The Tactical freight Simulator in HARMONY: a decision support tool to explore urban logistics

A case study into zero-emission city logistics

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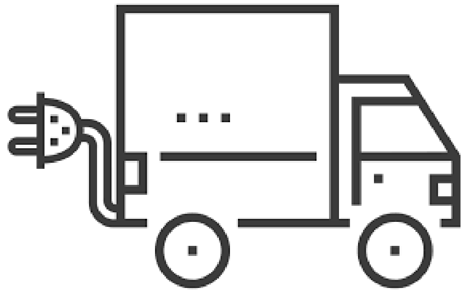
The story of Jos..



E commerce

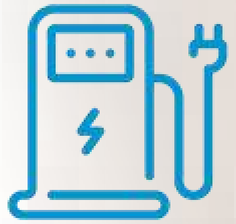
Road user charges

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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Tactical freight Simulator in HARMONY

Vision behind the H2020 project HARMONY:

Develop **a new generation of harmonised spatial and multimodal transport planning tools** which comprehensively model the dynamics of the changing transport sector and spatial organisation, enabling metropolitan area authorities to lead the transition to a low carbon new mobility era in a sustainable manner.

Objective of the **Tactical Freight Simulator** (WP6):

To simulate the tactical decision making behind **urban freight transport demand** to support evidence based decision making in city logistics. Therefor the approach is **empirical** (data-based), and **agent-based** to represent the heterogeneity in city logistics.

The TFS is a continuation of the MASS-GT model developed at TUD: a multi-agent simulation framework.

Challenges: **complexity** and **data**

Logistic decisions across different layers:

	Logistic decision	Agents involved
Commodity market	Commodity supplier choice	Receiver, Producer
Logistic layer	Transportation sourcing	Shipper (Producer or receiver), Hired account carrier
	Distribution channel	Carrier (own/hired account)
	Consolidation point	Carrier (own/hired account)
	Frequency/shipment size	Shipper (Producer or receiver)
Transport layer	Vehicle type choice	Carrier (own/hired account)
	Tour formation	Carrier (own/hired account)
	Time-of-day	Carrier (own/hired account) / Receiver / Administrator
Network layer	Route choice	Carrier (driver) or Vehicles

Producers

Receivers

Hired account

Own account

Admin.

Vehicles

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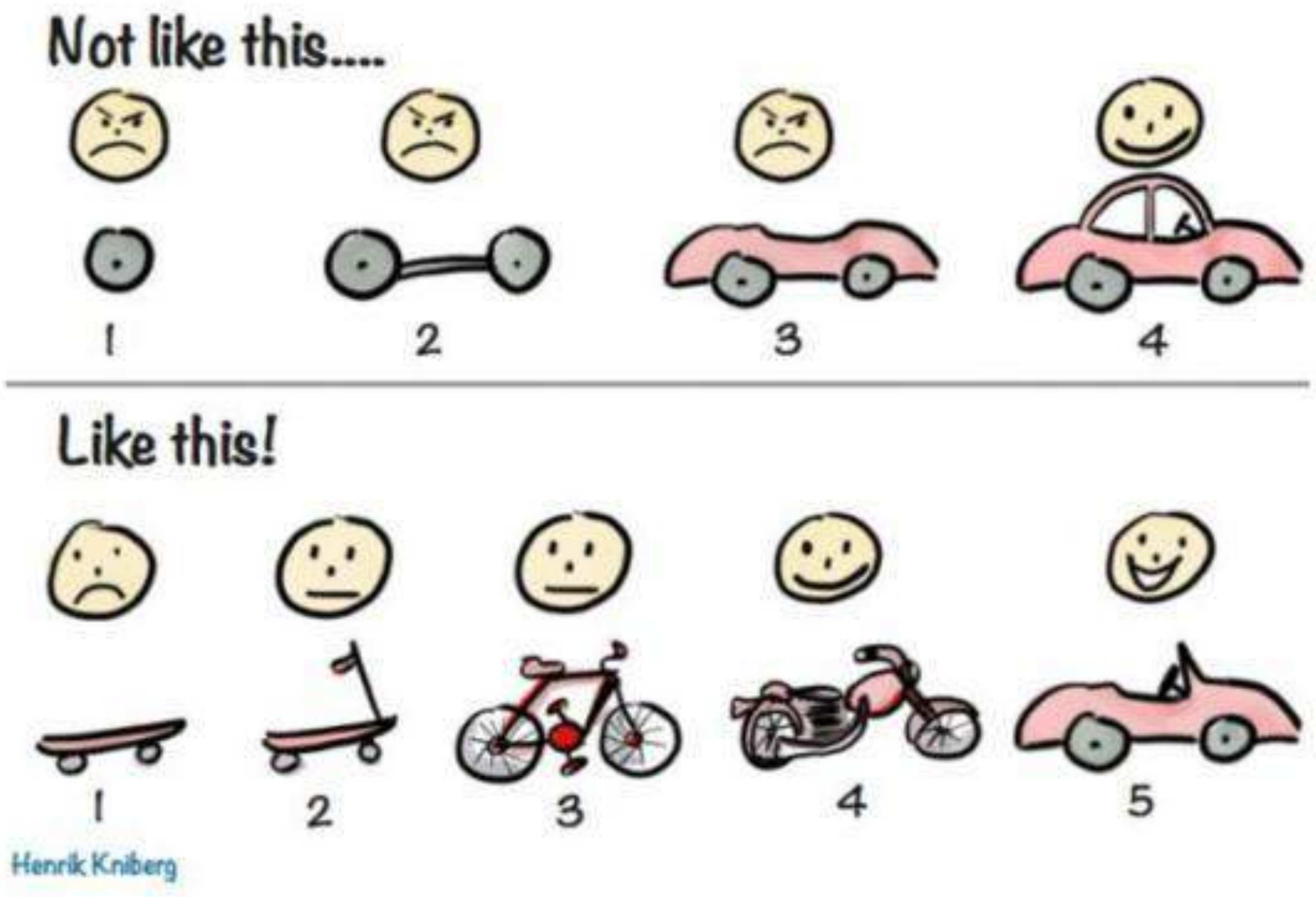
There are no existing models that simulate all of the above choices and decision makers

To manage complexity during mode development we apply the ‘*minimum viable product principle*’



- The HARMONY-TFS is the third step in the process: the ***bicycle***

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XML data from Statistics Netherlands (CBS)

- Automated collection from Transport Management System (TMS)
- +2M individual trips in raw data !!!
- Offers huge potential for development of microscopic freight demand models

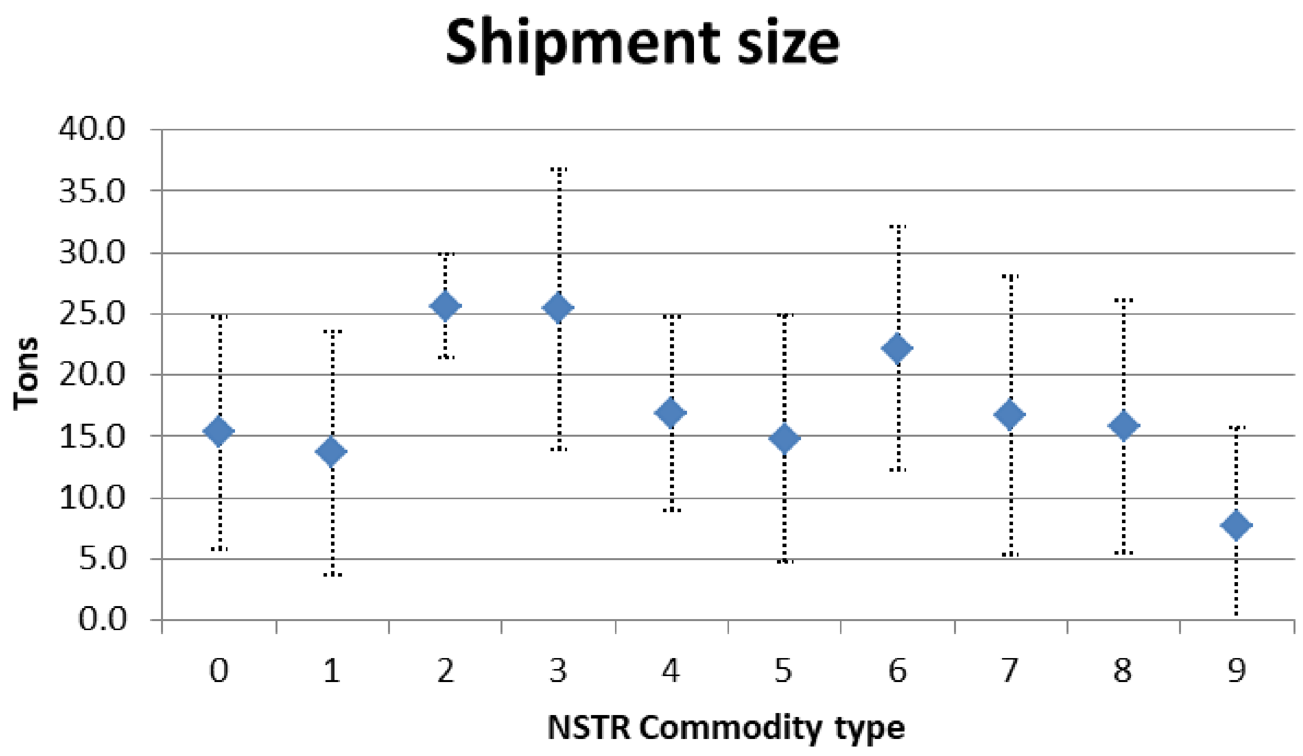
opgaveId (Truck)
License plate
Year & week
In BasGoed sample [yes/no]
Transporting company
Ownership type *Owned, hired, leased, or not owned anymore*
Fuel consumption [L per 100 km]
Home base *Country* *ZIP* *Town* *LatLon*
Carrying capacity [kg]
Vehicle type

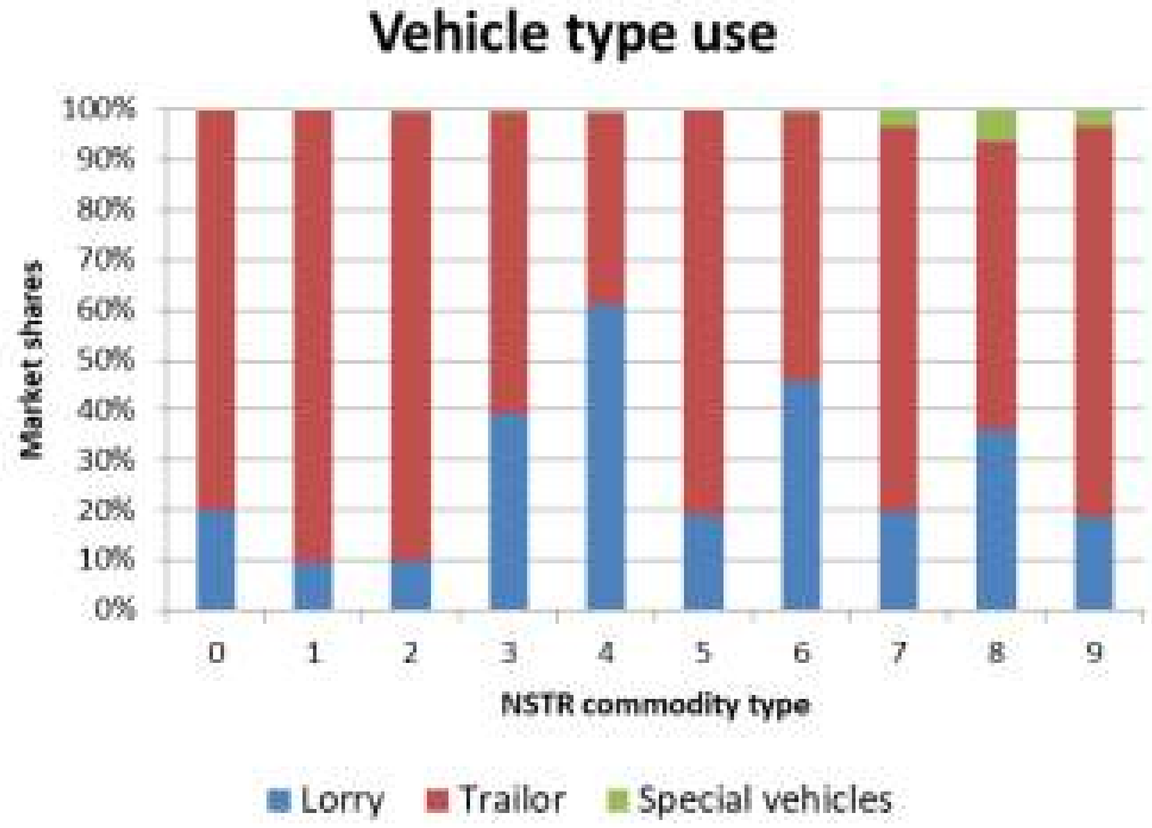
ritId (Tour)
Serial tour number *Describes order of tours for a truck*
Distance [km] *From origin to destination of tour*
Date & time *Start* *End*
Origin & destination *Country* *ZIP* *Town* *LatLon*
Operator type *Hired carrier or own-account*
Capacity utilization *% m2* *% m3*
Border crossing *Country*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

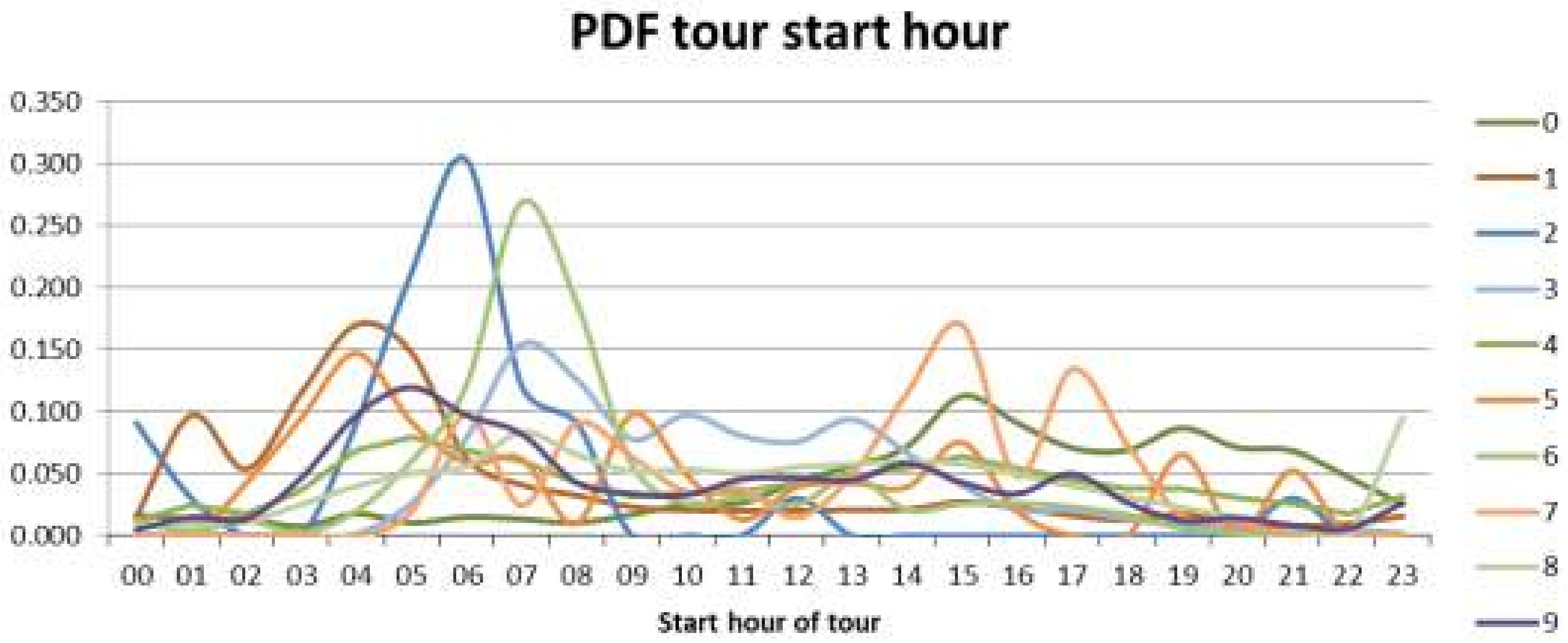
zendingId (Shipment)
Serial shipment number *Describes order of shipments for a tour*
Distance [km] *From loading to unloading point*
Gross weight [kg]
Shape *Fluid, solid bulk, sea containers, other containers, pallets, hanging goods, goods in ropes, mobile units with own power, or other mobile units.*
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]

Privacy!

Descriptive stats freight data:

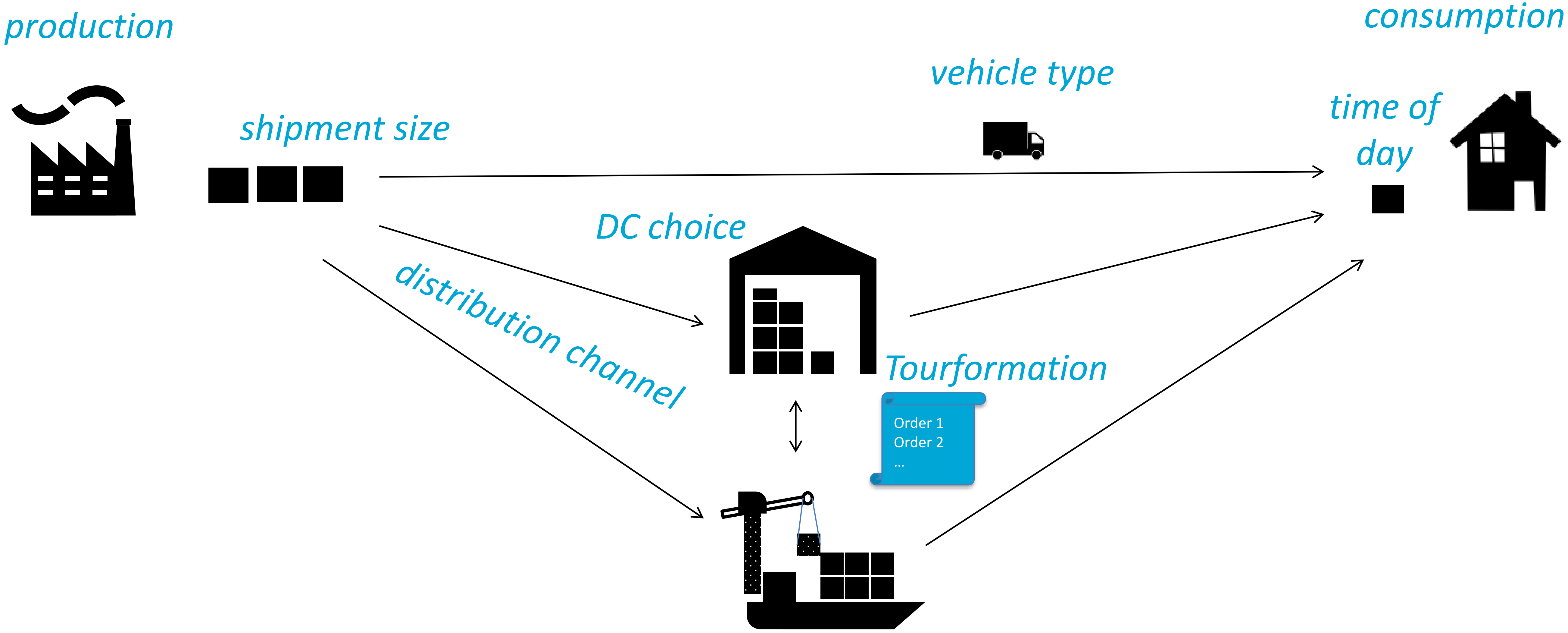






Conceptual model for MASS-GT

- 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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Main structure

MASS-GT prototype v3

Shipment module: simulates long-term decisions:

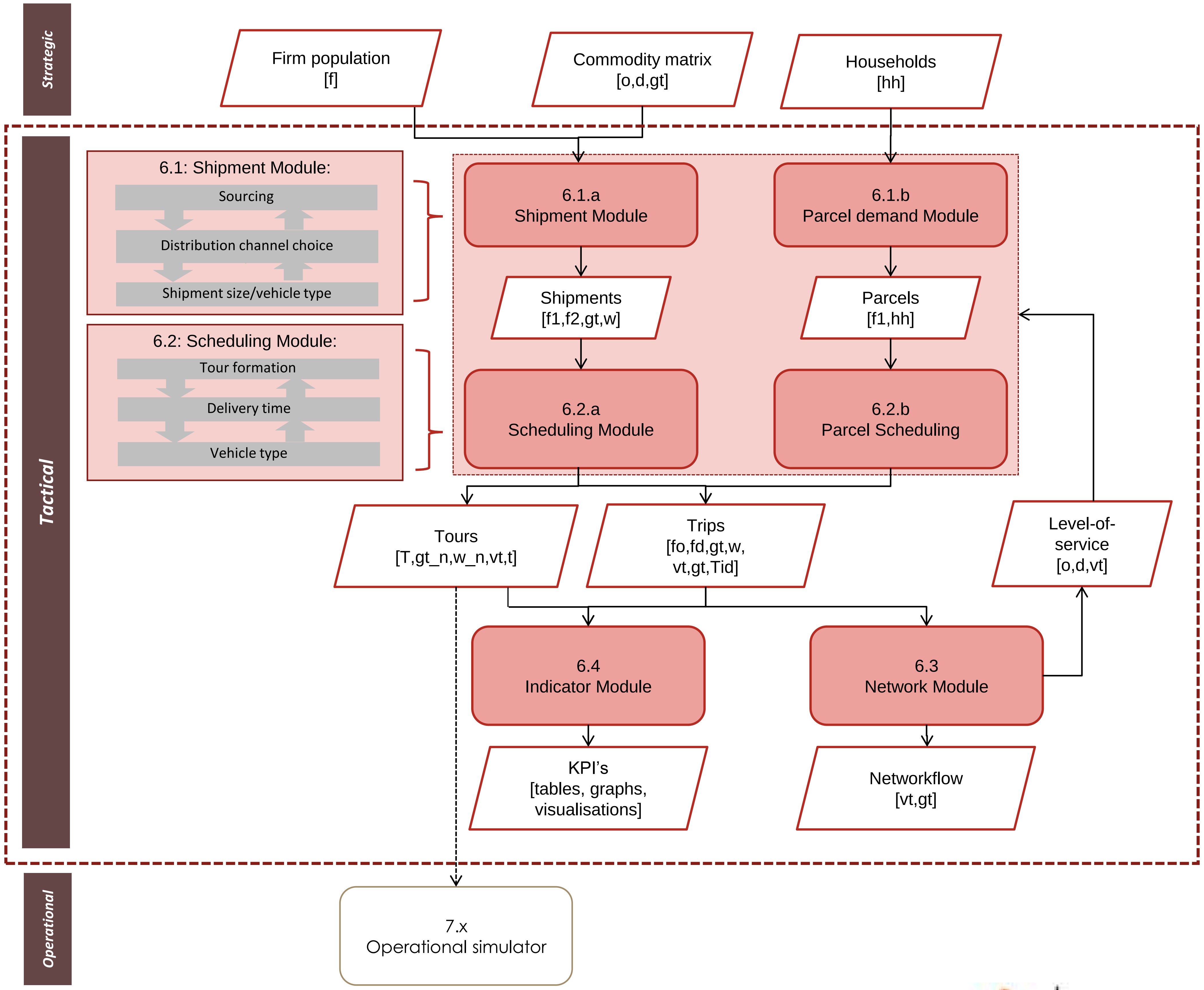
- ❑ Sourcing/Producer choice
- ❑ Distribution channel choice
- ❑ Shipment size & vehicle type (simultaneous)

Scheduling module: simulates daily decisions:

- ❑ Tourformation
- ❑ Time-of-day

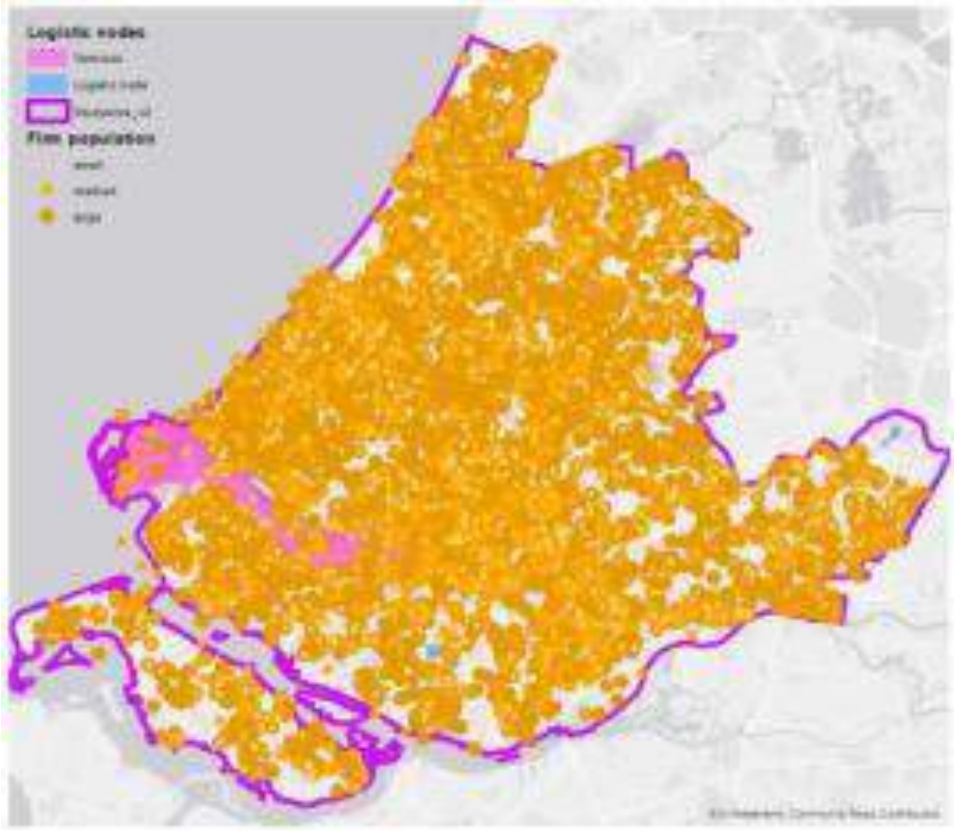
Two auxiliary modules:

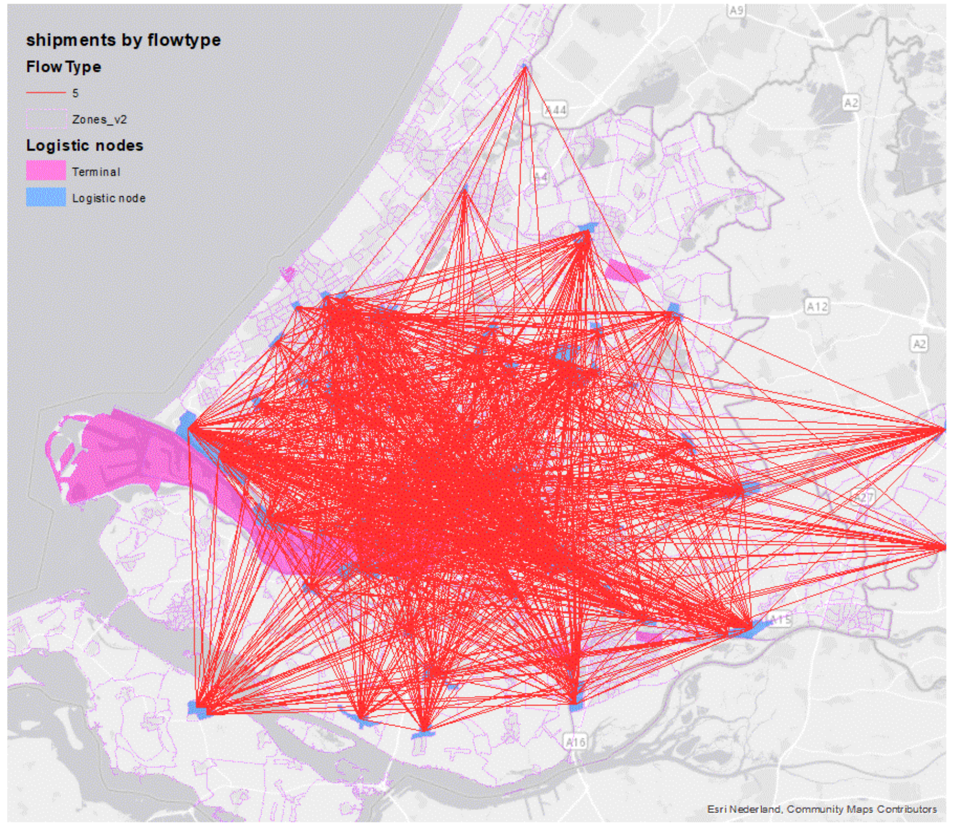
- ❑ Network Module (skim & routechoice)
- ❑ Indicator Module

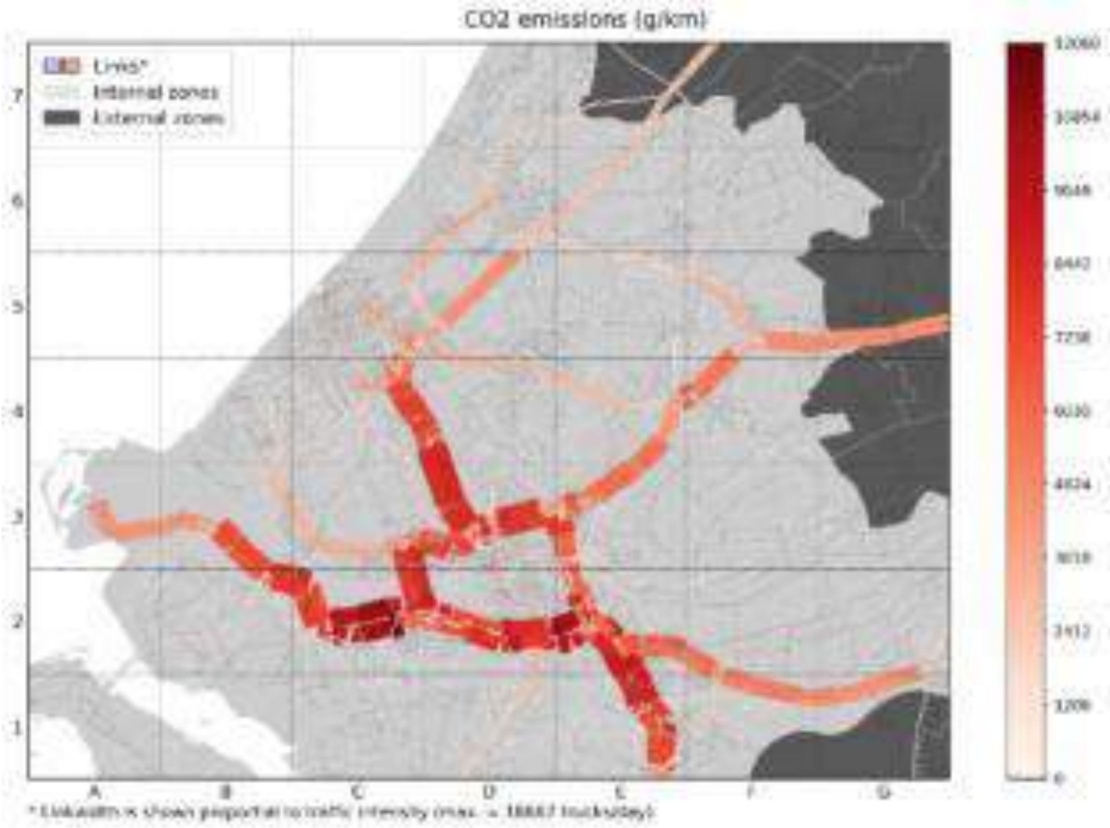


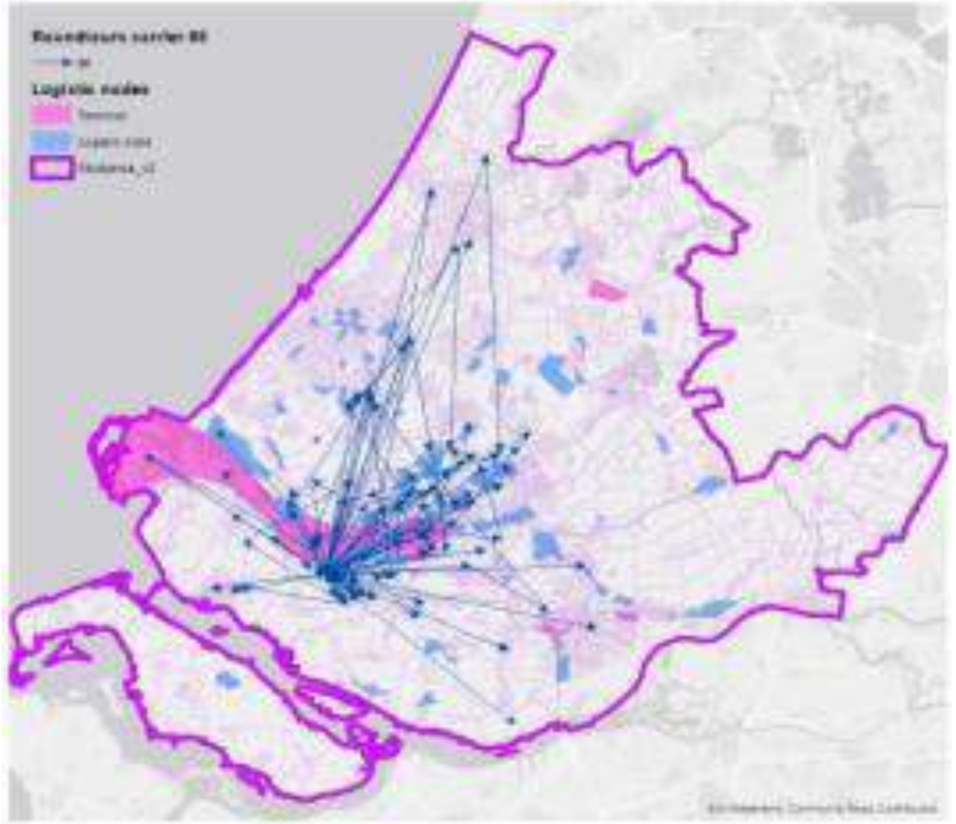
HARMONY

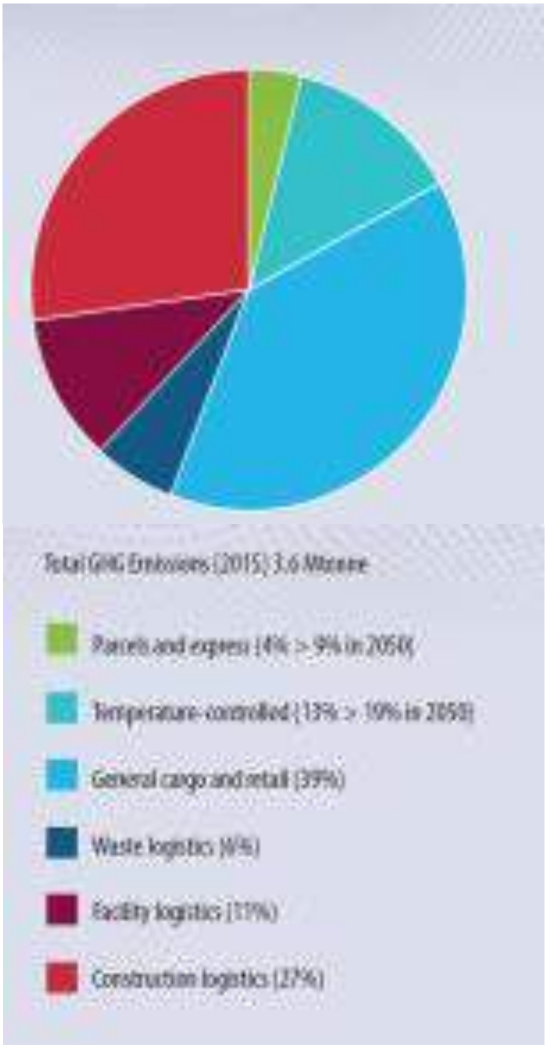
HARMONY TFS (MASS-GT v3) in 5 figures











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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:

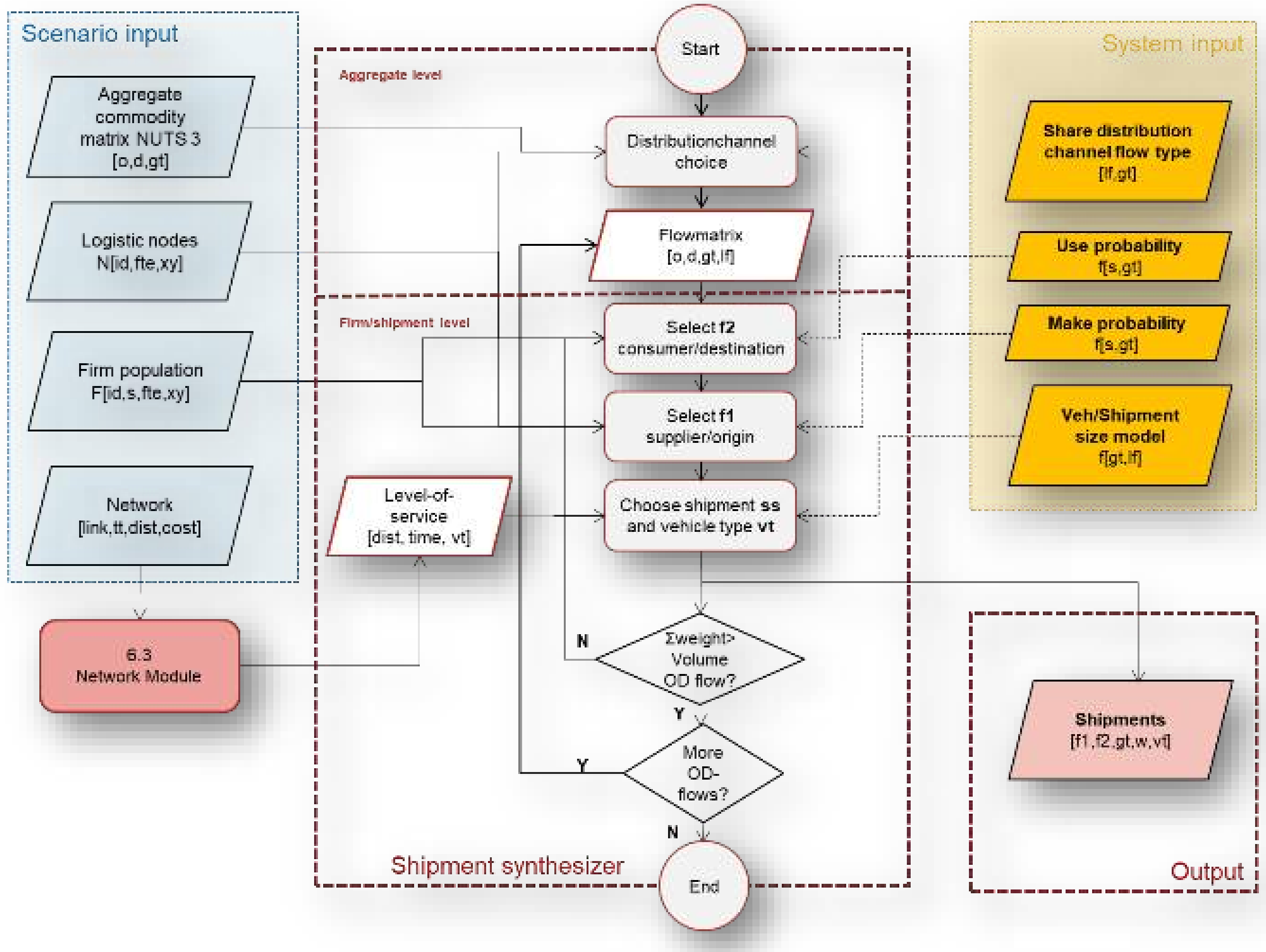
1. Allocation to distribution channel
2. Vehicle and shipment size choice
3. Selection of consumer
4. Selection of producer

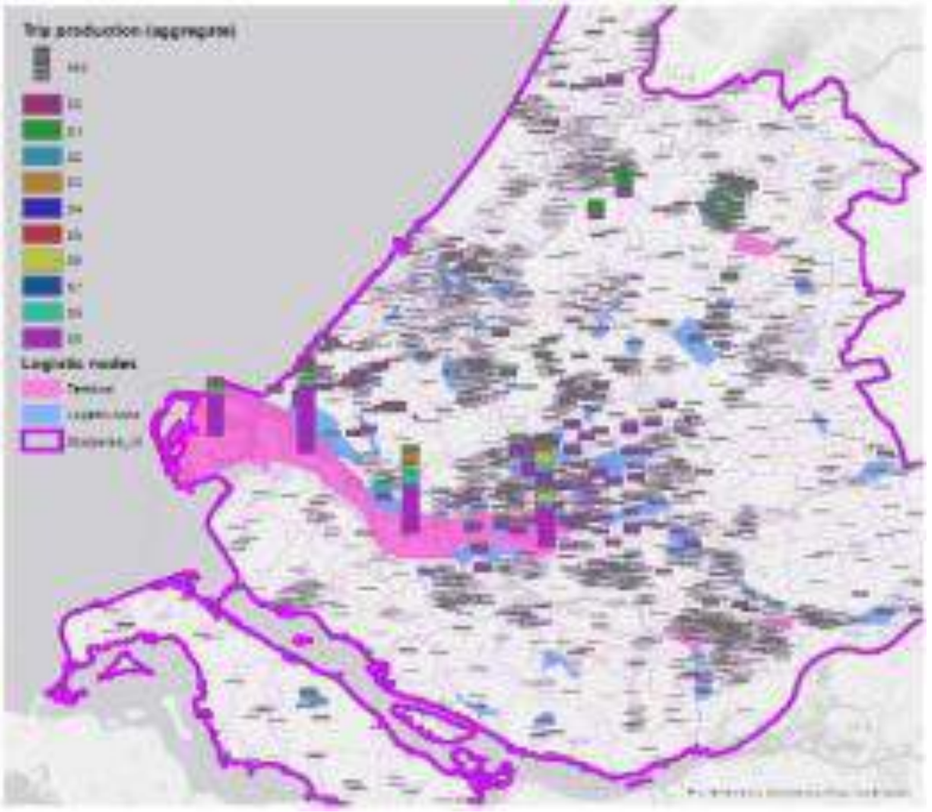
Output:

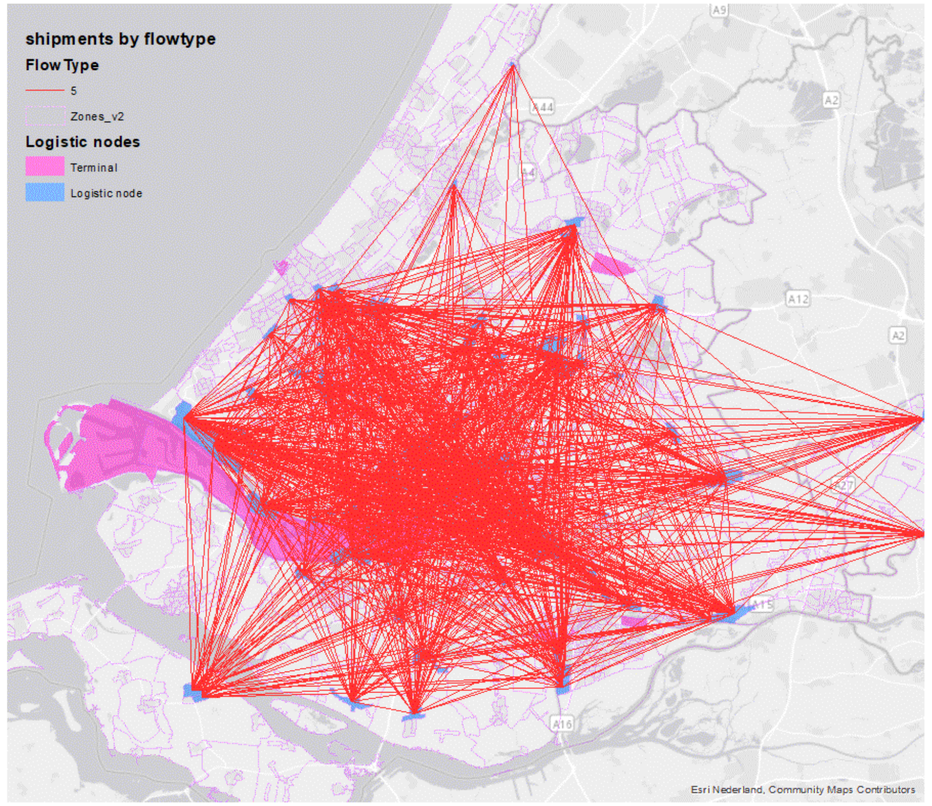
All shipments in the study area

Use already available data:

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



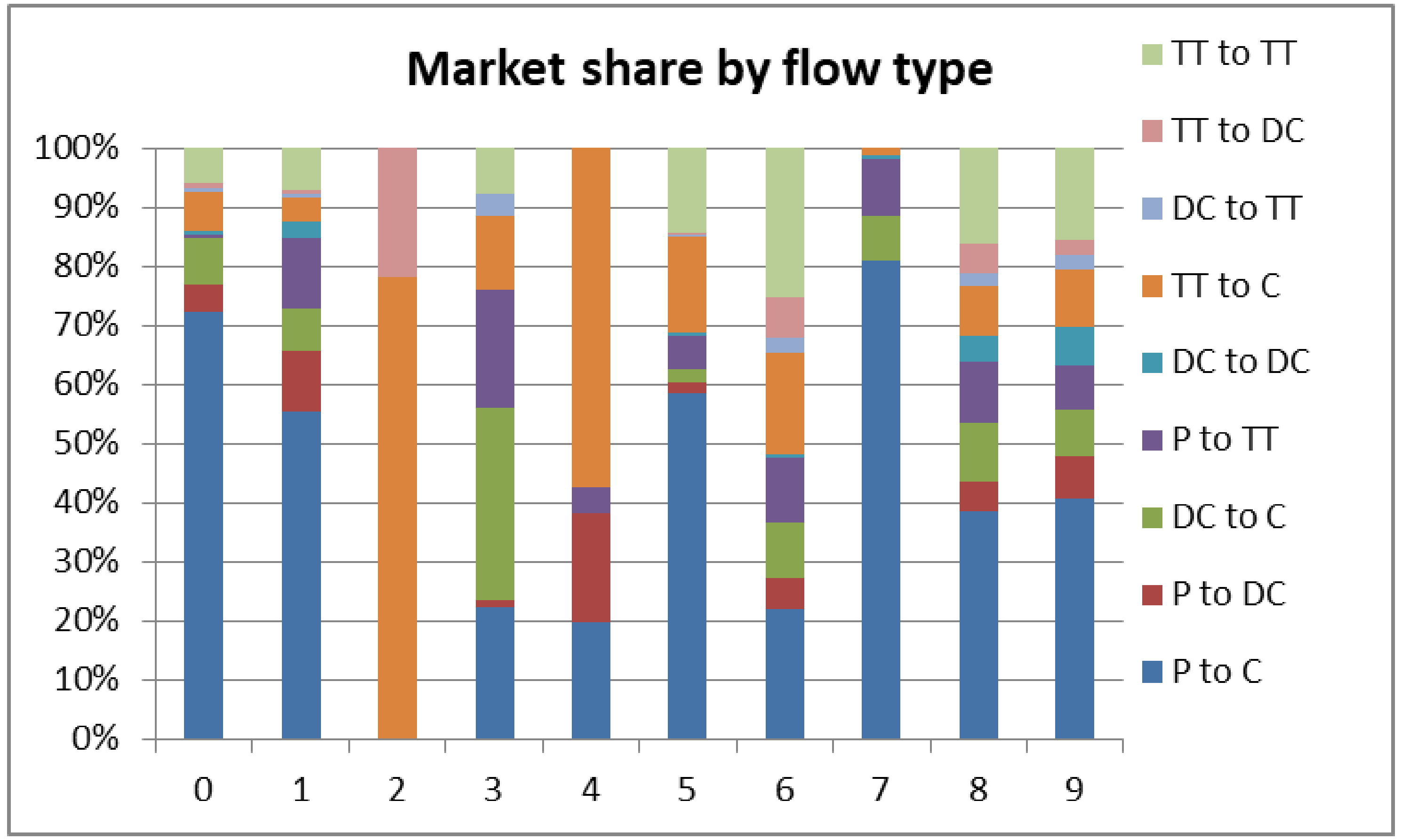




Distribution channel choice

Distribution channel choice:
The volume of logistic transport flows (direct, to DC, etc..) is calculated from observed market shares.

Observed market shares by commodity type from the XML data:



- For NST/R 9 (mixed cargo) less than 50% of transports is direct
- NST/R 2 (Solid mineral fuels) are transport mainly between terminal and consumer directly.

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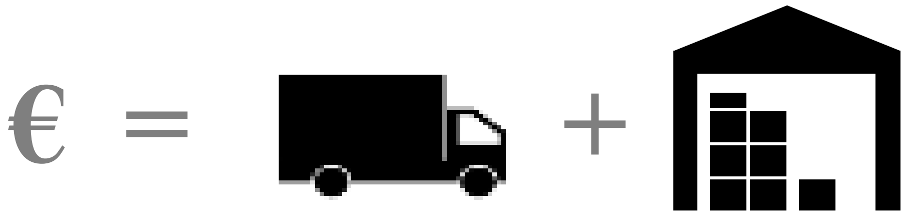
Vehicle and shipment size choice model

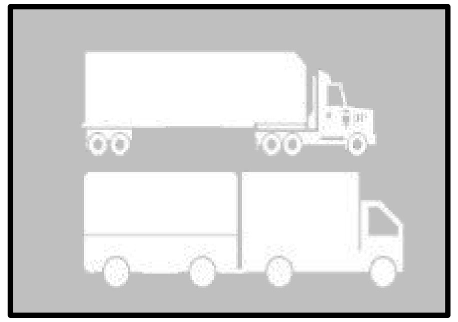
EOQ theory

The shipment module includes a **logistic choice model** for **vehicle type** and **shipment size**. Both logistic choice are explained by a logistic cost function that includes **transport costs** and **inventory holding cost**:

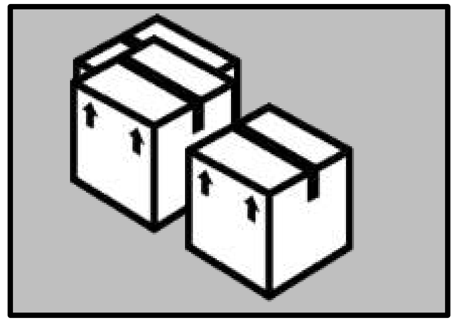


Random Utility Theory

Vehicle and shipment size choice is simulated in a discrete-discrete MNL choice model:



Vehicle type



Shipment size

Paper about a case study with this model was presented last year at ETC 2019 in Dublin (now published in CSTP).

Consumer and supplier selection

Consumer alloction:

Probability of firm f belonging to sector s, being the **receiver** of shipment with commodity type gt depends on firm size, E, 'use' probability for the sector, $P_{s;gt}^{use}$, and other firms in destination zone:

$$P_{f;gt}^{receiv} = \frac{E_{f;s} * P_{s;gt}^{use}}{\sum_{i \in dest}\left[E_{i;s} * P_{s;gt}^{use}\right]}$$

Producer selection:

Probability of firm f belonging to sector s, being the **producer/sender** of shipment with commodity type gt depends on firm size, E, 'make' probability for the sector, $P_{s;gt}^{make}$, and other firms in origin zone:

$$P_{f;gt}^{sender} = \frac{E_{f;s} * P_{s;gt}^{make}}{\sum_{i \in orig}\left[E_{i;s} * P_{s;gt}^{make}\right]}$$

Scheduling module

Objective of the Scheduling module:

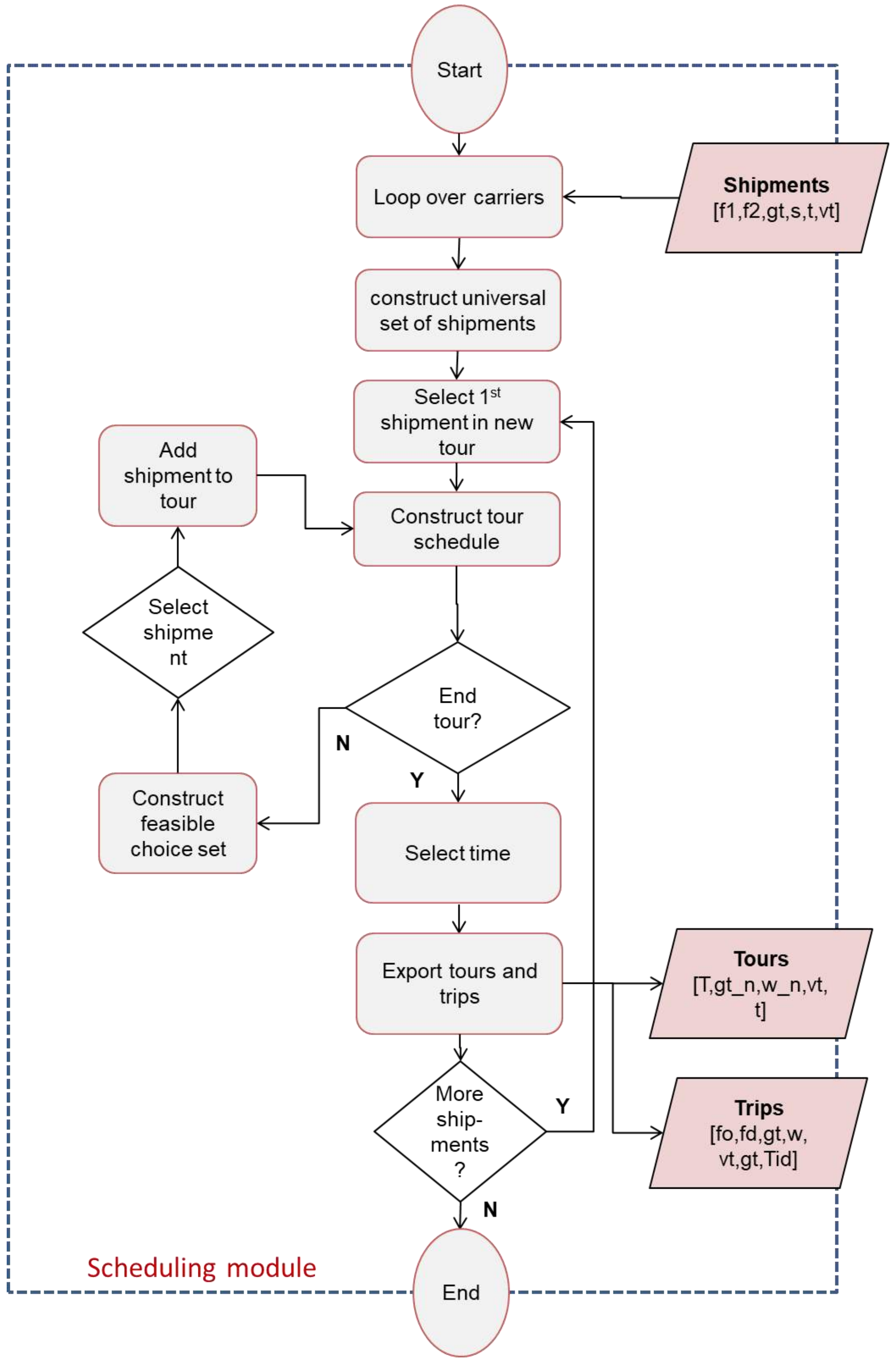
Simulate daily logistic decision making to schedule the delivery of all shipments that are transported to/from/within the study area.

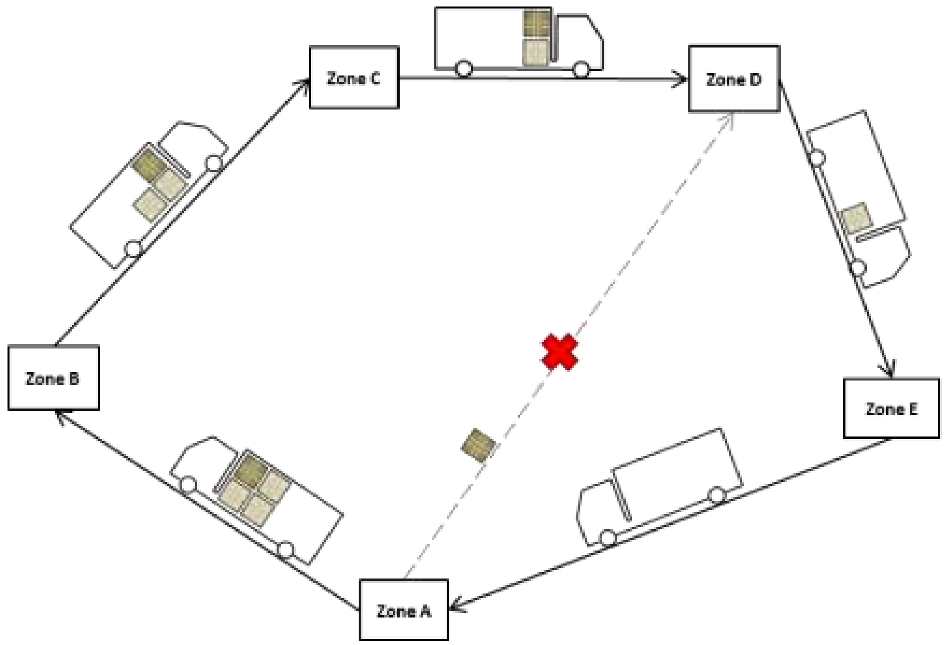
Builds tour patterns, in a step-wise procedure, simulating the following logistic processes:

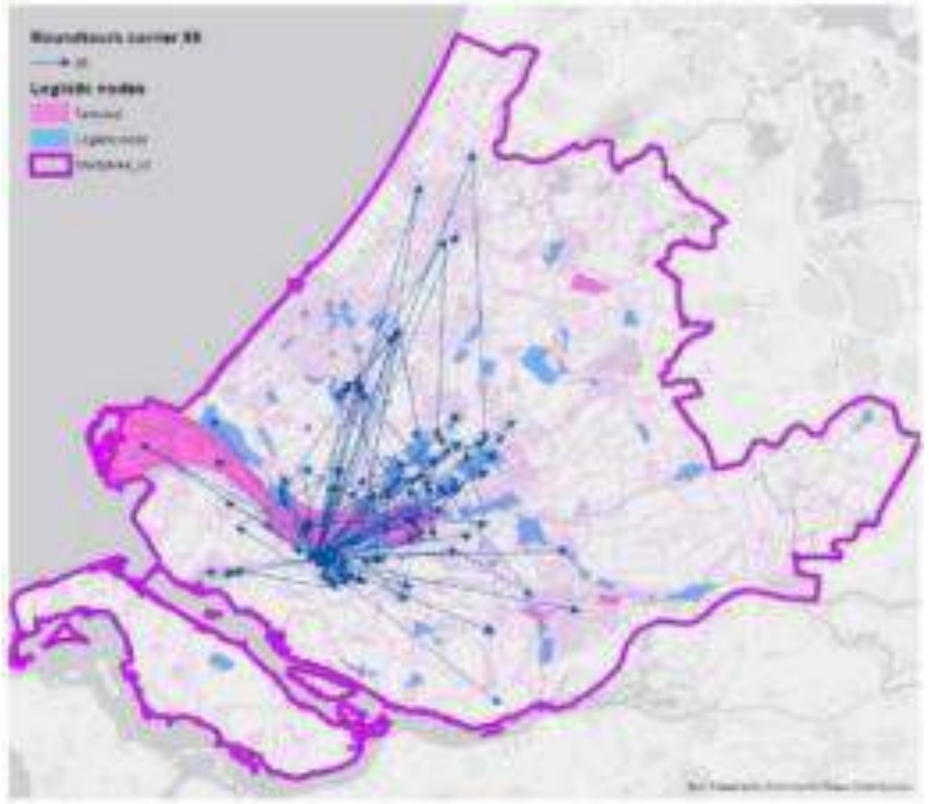
1. Tourformation
2. Delivery time

Output:

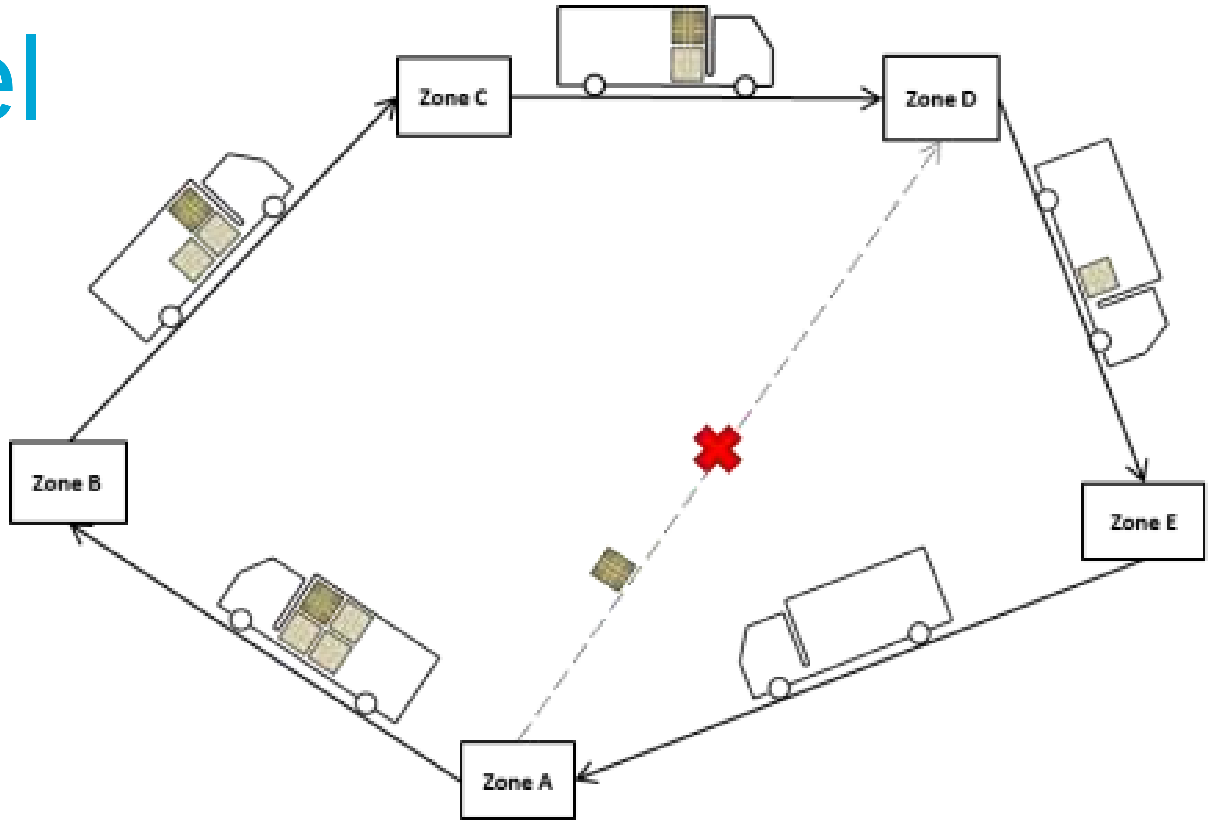
Truck round tours for the collection and delivery of all shipments in the study area







Tour formation choice model

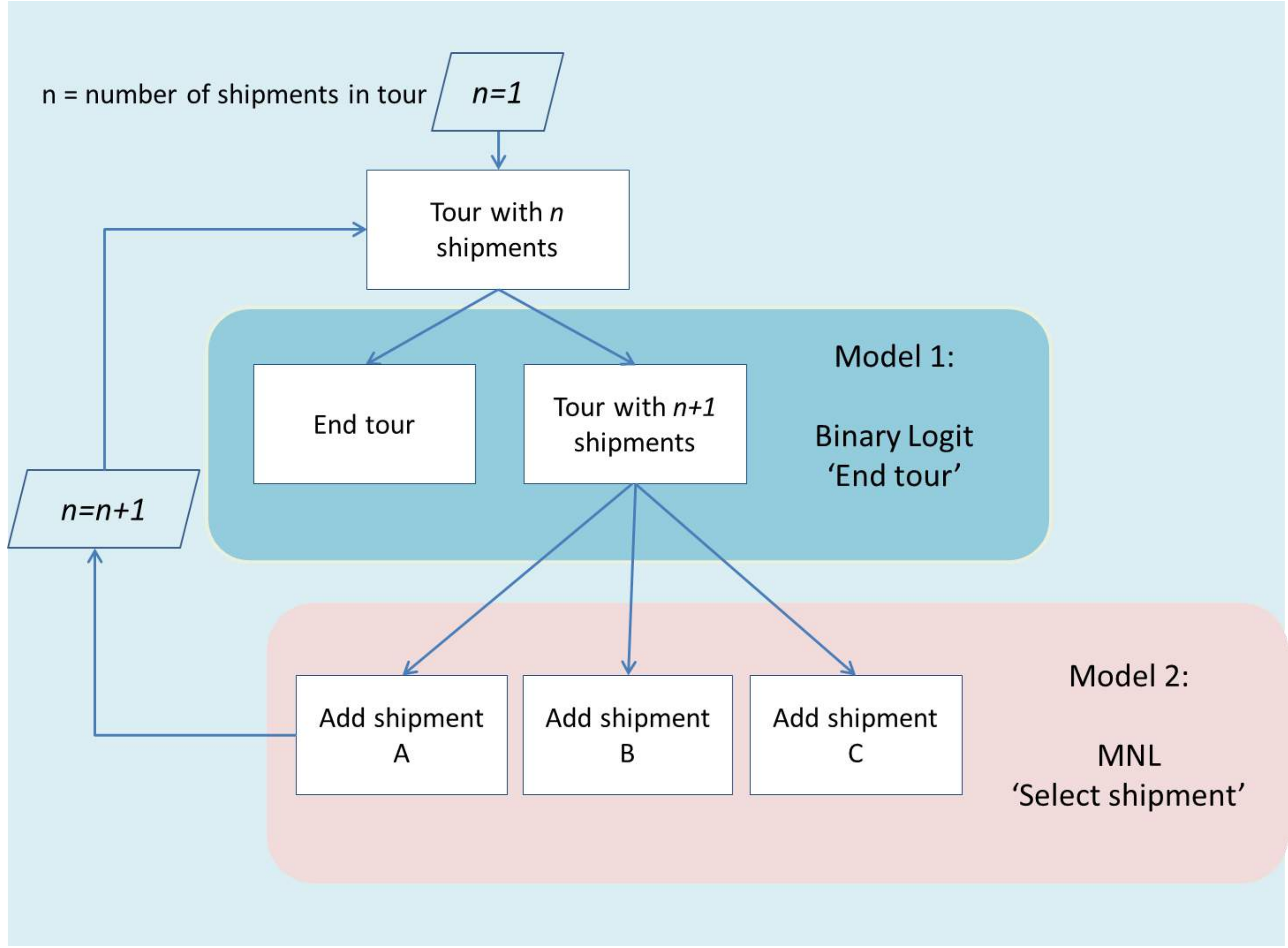


Purpose:

Choice model for the formation of roundtours making one or multiple stops

Approach:

- Shipment based
- Step-wise discrete choice models
- Constraints: capacity, tour duration, distance
- Attributes in utility function: transport costs, commodity types, vehicle type, location type



Detailed description of approach is published in:

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

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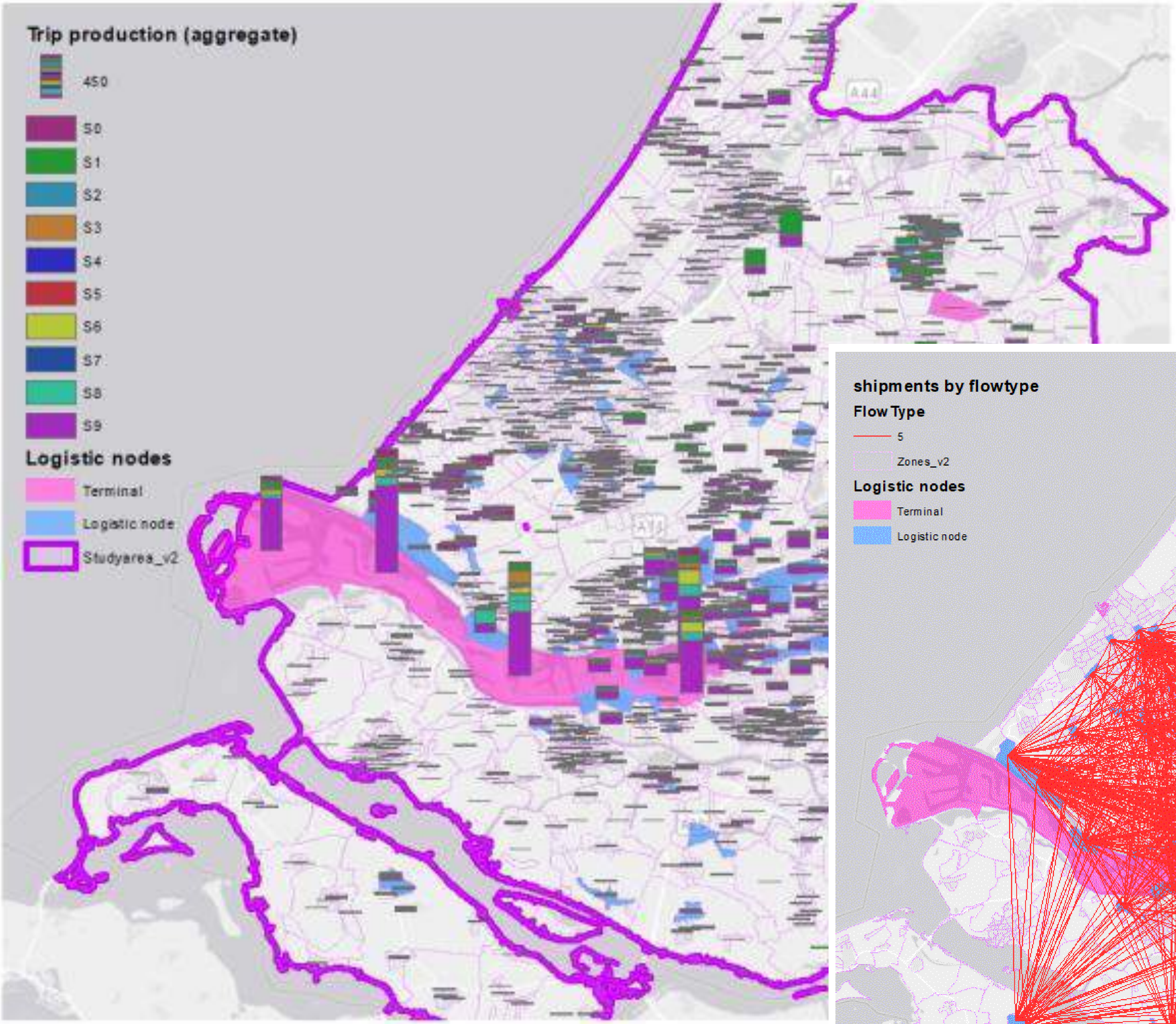
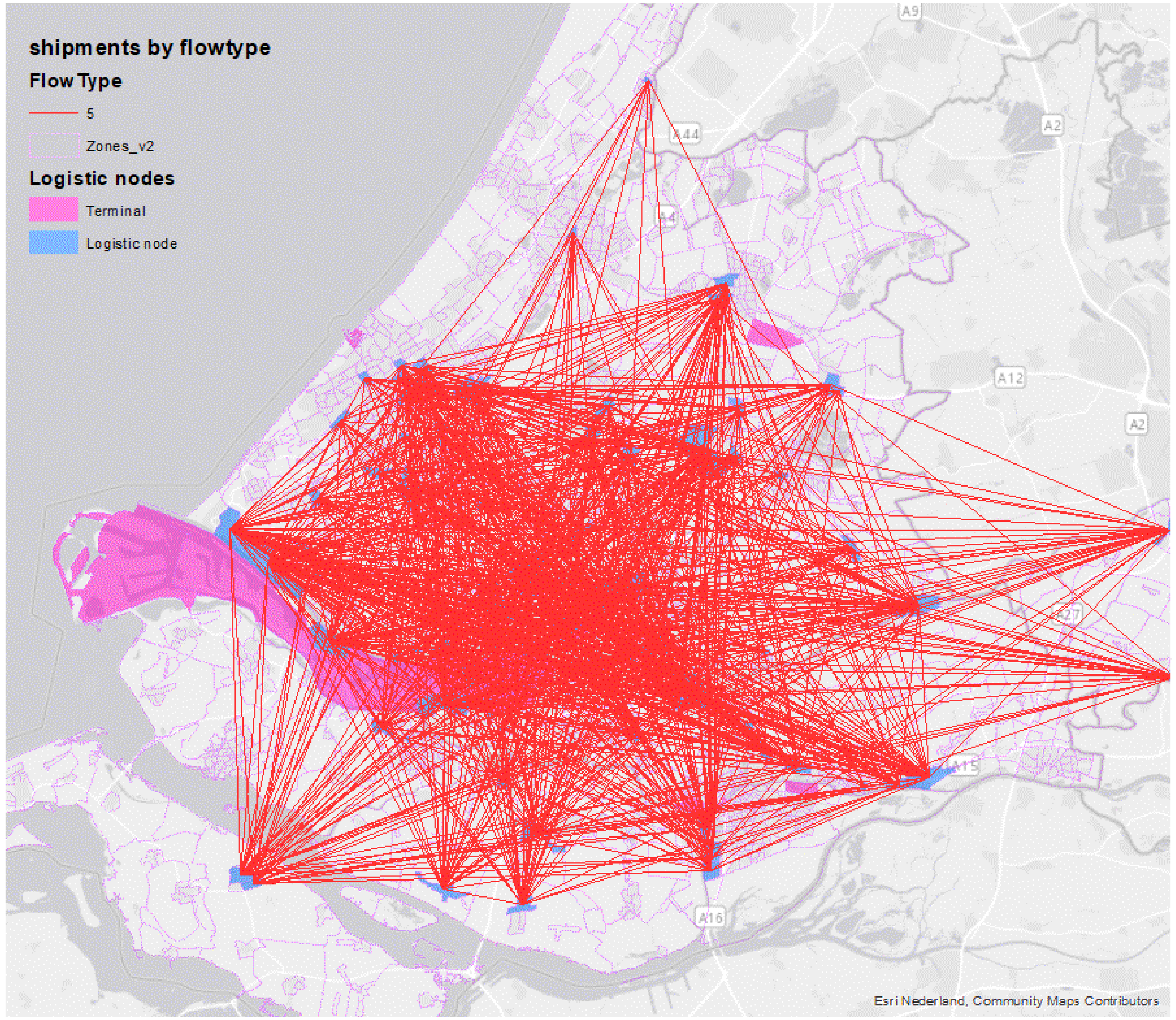
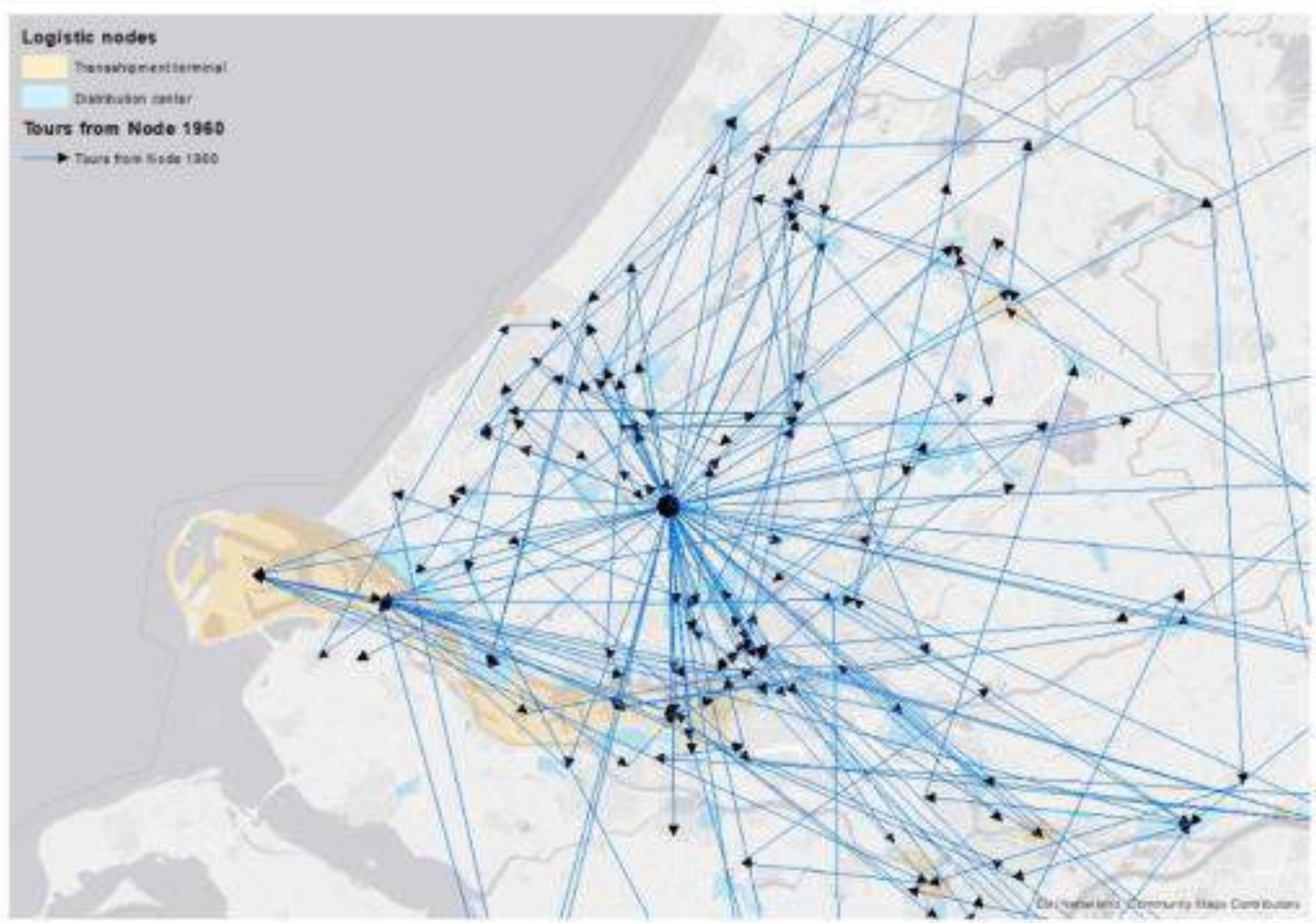
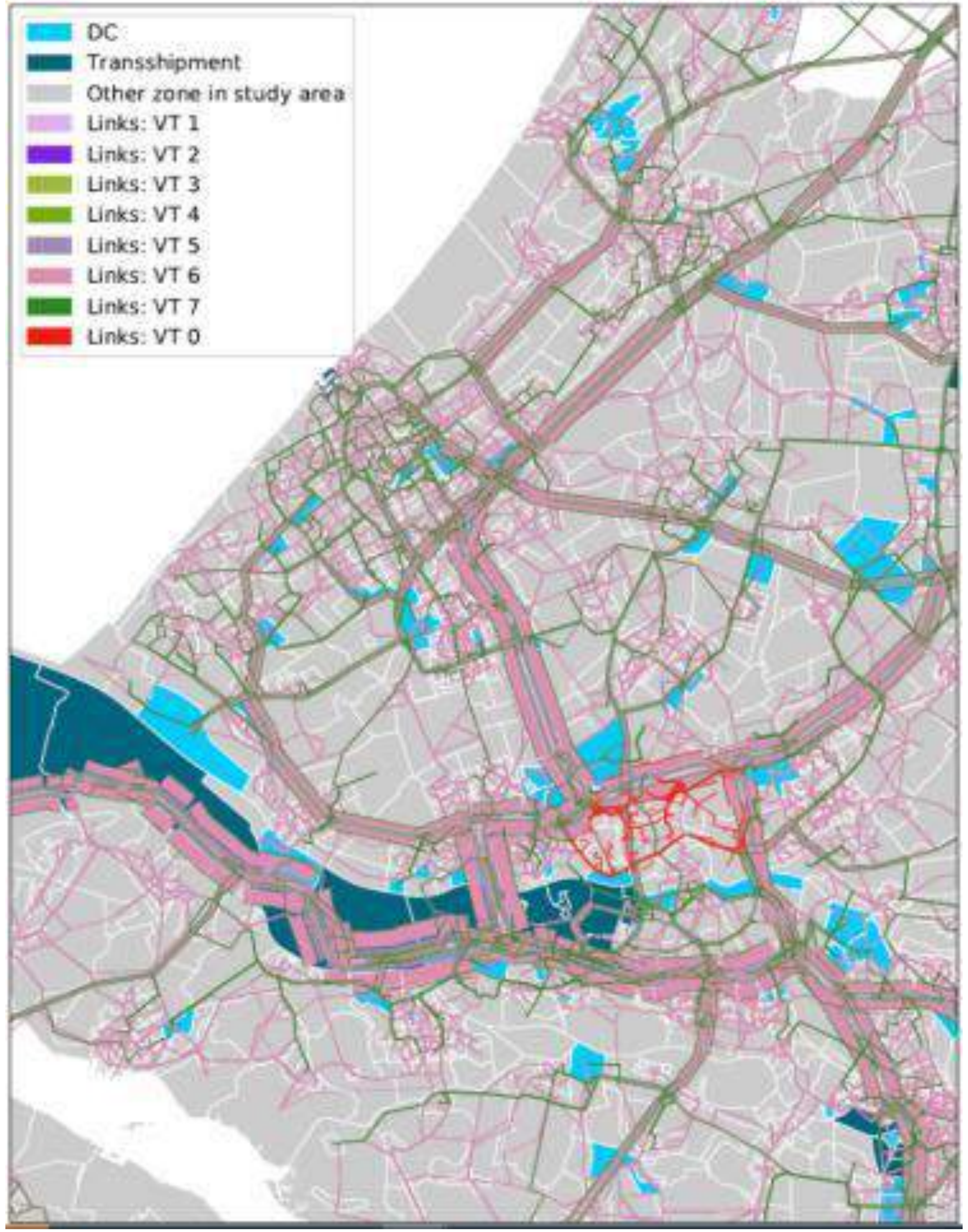
simulated demand





Simulated tour patterns and network flow (by vehicle type)





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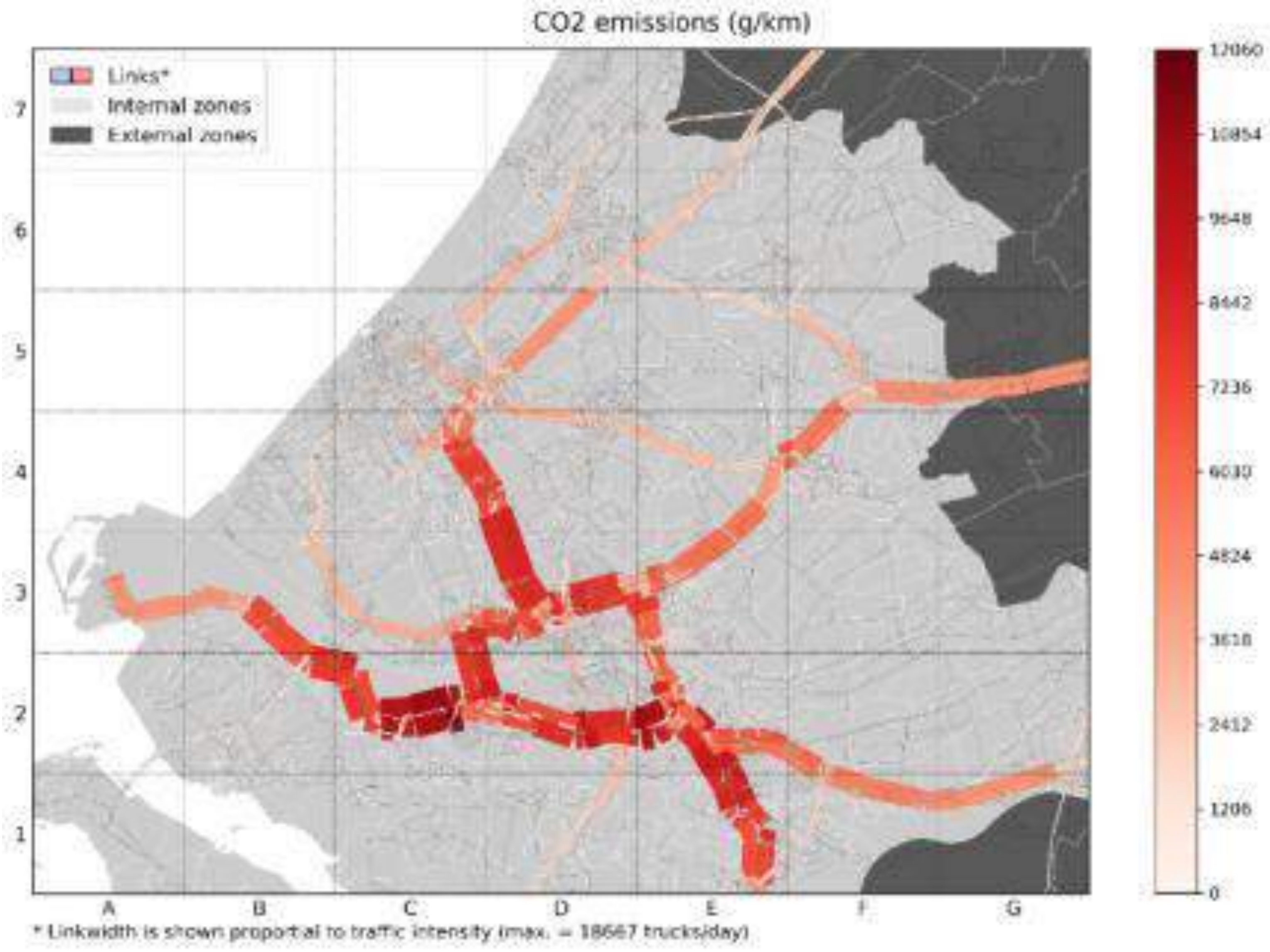
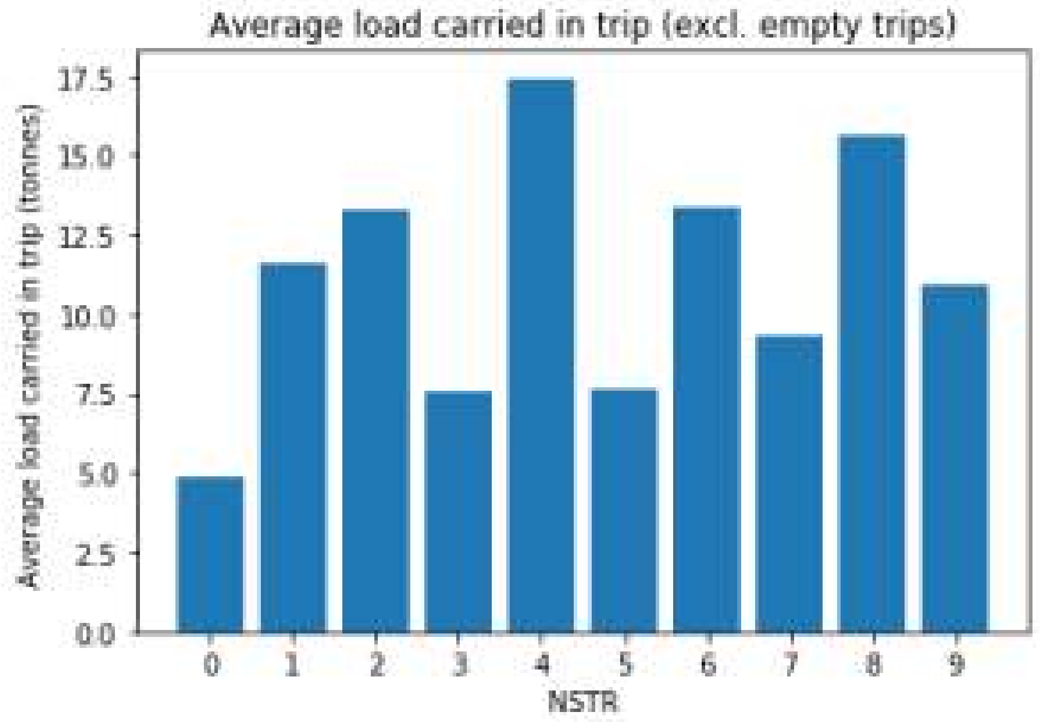
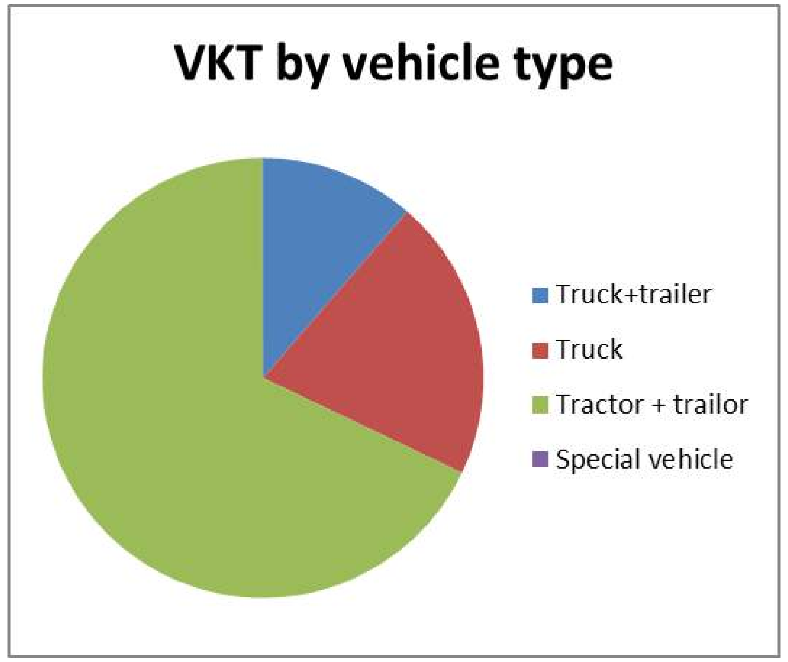
Shipment-based emission calculation:



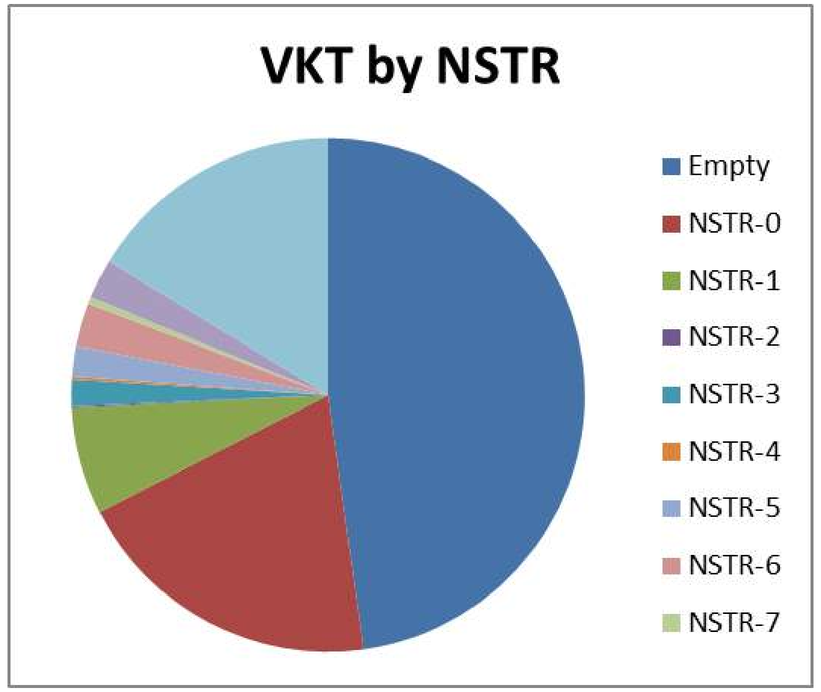
Logistic indicators:



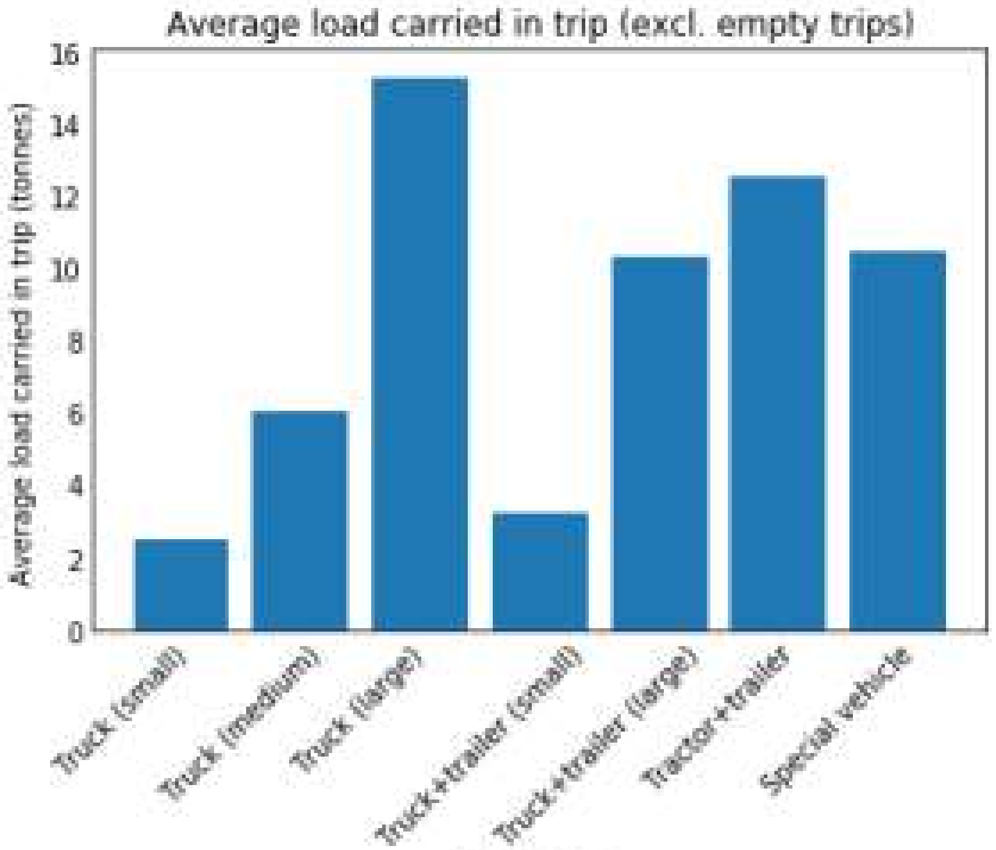
Average load per goods type



Vehicle kilometers by vehicle type



Vehicle kilometers per goods type



Average load by vehicle type

Zero-emission zone for Rotterdam

Policy context:

- Objective in the Climate Agreement: to reduce CO2 emissions and improve both air quality and accessibility in the city.
- Green Deal 010 Zero Emission City Logistics (GDZECL): achieve zero Emission city logistics by 2025 by introduction of a **zero-emission zone:** restricted access to the city centre only with zero-emission vehicles.

> “Largest share of transport movements in City logistics, are from small transporters with low volume” (Hans Quak, Senior Researcher at TNO).

- The zero-emission zone is an important mean to **greener vehicles**, but also **more efficient** city logistics: consolidation of small volumes

> “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.” (Jan Boeve, Director of TLN)

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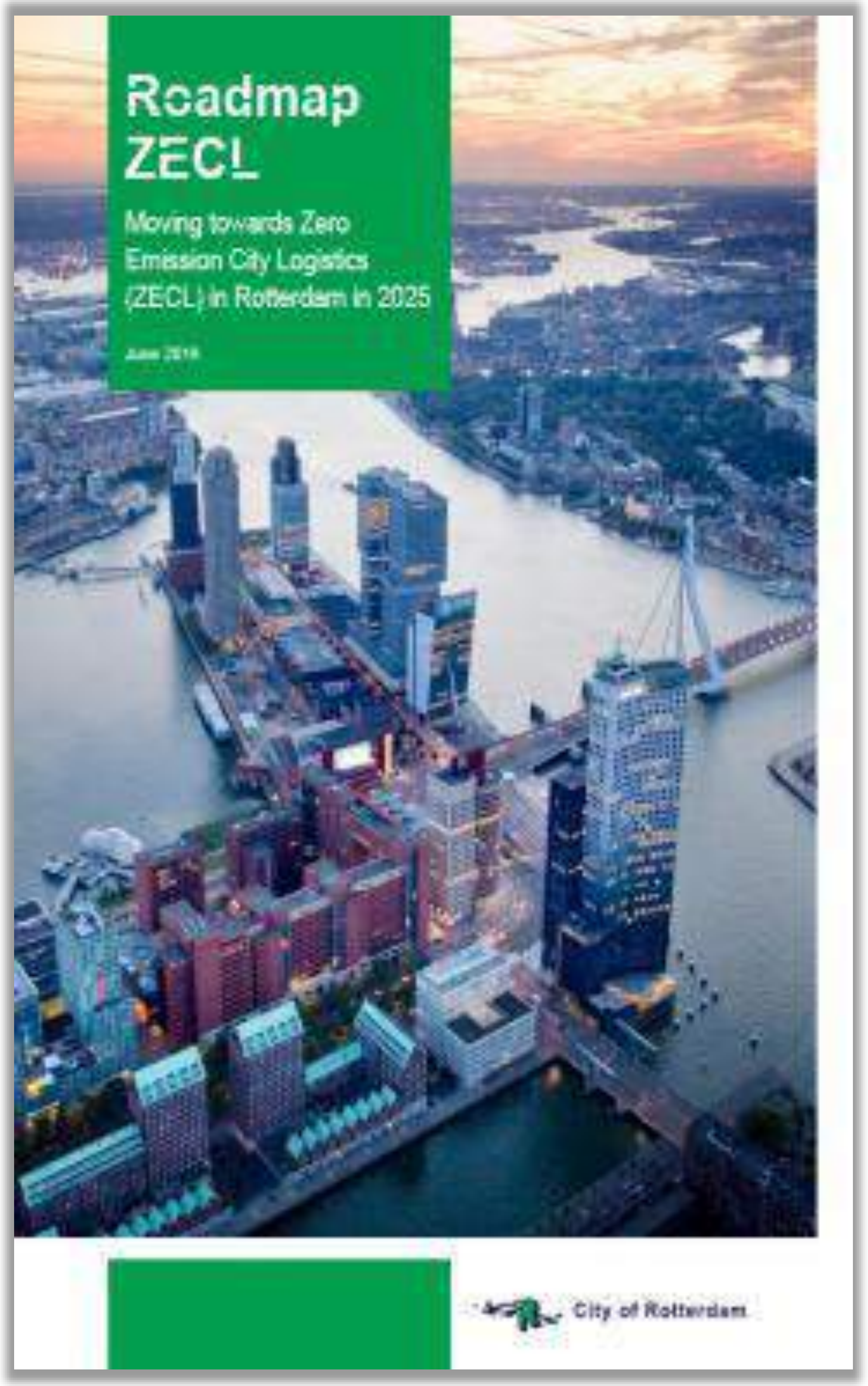
Zero-emission zone for Rotterdam

Questions for designing the zero-emission zone:

- Geography of the zone
- Location of UCC
- Impacts: on freight and vehicle flows & emissions
- Business models to operate UCC (subsidise, fleet size)

Case study: Roadmap zero-emission CL

- Rotterdam and TNO prepared a roadmap in which likely transitions for each segment in city logistics are forlumated.
- The transition scenarios consists of a change in **vehicle use** and consolidation via **urban consolidation centres** (UCC)



Zero emission zone for Rotterdam

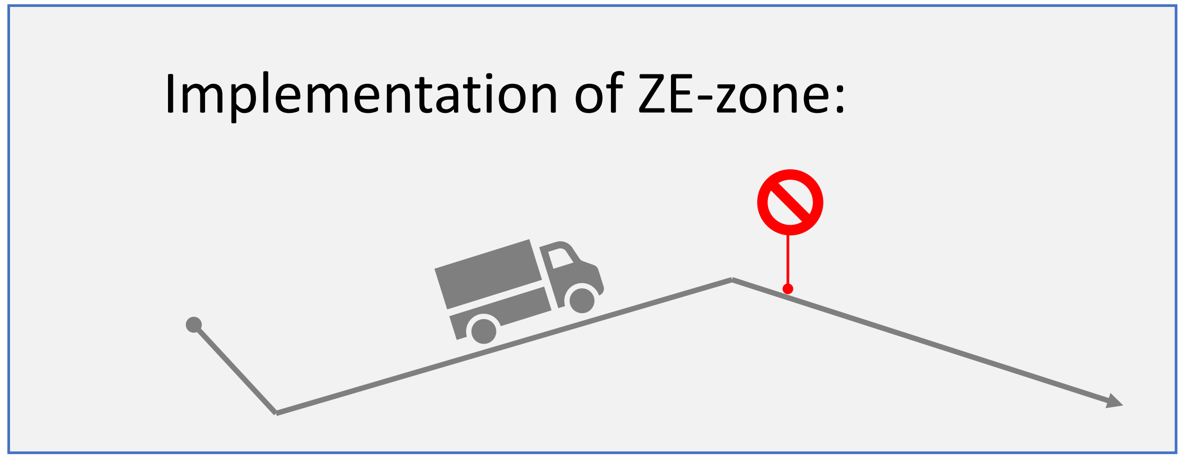
The Tactical Freight Simulator was used to analyse the ZE transition scenario.

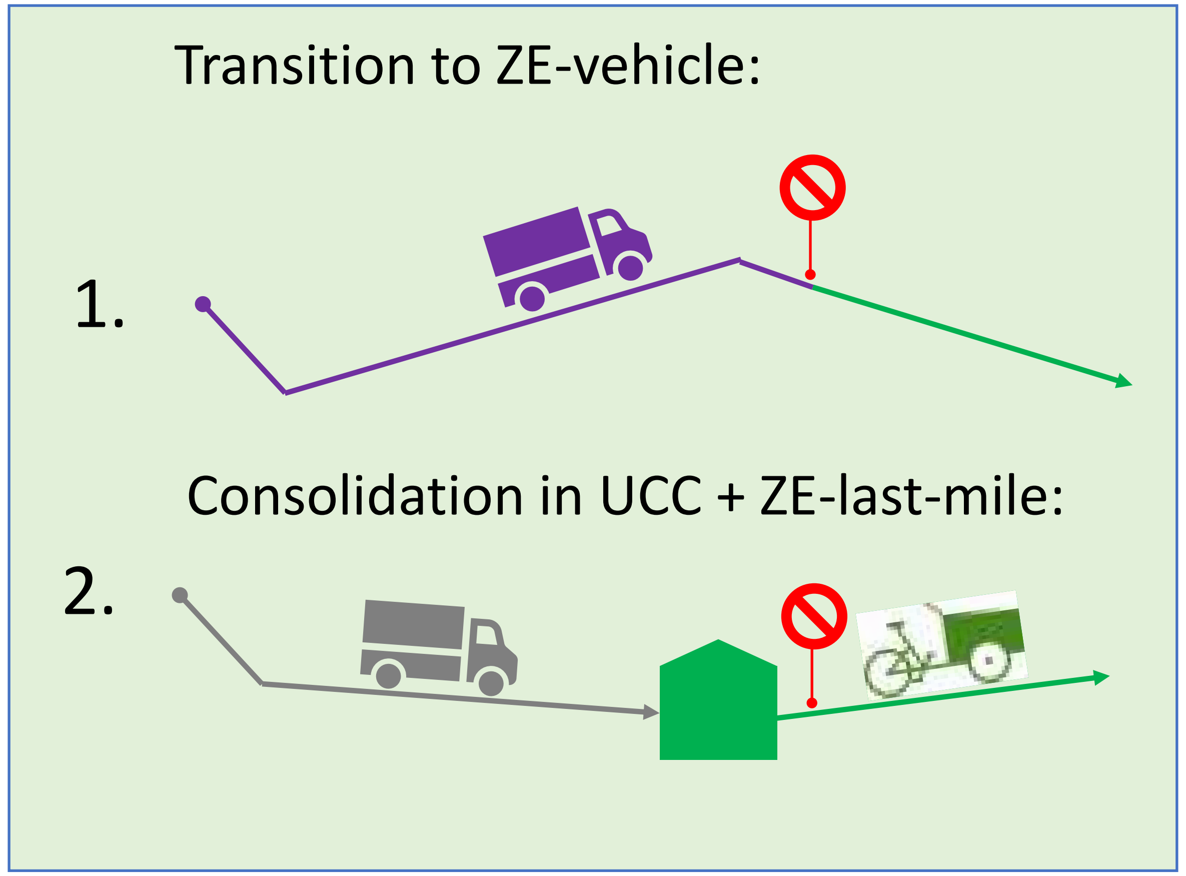
Geographic assumptions:

- Zero emission zone inside the orbital road around Rotterdam
- Depending on the logistic segment, all shipments to and from this area are redistributed via 7 Urban Consolidation Centers (see map)
- Delivery and collection within this area takes place with ZE vehicles

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

Zero-emission transition scenario

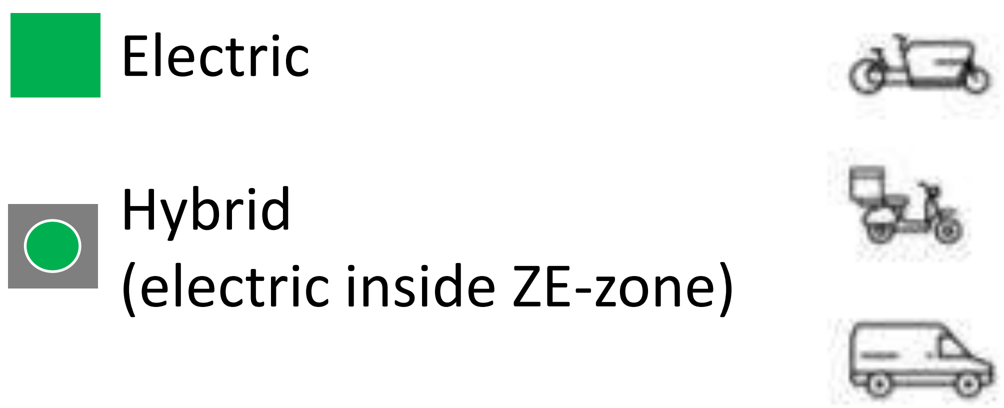




The transition scenario assumes two possible responses from the introduction of the ZE-zone on urban distribution:

1. Shift from conventional to ZE-driveline (electric, Hybrid)
2. Consolidation in a dedicated hub, and last-mile using ZE-vehicles.

For the last-mile distribution to/from the UCC different ZE-vehicles are used:



For each logistic segment quantitative scenarios were formulated for the expected use of UCC and ZE-vehicle types.

Quantitative transition scenarios

UCC propensities by logistic segment:

Logistiek segment	Bundel Potentie:
Temperature controlled	15%
General freight (food)	20%
General freight (other)	20%
Waste	0%
Express and parcels	50%
Facilities/service	20%
Construction	30%
Dangerous goods	0%

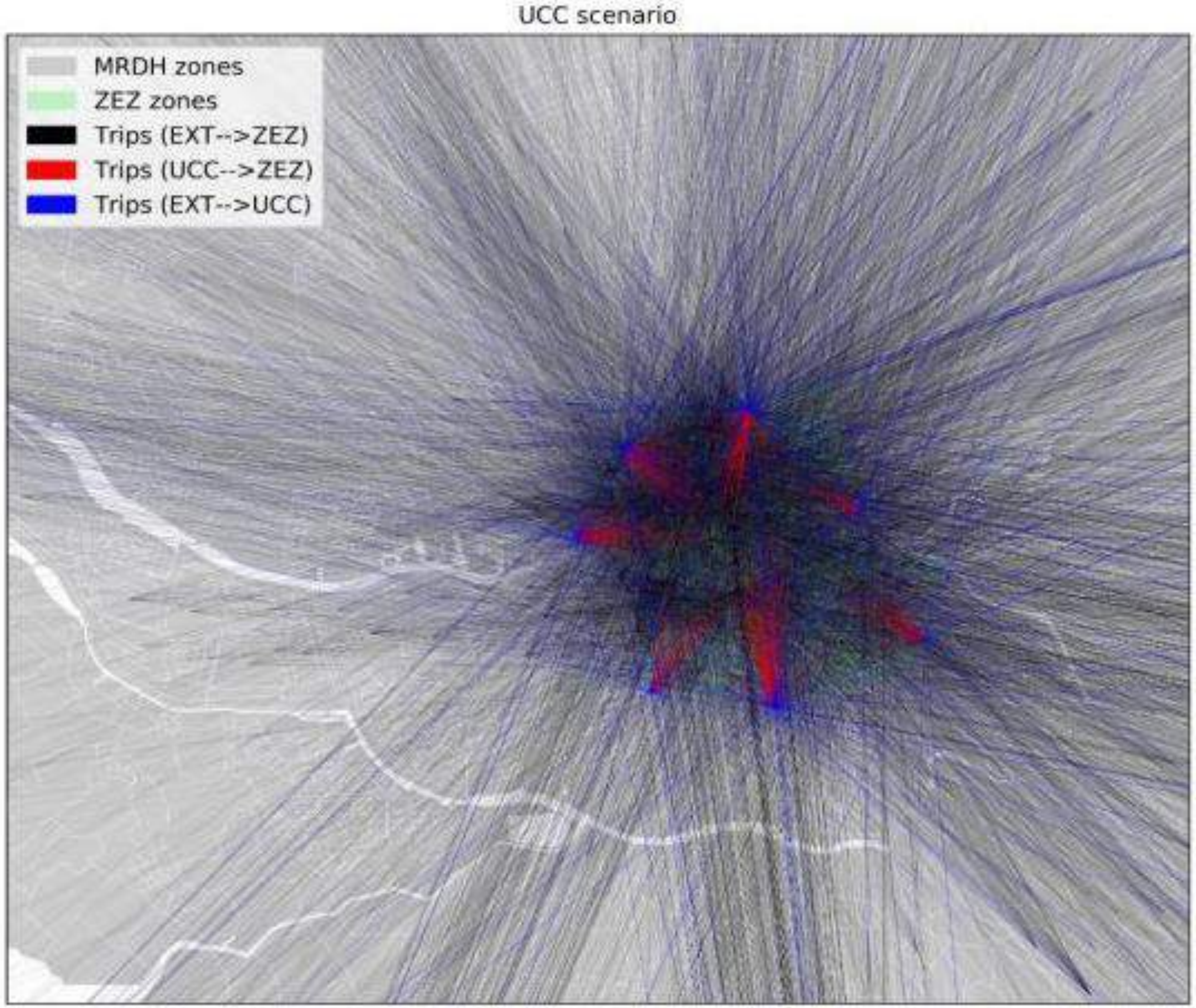
Assumptions are based on an interpretation of the Roadmap Zero-Emission City Logistics (Rotterdam, juni 2019)

Zero-emission vehicle type shares per logistics segment:

Vehicle type + combustion	Logistiek segment: General freight (food)	General freight (other)	Tempe-rature control-led	Facilities/ service	Construc tion	Waste	Express and parcels
LEVV-Electric	6%	6%	27%	20%	0%	22%	50%
Moped-Electric	0%	0%	14%	0%	0%	0%	0%
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%
TractorTrailer-Electric	4%	4%	1%	0%	6%	0%	0%
TractorTrailer-Hydrogen	4%	4%	1%	0%	6%	0%	0%
TractorTrailer-Hybrid	11%	11%	3%	0%	17%	0%	0%
WasteCollection-Electric	0%	0%	0%	0%	0%	11%	0%
WasteCollection-Hydrogen	0%	0%	0%	0%	0%	11%	0%
WasteCollection-Hybrid	0%	0%	0%	0%	0%	33%	0%
SpecialConstruction-Hydrogen	0%	0%	0%	0%	2%	0%	0%
SpecialConstruction-Biofuel	0%	0%	0%	0%	8%	0%	0%

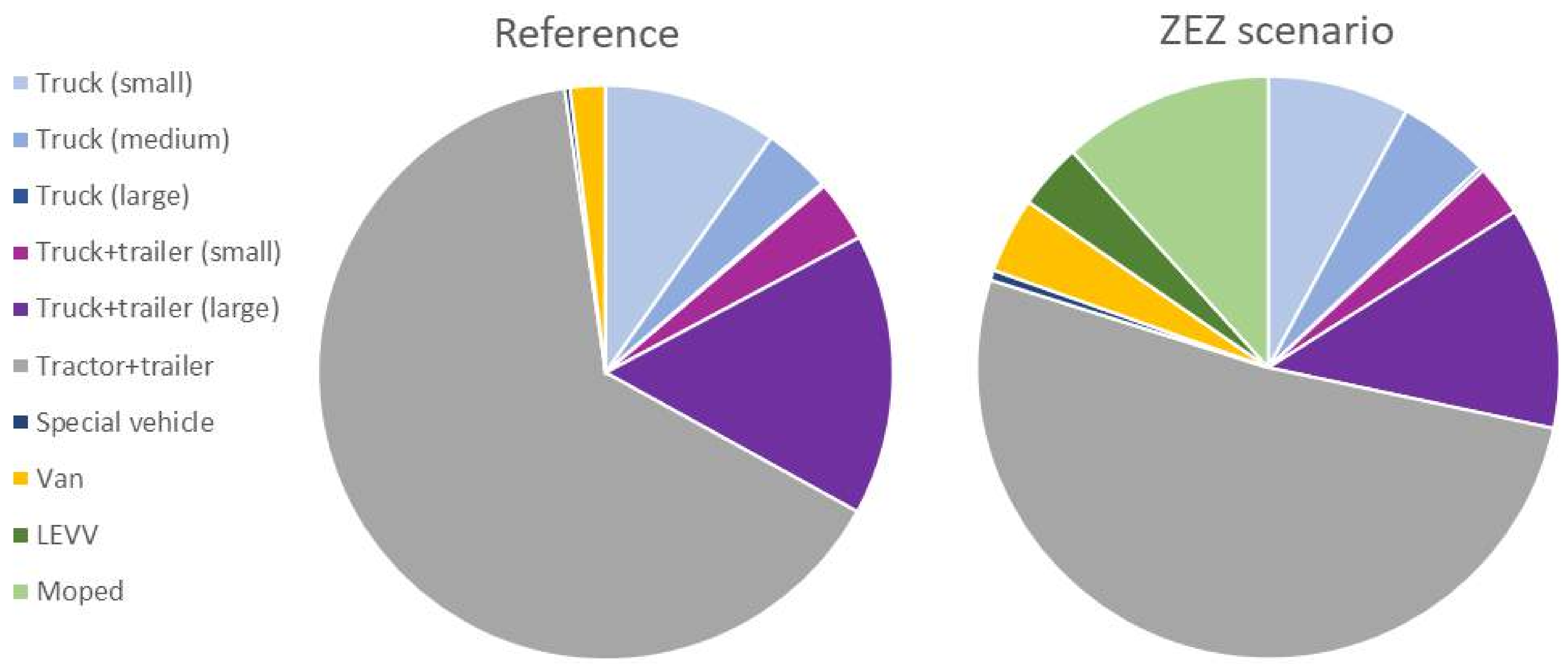
Impact on shipment patterns

- Part of the shipments to/from the ZE-zone are consolidated in 7 urban consolidation hubs
- The collection and distribution patterns of these shipments are redirected through these UCCs (see map).
- This leads to a small increase in vehicle kms in the study area (+0.25%)



Impact on vehicle use inside the ZEZ

The transition scenario leads to a shift in the composition of vehicle movements inside the ZE-zone. See the vehicle kilometers before (reference) and after the transition (ZEZ).



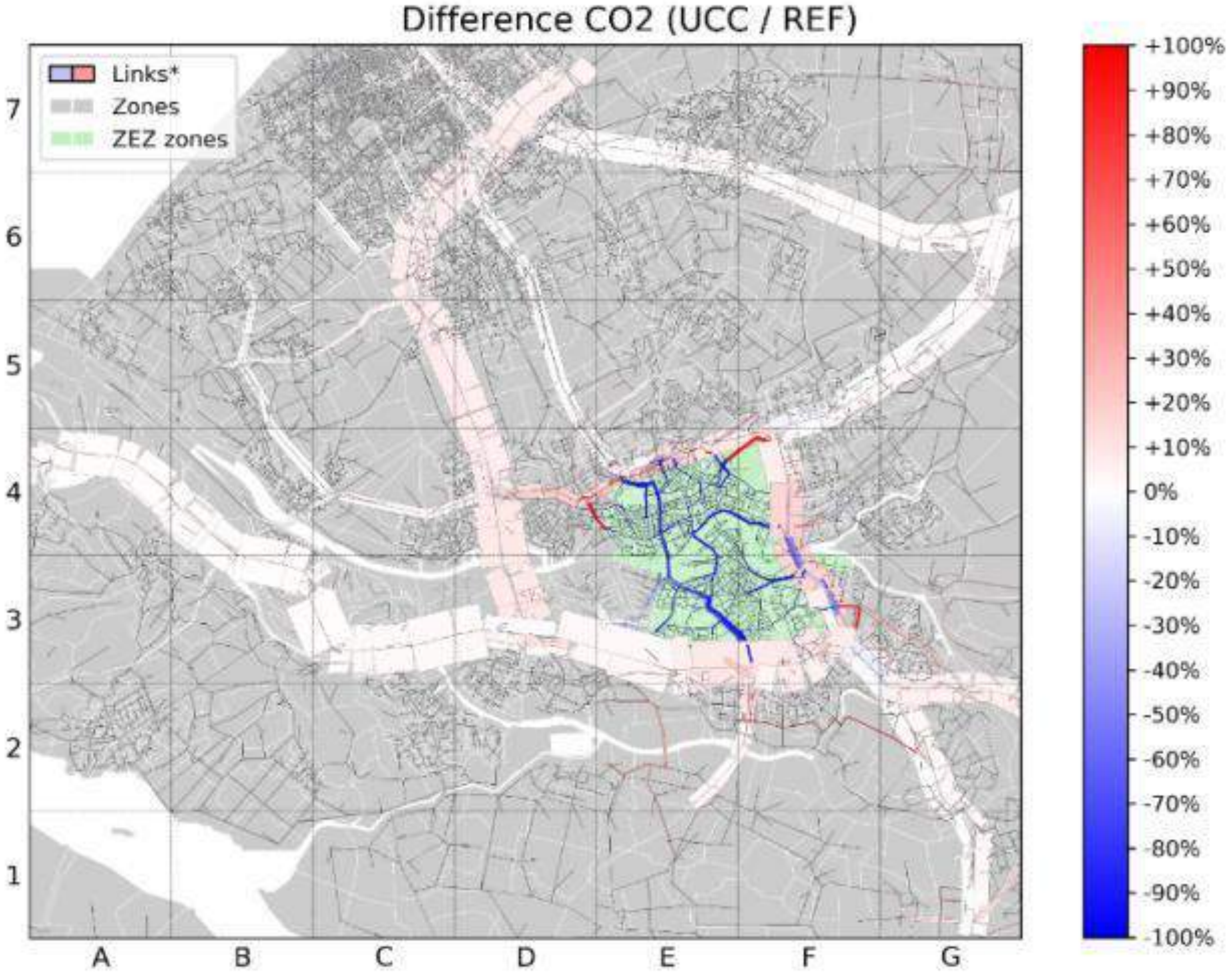
- Decrease in use of Tractor+trailer combinations (or with hybrid driveline)
- The share of new ZE-vehicles (LEVV and e-moped) is expected to be 10% in total vkms
- A large share of the reduction of emission will be the result of a shift to cleaner combustion types (electric, hybrid, hydrogen, biofuel)

Results on emissions: at network level

- ➢ The transitions in Distribution channel choice (use of UCC), and Vehicle type use within the ZEZ are simulated.
- ➢ Reduction in total emissions with municipality of Rotterdam: ca. 3%

Emissies (kg)	Referentie	ZE-zone	Verschil (%)
CO2	2,116,000	2,051,176	-3.06%
SO2	13	12	-3.05%
PM	114	111	-3.13%
NOX	13,485	13,029	-3.39%

- ➢ But: rerouting leads to an increase of emissions in the surrounding area (red links):



Conclusions and outlook

- Emerging sources of '**big data**' allow the development of a new generation of empirical multi-agent simulation models for urban freight planning.
- **Multi-agent simulation** models allow a better representation of stakeholders (e.g. logistic segments), and implementation of scenarios for city logistics.
- Presented **scenario-based analysis** of zero-emission zoning shows how the model is used for system wide impact assesment.
- Many assumptions are needed to formulate the scenarios. We believe more detail in the implementation of scenarios improves the **validity** of the analysis

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