stand and can prepare their business model accordingly."

Best Research Paper award @TRB !

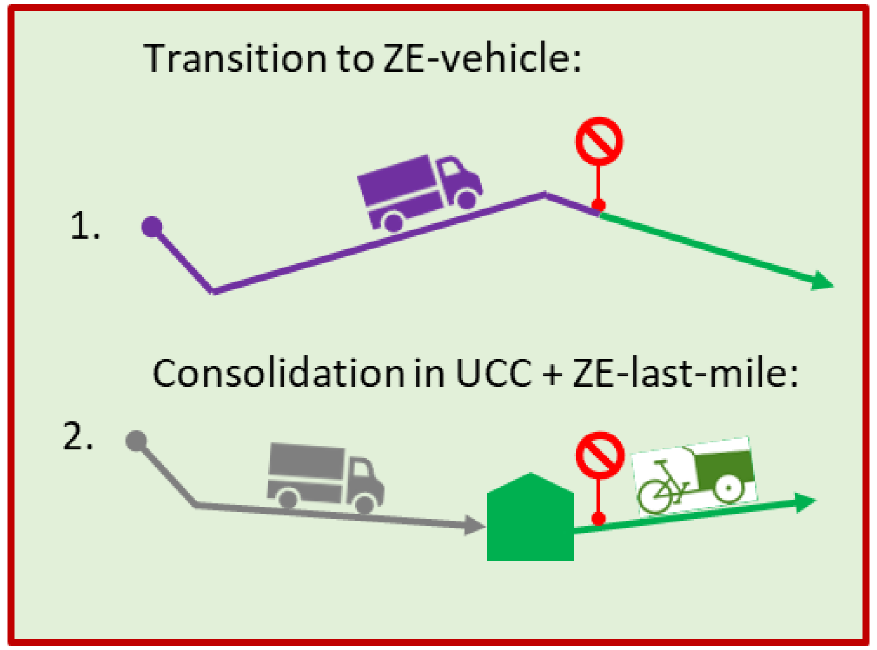
Paper "*Application of the HARMONY tactical freight simulator to a case study for zero emission zones in Rotterdam*", presented at TRB conference jan 2021, and published in TRR (open access)

Zero emission scenario: geography

Assumptions:

❖ Only ZE vehicles may enter the zero emission zone

❖ A proportion of shipments are redistributed via 7 UCC's



❖ Delivery and collection from the UCC takes place with dedicated ZE vehicles

❖ Analysis based on transitions scenario's for each logistic segment

Possible configuration of the zero-emission zone, and 7 Urban Consolidation Centers

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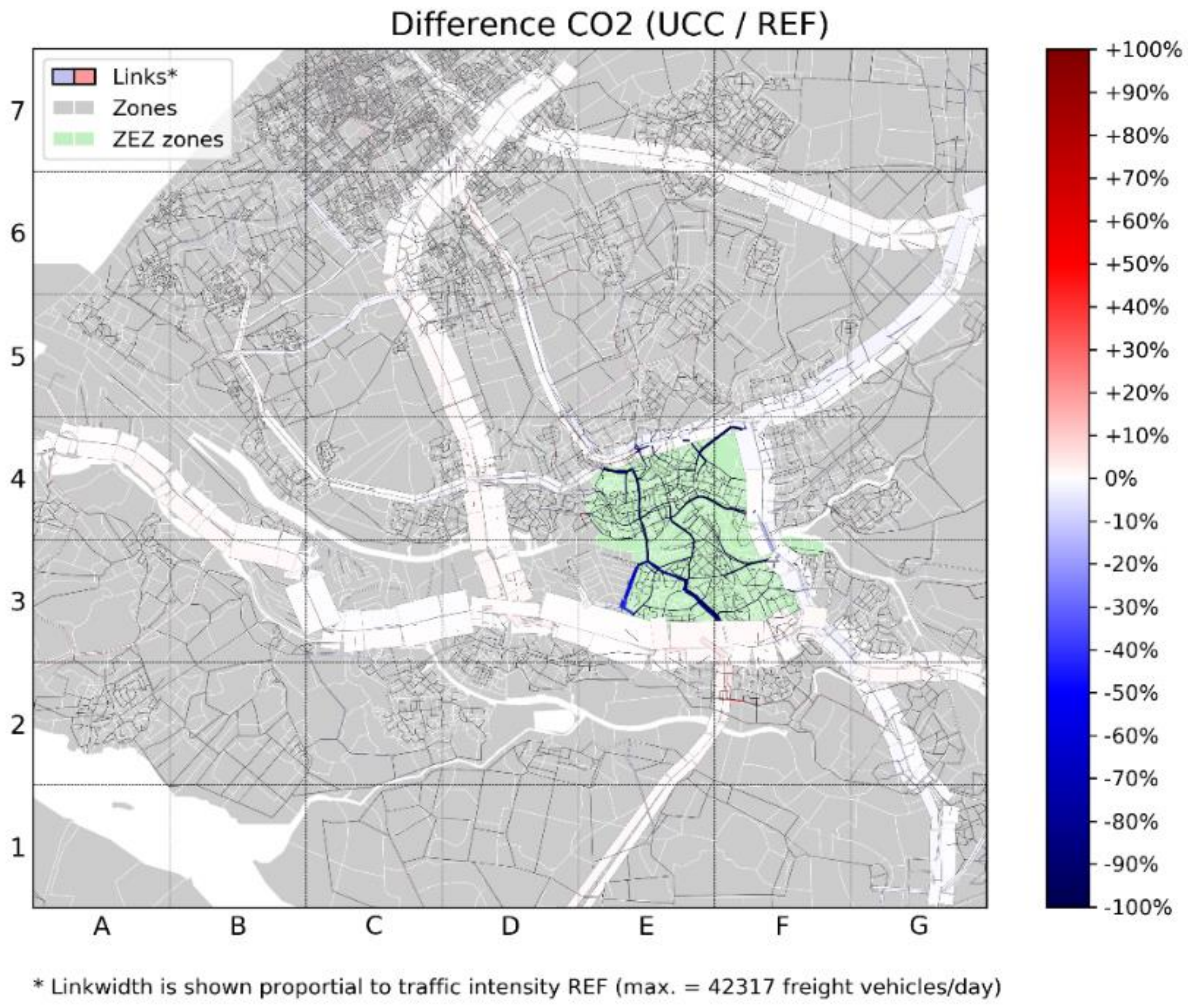
Results: impact on emissions at network level

- ❖ Emissions of all vehicle movements are calculated using the vehicle type, link speeds, and load of the vehicles.
- ❖ Reduction in total emissions within the municipality of Rotterdam: ca. 8%. This includes all the freight traffic to and from the port area.

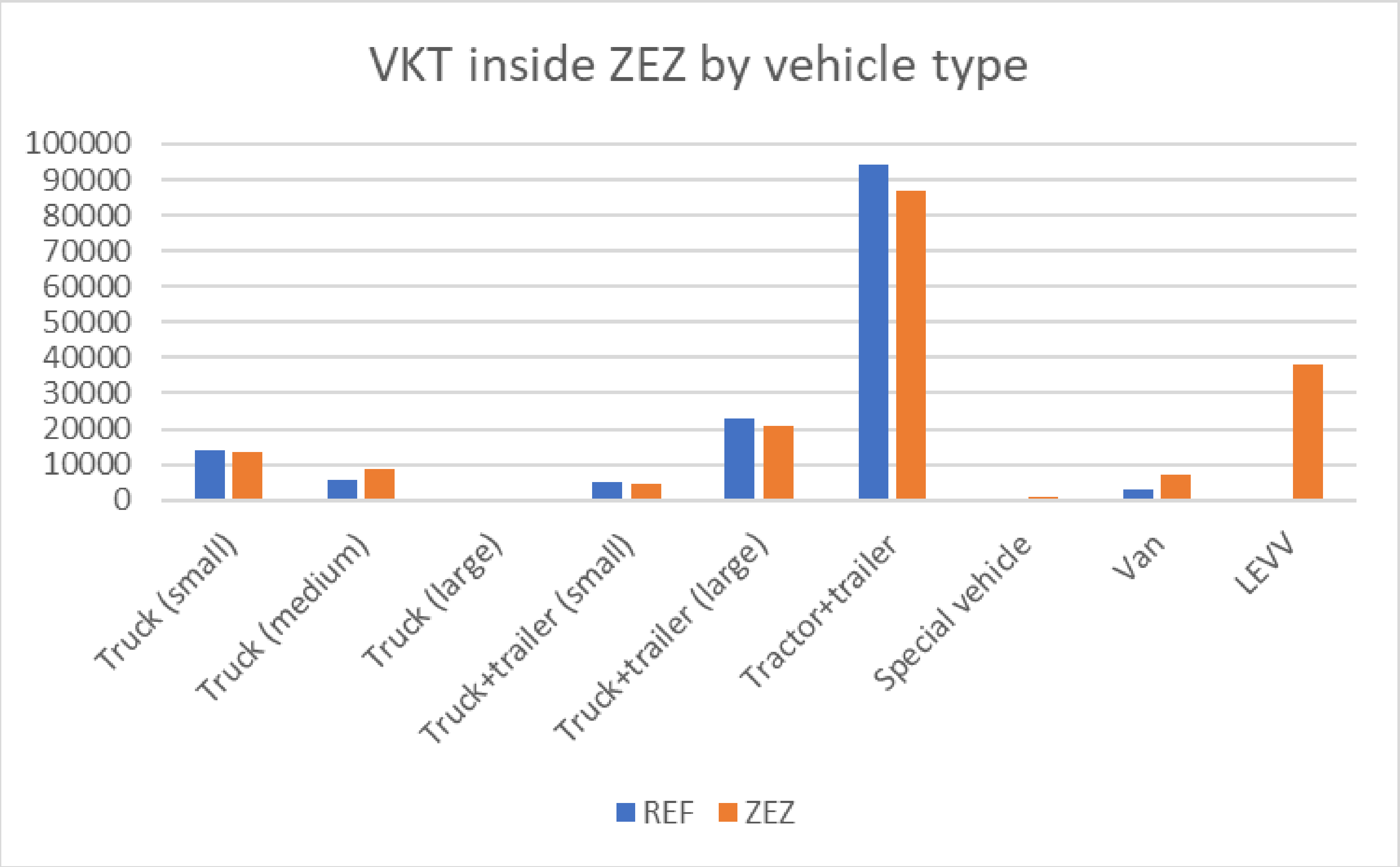
Type	Inside the ZEZ	City of Rotterdam	Study area (prov. South Holland)
CO2	-91%	-8%	-1%
SO2	-91%	-8%	-1%
PM	-89%	-8%	-1%
NOX	-91%	-9%	-1%

- ❖ Rerouting of shipments to the hubs also leads to small increases of emissions in the surrounding area.



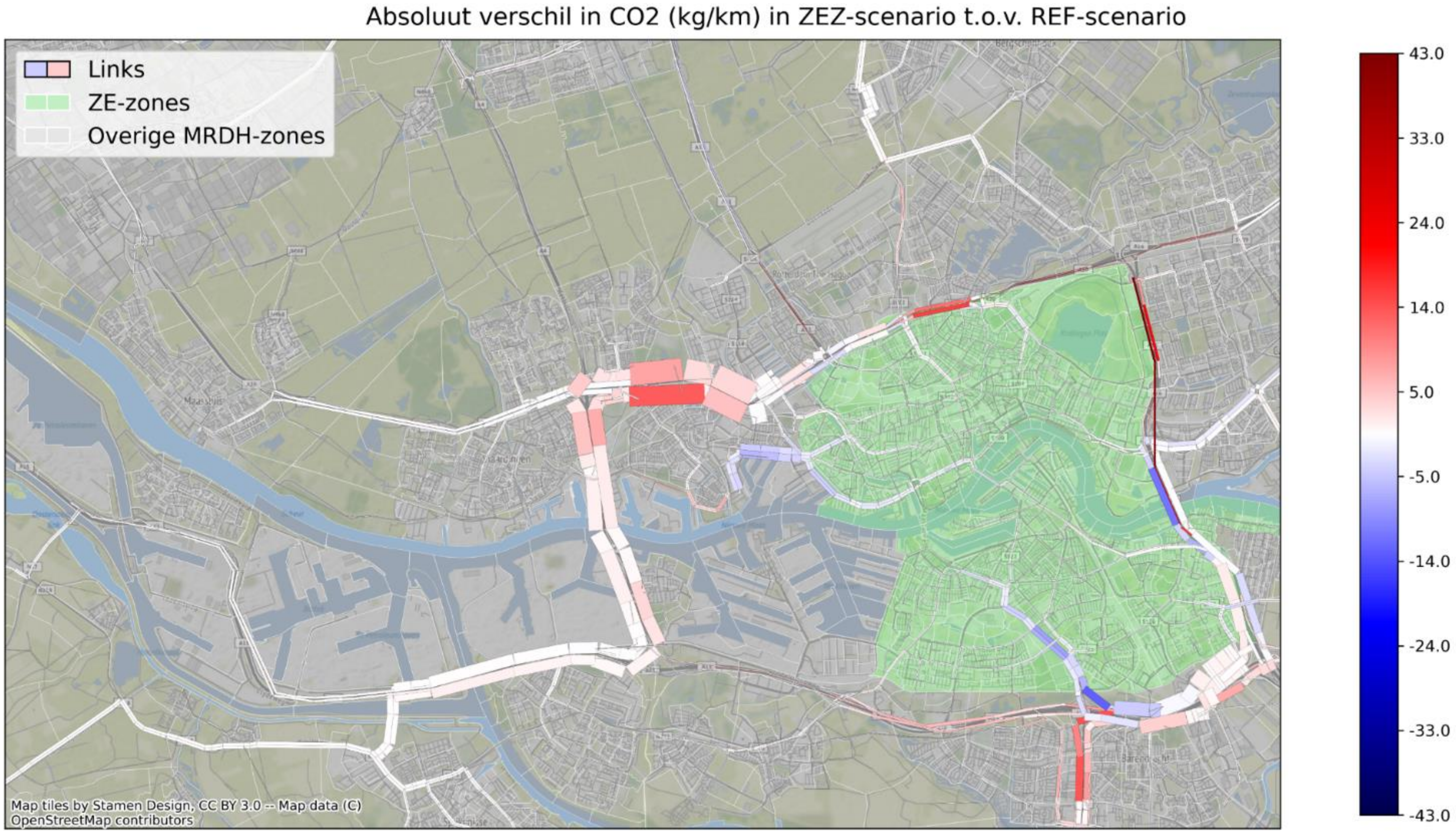
Impact on vehicle use inside the ZEZ

The composition of vehicle kilometers inside the ZE-zone will change in the Zero-emission scenario (ZEZ):



- Decrease in use of Tractor+trailer combinations (or with hybrid driveline)
- The share of new ZE-vehicles (LEVV and e-moped) is expected to be 10% in total vkms
- A large share of the reduction of emission will be the result of a shift to cleaner combustion types (electric, hybrid, hydrogen, biofuel)

Impact on emissions for parcel delivery



Conclusions on the impact of the zero-emission zone

- ❖Impacts are not trivial: emissions within the ZEZ are reduced, but vehicle kilometers (VKT) outside the zone increase slightly as a result of the rerouting of shipments through the UCCs.
- ❖Emissions are reduced by 90% inside the ZEZ; at the city scale by 10%, considered a significant impact at city level.
- ❖ZE zone is a good step towards the ambition to reduce CO2 emissions by 49% by 2030, but more measures are needed to further decarbonize long-haul freight transportation.

Decarbonisation scenarios for road freight transport

Inventory of decarbonisation measures

Inventory of measures from recent studies:

- “Fit for 55”, EC, (2021)
- “Roadmap Logistiek Laadinfrastructuur”, NAL (2021)
- “Decarbonising transport in Europe: non urban freight modelling”, ITF (2021)
- “The roadmap of the PI”, Alice (2020)
- “Roadmap Zero Emissie Stadslogistiek”, Rotterdam (2019)
- “Roadmap towards zero emissions logistics 2050”, Alice/SFC (2019)
- "Decarbonizing Logistics: distributing goods in a low carbon world", McKinnon (2018)

Measure:	Label
Demand Reduction (DR):	
Distance charging	DR1
Productpackaging Dematerialisation Waste reduction	DR2
Clean Energy (CE):	
Electrification of trucks	CE1
Electrification of vans	CE2
Zero emission zones	CE3
Clean fuels	CE4
Energy Efficiency (EE):	
Fuel efficiency	EE1
Driving behaviour	EE2
Logistic Efficiency (LE):	
New last mile solutions: CS + microhubs	LE1
Modular loading units Tour optimisation	LE2
Asset sharing	LE3

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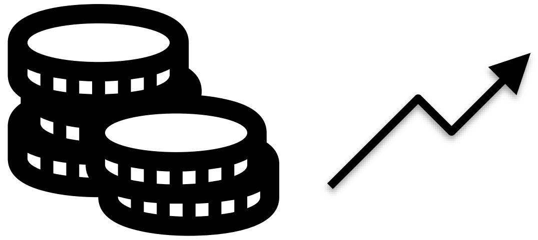
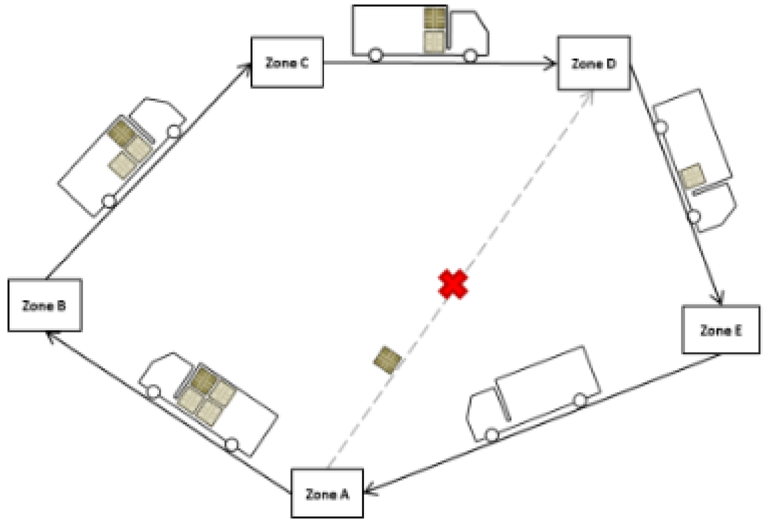
Implementation of the measures in the model (1/2)

- Unit prices,
  - HGV charge

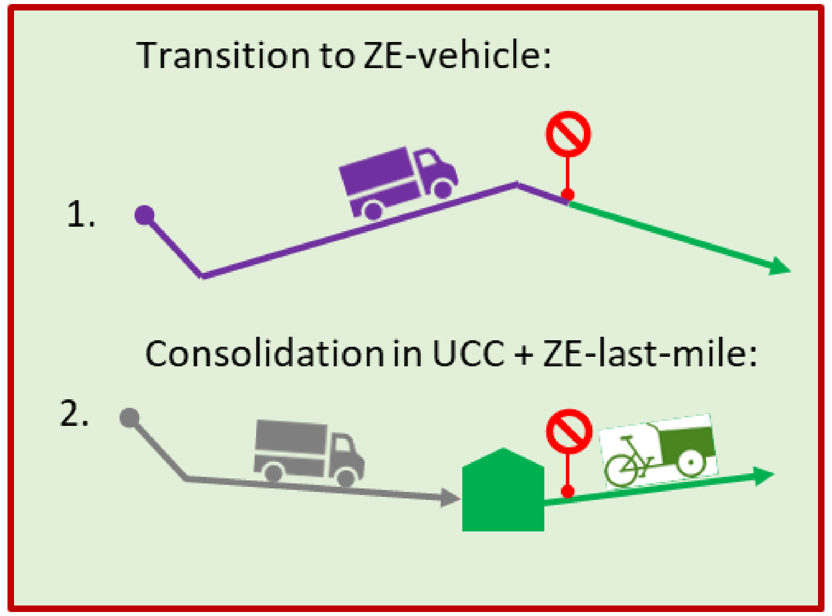


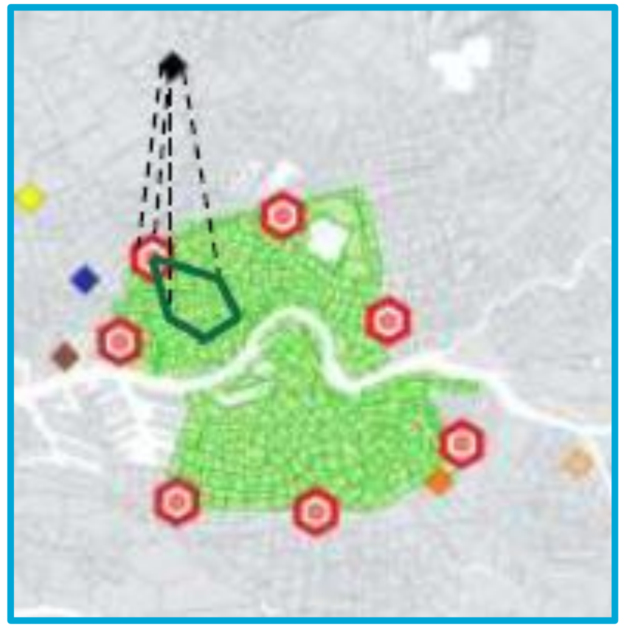
- Emission factors:
  - Fuel efficiency gains
  - Driving behaviour

- Logistic choice parameters:
  - More efficient planning

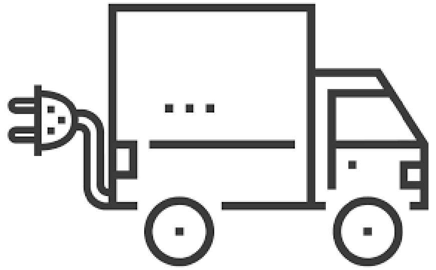


- Transition scenario's:
  - Zero emission zones



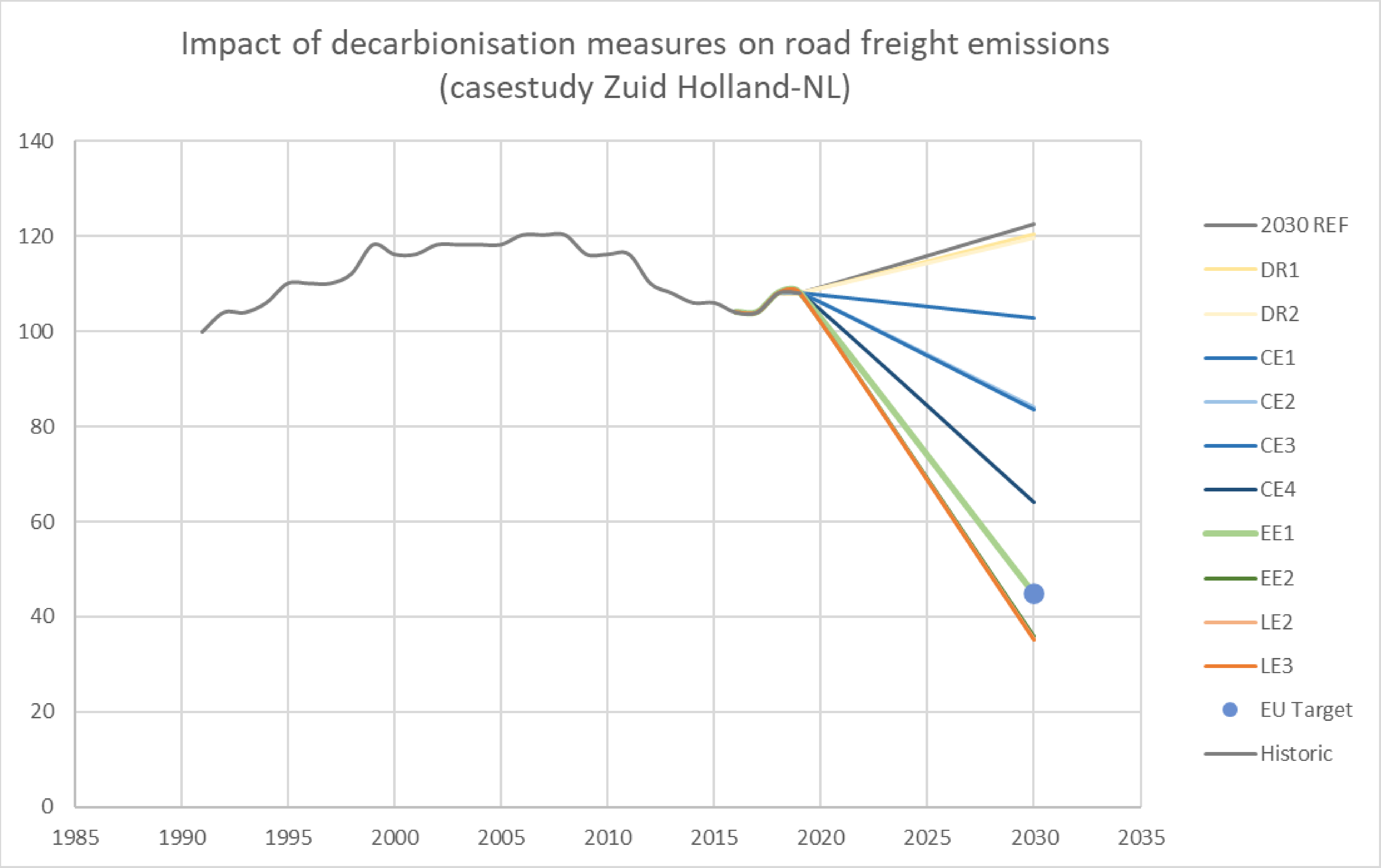


  - Vehicle market shares, e.g. for penetration new vehicle technology
  - Transition scenario new services (e.g. crowdshipping, microhub)



- Commodity demand (external scenario):
  - Modal shift and demand

Impact measures on CO2 emissions



Demand Reduction (DR):	
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Fuel efficiency	EE1
Driving behaviour	EE2
Logistic Efficiency (LE):	
New last mile solutions: CS + microhubs	LE1
Modular loading units Tour optimisation	LE2
Asset sharing	LE3

in this optimistic scenario the climate goal is within reach

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Conclusions and outlook

Goals Fit for 55 seems feasible with rigorous measures

Impacts are locally very diverse: urban simulation models are needed to make a more reliable impact assessment

This assessment is based on optimistic assumptions

In future work alternative assumptions will be testes for realistic / pessimistic scenarios

Impact assessment can also be used to track the progress to achieve decarbonisation goals

Summary of the lecture

Urban freight: a **complex** system, with many relevant developments to analyse.

Models are evolving from basic 4 step towards **advanced multi agent systems**, such as MASS-GT:

- Simulation of individual decision making can capture better the heterogeneity of city logistic stakeholders
- New sources of automated big-data collection enable model development

Presented **scenario-based analyses** of zero-emission zoning and decarbonization show how the model is used for system wide impact assessment.

TU Delft

Questions and answers?

Thank you for
your kind attention!

Contact information: m.a.debok@tudelft.nl / debok@significance.nl

Further reading about MASS-GT

Papers related to MASS-GT/HARMONY Tactical freight Simulator:

- De Bok et al. (2021) “Impacts of a low-emission zone on freight delivery patterns in Rotterdam: a case study with the HARMONY tactical freight simulator” Transportation Research Record, forthcoming
- Thoen, S, L Tavasszy, M de Bok, G Correia, R van Duin (2020) Descriptive modeling of freight tour formation: A shipment-based approach, *Transportation Research Part E*, Volume 140, Pages XX – XX
- de Bok, M, L Tavasszy, S Thoen (2020) Application of an empirical multi-agent model for urban goods transport to analyze impacts of zero emission zones in The Netherlands, *Transport Policy*, Volume XX, Pages XX – XX. (in press).
- Thoen, S, M de Bok and L Tavasszy (2020) Shipment-based urban freight emission calculation. Paper to be presented at the IEEE Forum on Integrated and Sustainable Transportation System (ISTS) in Delft.
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Next Seminar

SHARED AUTONOMOUS ELECTRIC VEHICLES TRANSPORT SCHEDULING WITH CHARGING CONSIDERATIONS: OPTIMIZATION-BASED PLANNING APPROACHES

Etienne Liu and Hadrien Herubel, Future Cities Lab

WEDNESDAY, November 24th, 2021 | 10-11 AM CEST

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