MASS-GT

An empirical agent-based model for urban road freight transport

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Decarbonising Road Freight EXPERT WORKSHOP
28-29 June 2018
OECD – Boulogne

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Urban freight modeling

Urban freight transport has many externalities:

- Environmental impacts (CO2, Nox, PM10)
- Social impacts (Noise, Safety)
- Economic impacts (Travel time losses)

Many relevant developments for freight transport demand:

- Last-mile distribution
- Environmental zoning
- Road user charges for heavy vehicles
- Growth of e-commerce

! However, there are hardly any analytical tools available for the impact assessment of policies on freight transport demand !

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Evolution of strategic freight models

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

Basgoed
TransTools
and many
more…

ADA
SVRM4
Trimode
SMILE+
…

FAME (US)
FREMIS (US)
INTERLOG (D)
TAPAS (S)
…

Aggregate → Disaggregate → Microsimulation

- 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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Logistic Choices and Agents

Commodity Market

Producers

Sourcing

Receivers /consumers

Choices in a supply chain are interrelated

Logistic services market

3PL's

Own account

Network design

Location selection DC's

Warehousing and storage

Packaging/ shipment size

Transport market

Carrier selection

Mode selection

Vehicle type choice

Routing and scheduling

3PL's

Own account

Issues: DATA and moddeling COMPLEXITY

Infrastructure (Market): Network and performance

Policy makers

Pricing measures

Infrastructure investment

Subsidies

Environmental zones

Zoning schemes

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Objective of MASS-GT

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

Two main challenges:

1. Data: to analyse logistic decision making, and develop the simulation framework. For this purpose we use high density freight transport data
2. Manage complexity during model devlopment. For this puropose we follow an incremental development process

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DATA

XML data CBS

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]

- Automated collection from TMS
- +2M individual trips in raw data
- Load/unload locations: Lat/long
- Privacy regulations

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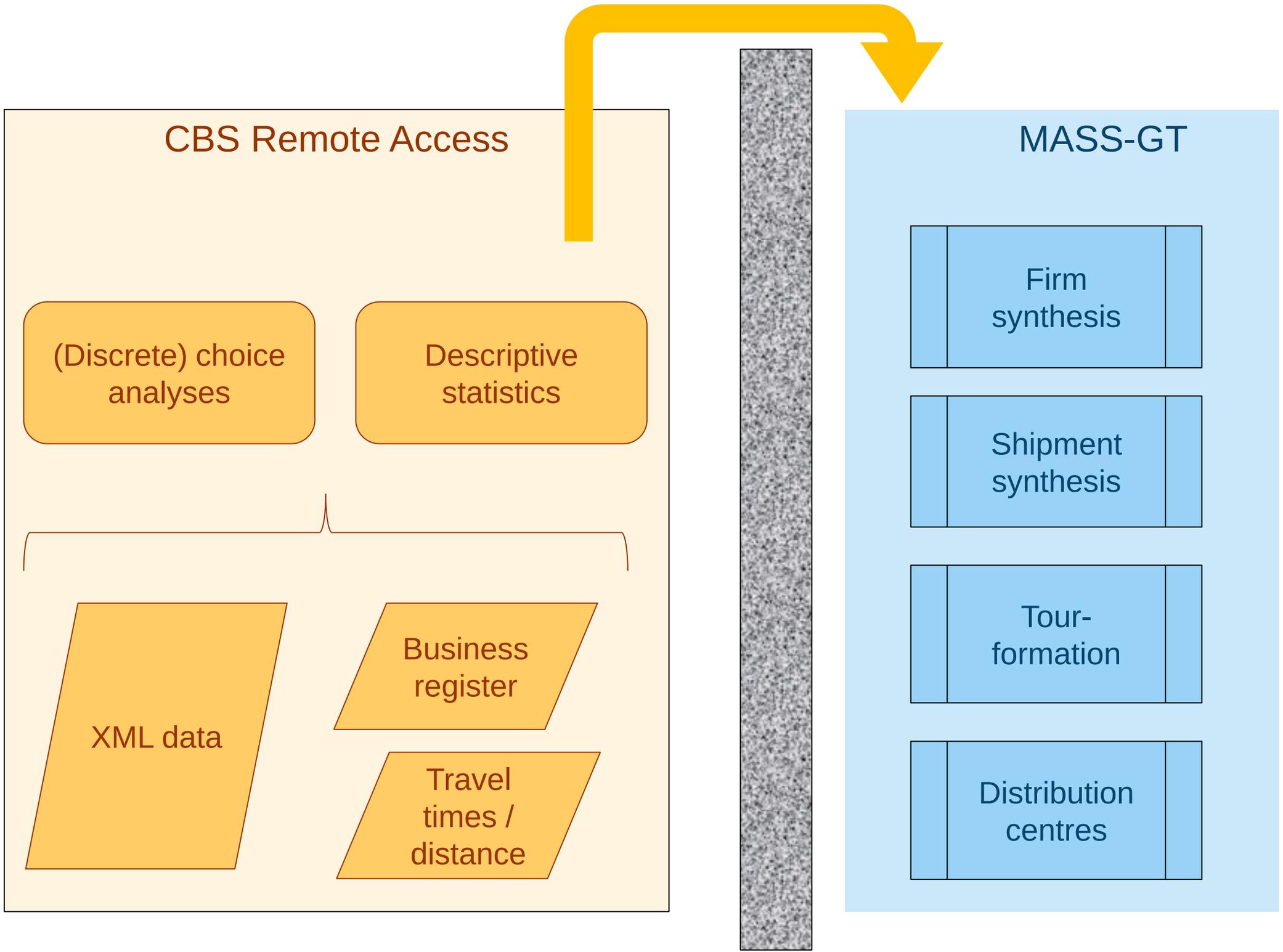
Data: illustration

Strict separation between data analysis and model application:



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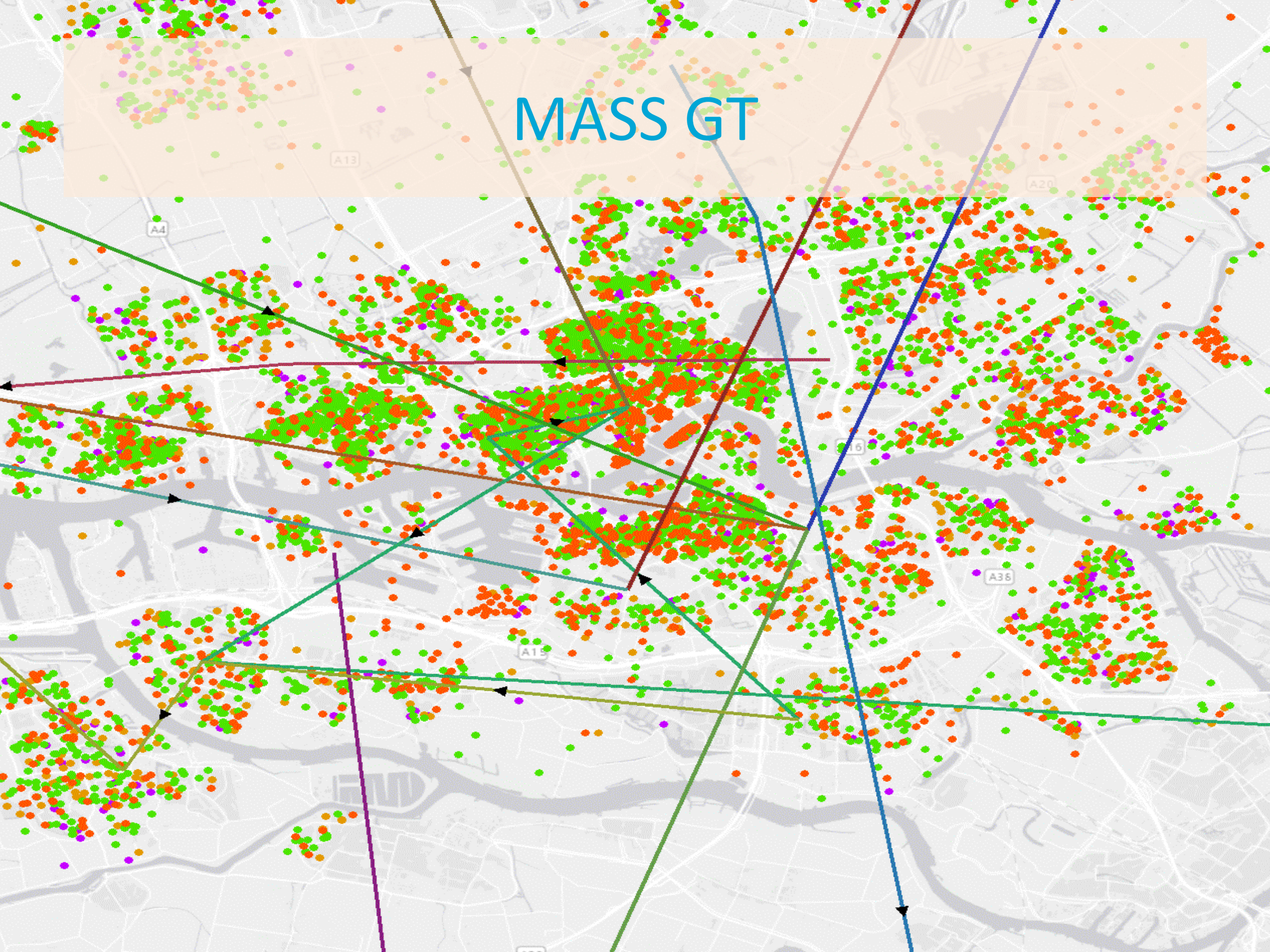
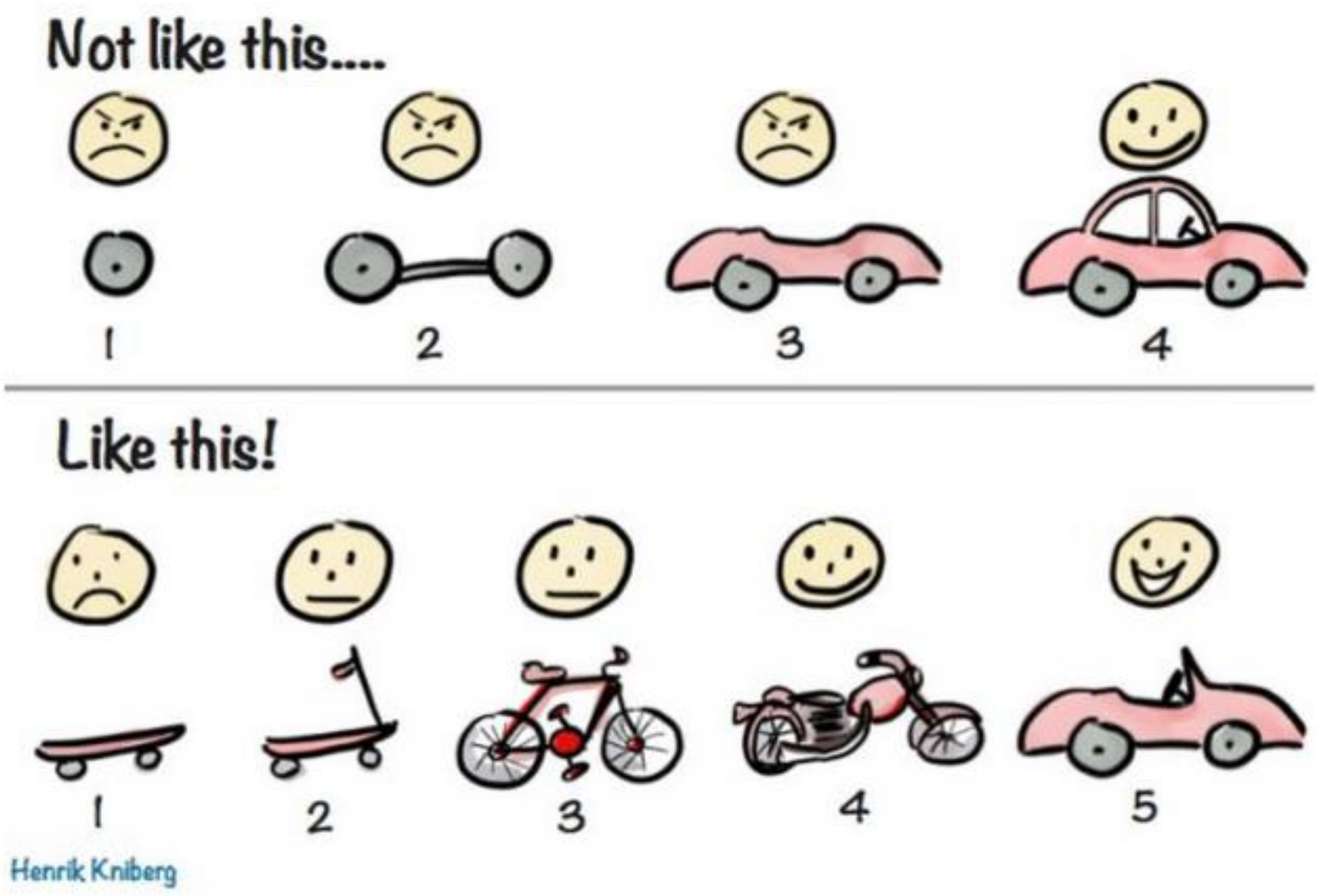
MASS GT



Incremental development process (minimum viable product principle)



- This contribution presents our first *Skateboard*

MASS-GT: structure of first prototype

Objective:

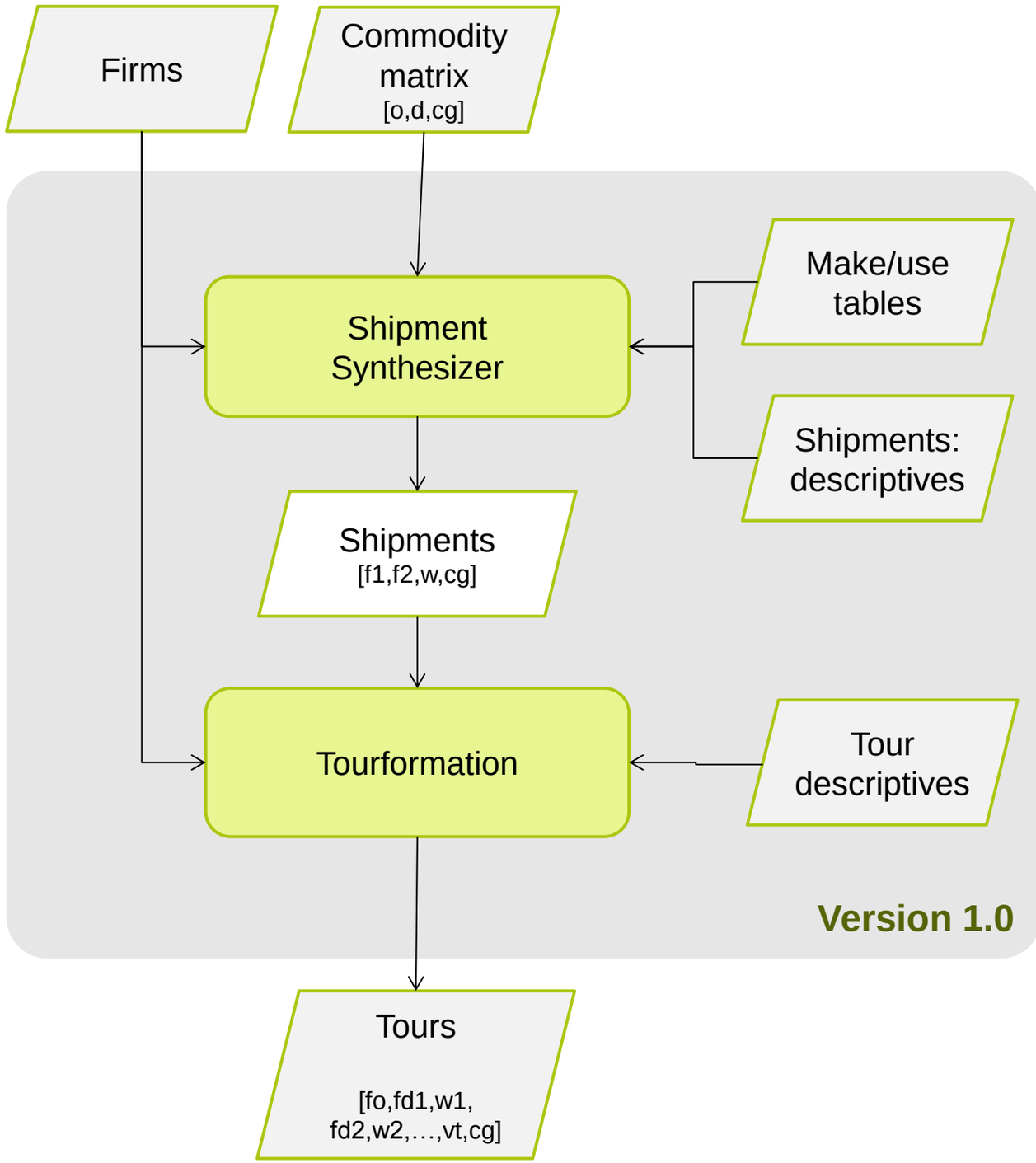
- Simulate urban freight transport patterns.

Main spec's:

- **Data-driven** approach
- **Monte Carlo simulation** (MCS) is used to determine shipment or tour characteristics

Prototype consists of two modules::

- **Shipment** synthesizer
- **Tour formation** model.



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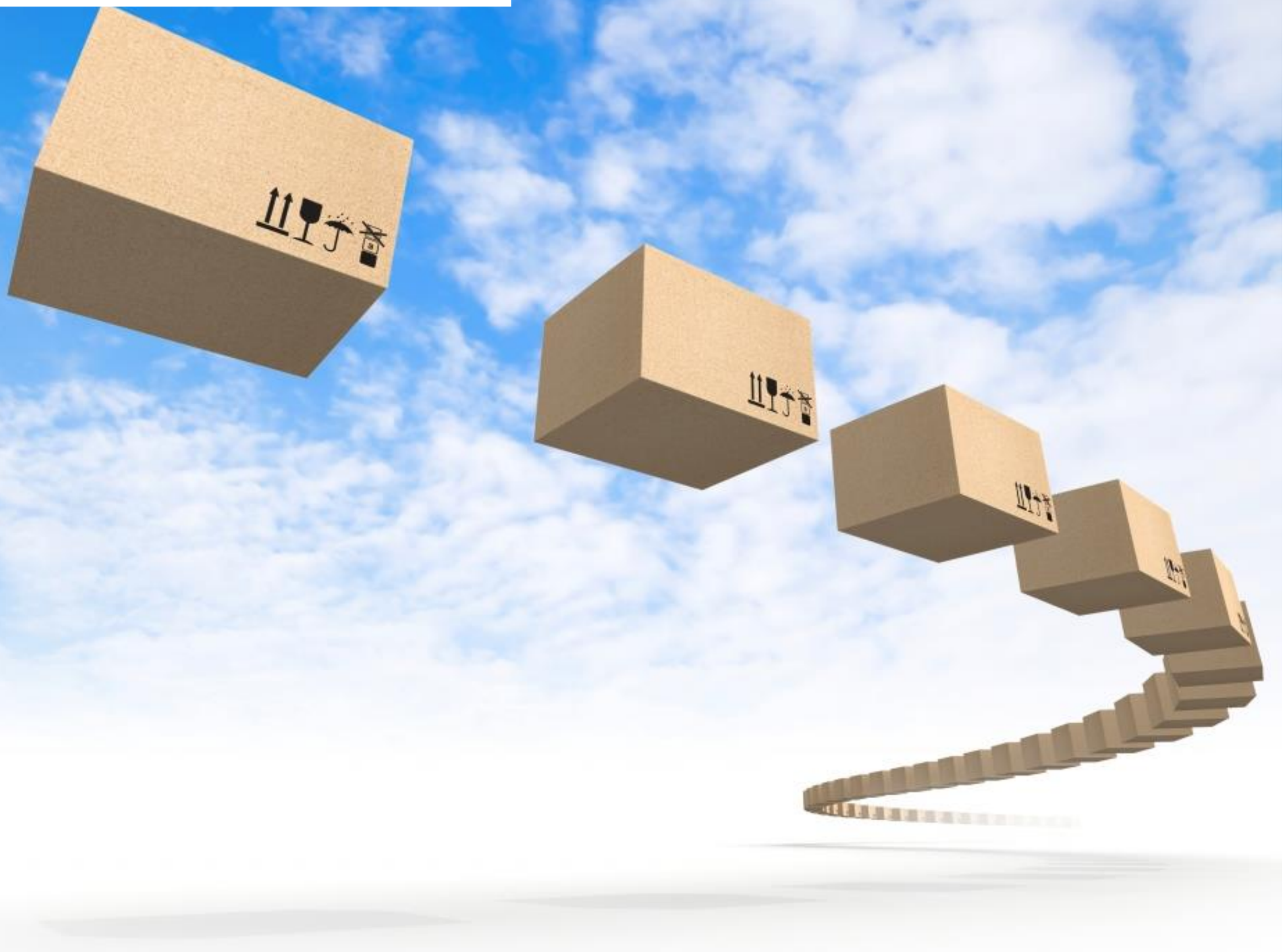
Shipment Synthesizer

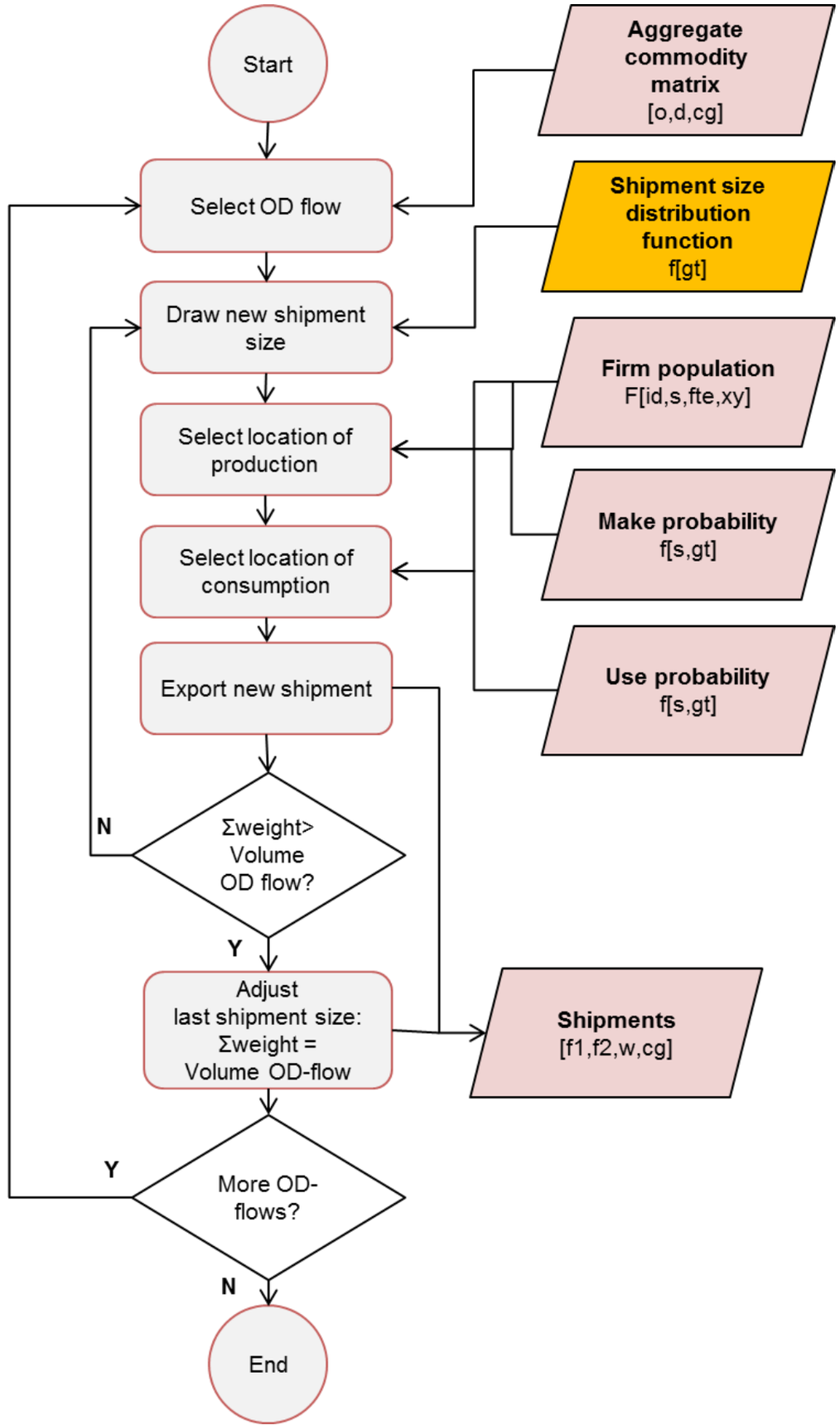


Shipment synthesizer

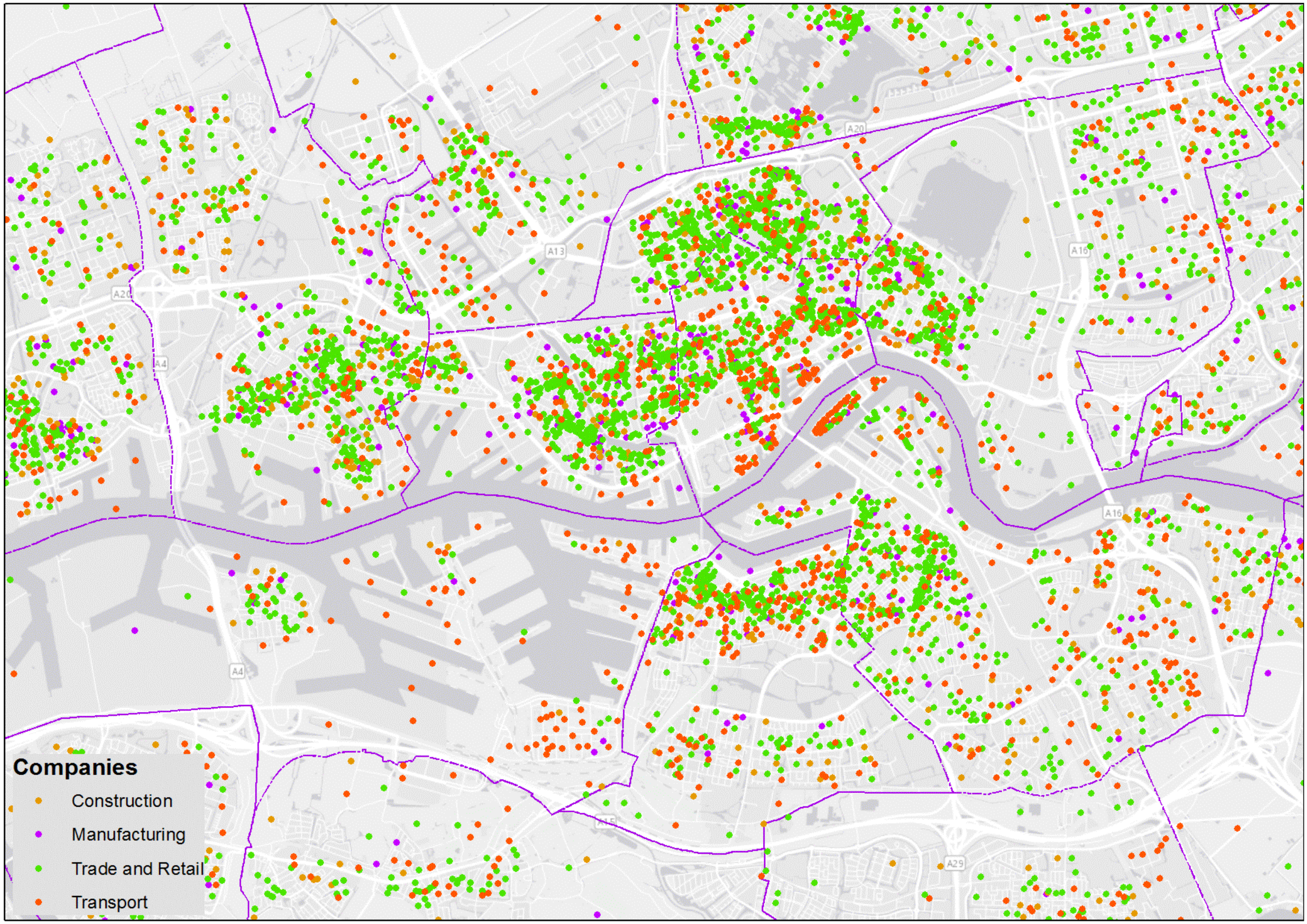
- Determine shipment size:

Probability density function for shipment size by commodity type:

		Shipment size	
	NST/R	Average	StdDev
0	Agricultural products and live animals	15.3	9.5
1	Foodstuffs and animal fodder	13.7	9.9
2	Solid mineral fuels	25.6	4.2
3	Petroleum products	25.4	11.5
4	Ores and metal waste	16.8	7.9
5	Metal products	14.8	10.1
6	Crude and manufactured minerals, building materials	22.2	9.9
7	Fertilizers	16.7	11.4
8	Chemicals	15.8	10.3
9	Machinery, transport equipment, manufactured articles a	7.7	8.0



Allocation of shipments to firms



Shipment synthesizer

Allocation of shipments to firms:

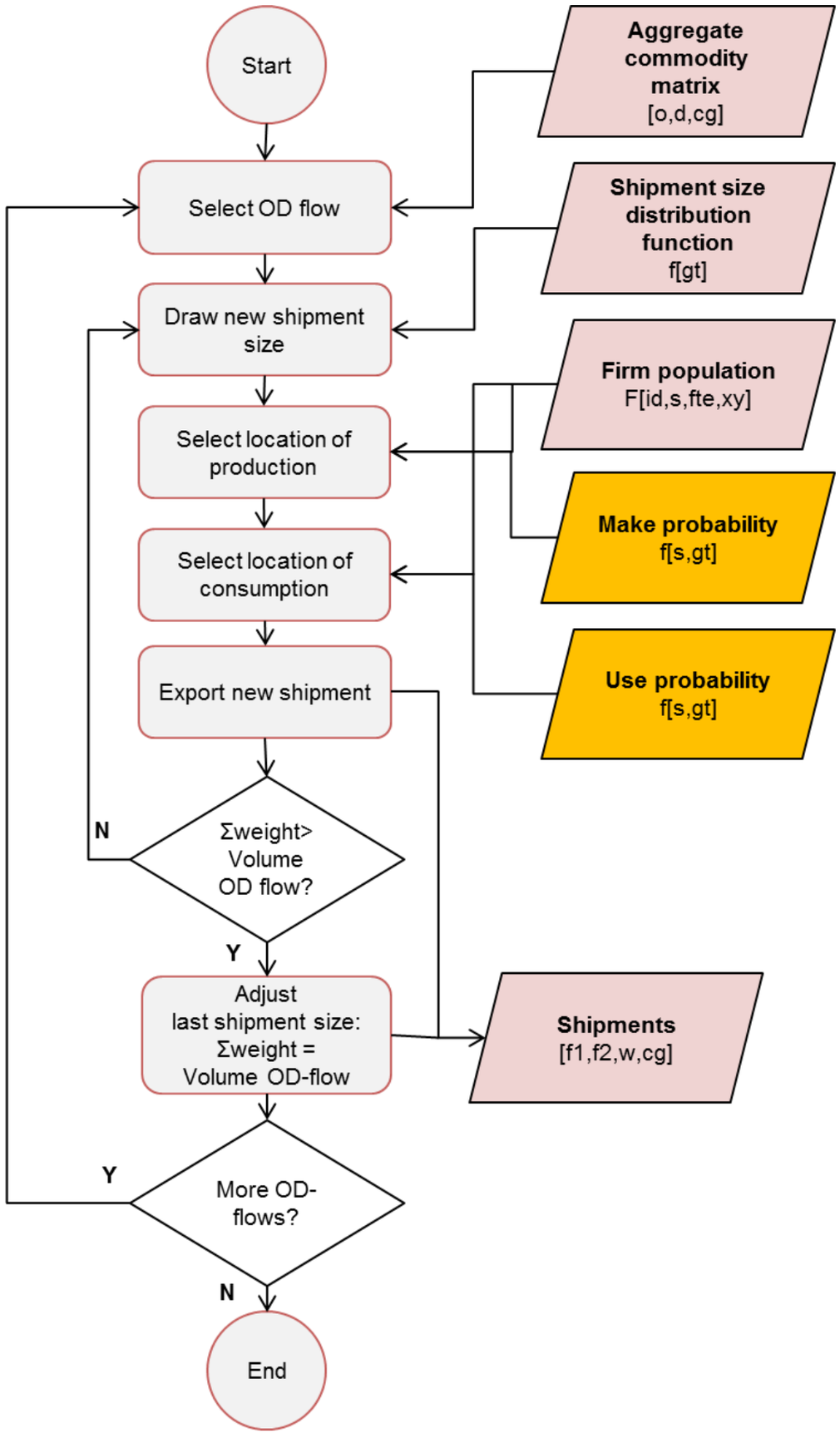
- By commodity and make/use tables [Source: EM-Basgoed]

Producers: ‘make’ probability by sector:

		NST/R									
	Make sector	0	1	2	3	4	5	6	7	8	9
1	Agriculture	0.91	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Manufacturing	0.06	0.00	1.00	1.00	0.18	0.95	1.00	1.00	0.94	1.00
3	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Trade and Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Restaurants and Food services	0.02	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
6	Transport, Warehousing and Con	0.00	0.00	0.00	0.00	0.82	0.05	0.00	0.00	0.01	0.00
7	Finance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Business services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Health Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	General Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Consumers: ‘use’ probability by sector

		NST/R									
	Use sector:	0	1	2	3	4	5	6	7	8	9
1	Agriculture	0.13	0.11	0.01	0.04	0.00	0.00	0.01	0.62	0.04	0.01
2	Manufacturing	0.15	0.02	0.97	0.73	1.00	0.85	0.23	0.34	0.79	0.53
3	Construction	0.03	0.00	0.02	0.03	0.00	0.12	0.67	0.00	0.05	0.12
4	Trade and Retail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Restaurants and Food services	0.64	0.70	0.00	0.02	0.00	0.01	0.01	0.00	0.03	0.05
6	Transport, Warehousing and Con	0.01	0.01	0.00	0.11	0.00	0.01	0.02	0.02	0.01	0.15
7	Finance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
8	Business services	0.03	0.14	0.00	0.04	0.00	0.00	0.04	0.01	0.03	0.07
9	Government	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.01	0.01	0.04
10	Education	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	Health Services	0.01	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.02
12	General Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



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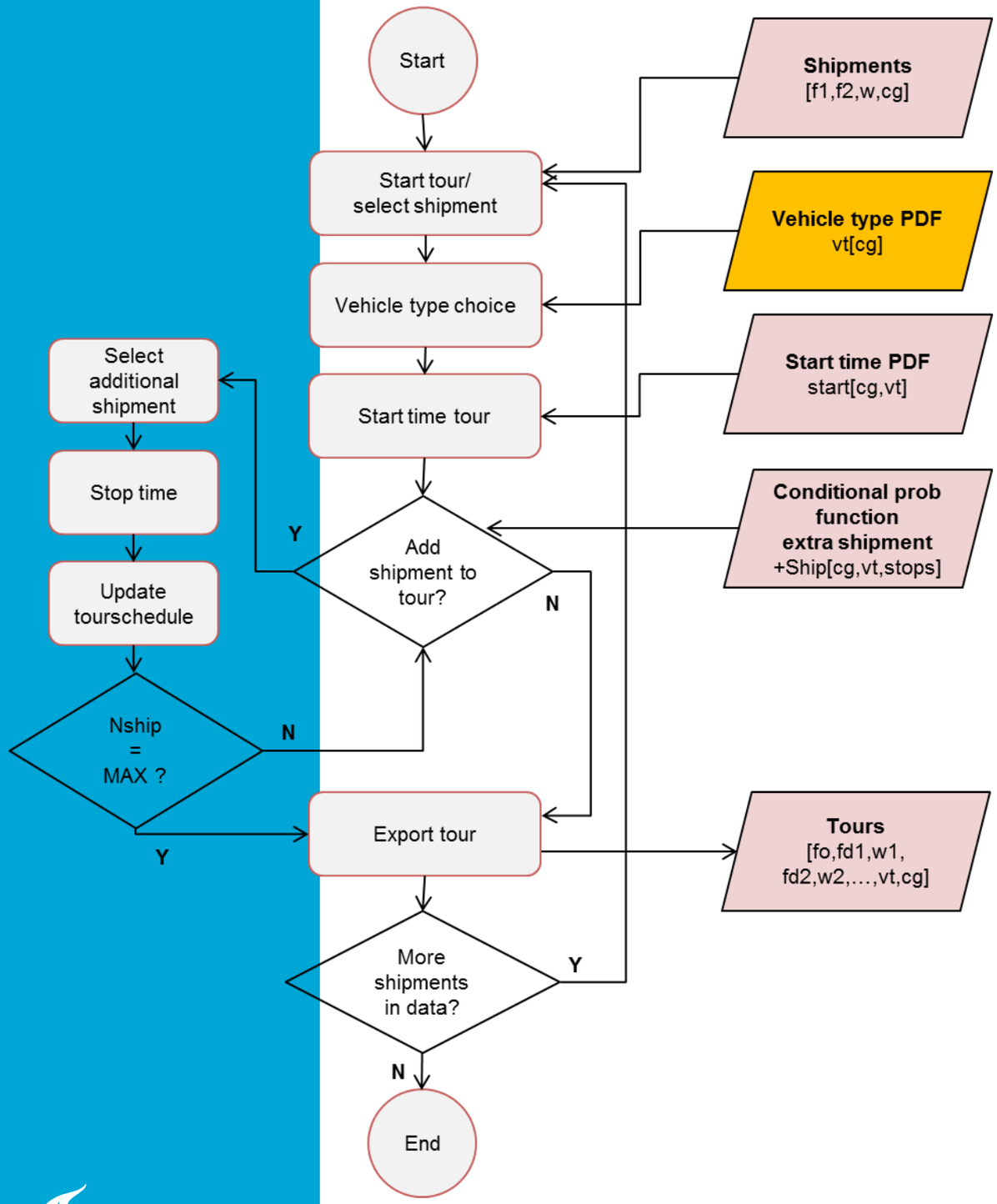
Tour formation model

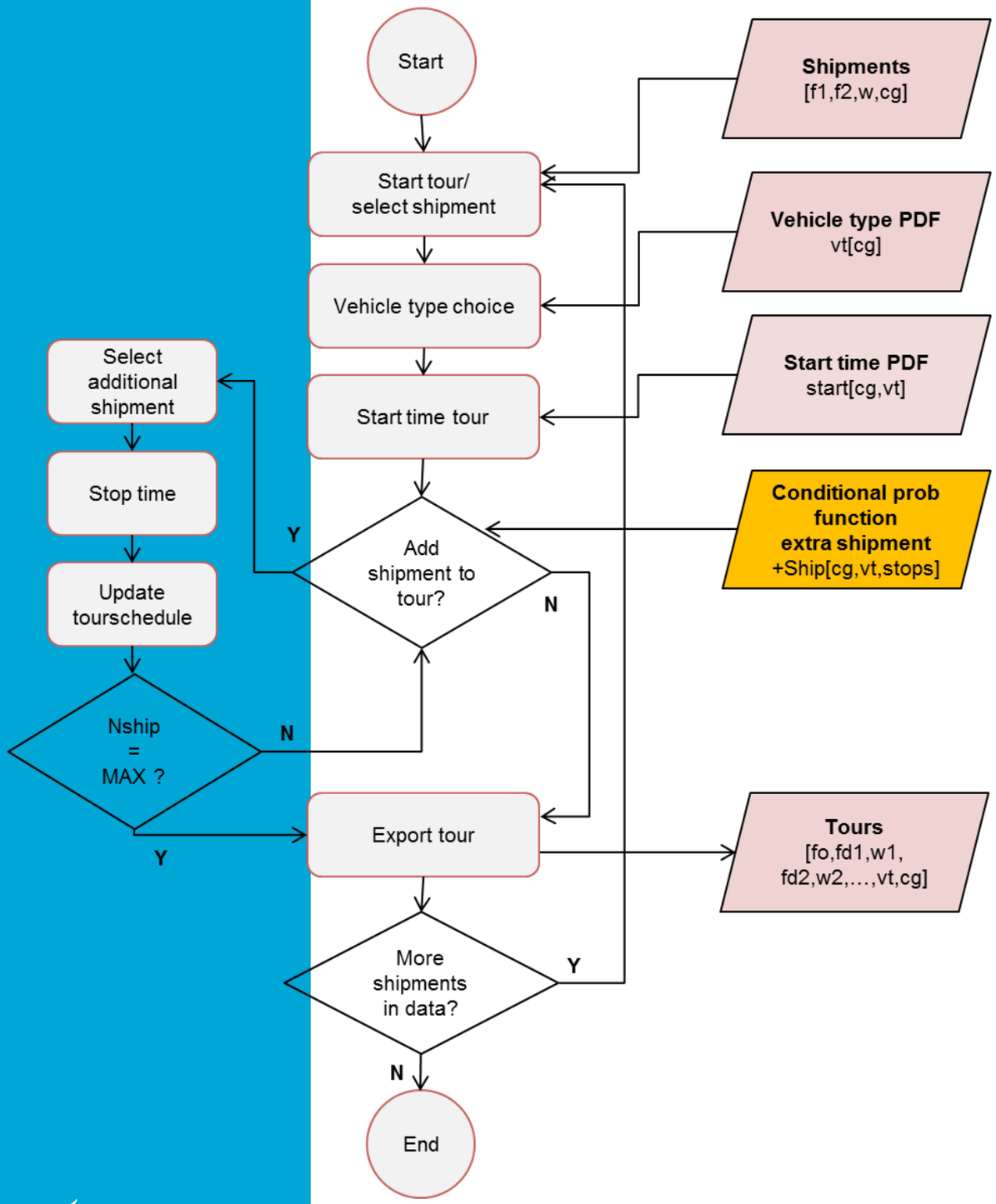
Tour formation: input statistics



- Determination of vehicle type: Probability density function

	NST/R	2: Lorry	3: Trailer truck	4: Special Vehicles
0	Agricultural products and live animals	0.200	0.800	0.000
1	Foodstuffs and animal fodder	0.096	0.902	0.002
2	Solid mineral fuels	0.100	0.896	0.003
3	Petroleum products	0.394	0.603	0.003
4	Ores and metal waste	0.609	0.383	0.007
5	Metal products	0.190	0.809	0.000
6	building materials, minerals	0.459	0.538	0.003
7	Fertilizers	0.195	0.770	0.035
8	Chemicals	0.362	0.574	0.064
9	Machinery, transport equipment, manufactured	0.185	0.781	0.034

Tour formation: input statistics



- 'Stop' probability:

Conditional probability function additional shipment: P(n+1|n)

	Conditional probability function additional tour: P(n+1|n)				
	2	3	4	5	Round
NST/R 0: Agricultural products a	0.000	0.000	0.000	0.000	0.000
2: Lorry	0.435	0.821	0.854	0.854	0.030
3: Trailer truck	0.448	0.810	0.820	0.826	0.009
4: Special Vehicles	0.000	0.000	0.000	0.000	0.000
NST/R 1: Foodstuffs	0.000	0.000	0.000	0.000	0.000
2: Lorry	0.832	0.941	0.923	0.916	0.003
3: Trailer truck	0.640	0.800	0.800	0.817	0.017
4: Special Vehicles	0.941	0.969	0.845	0.942	0.019
NST/R 2: Solid mineral fuels	0.000	0.000	0.000	0.000	0.000
2: Lorry	0.251	1.000	1.000	0.450	0.000
3: Trailer truck	0.033	1.000	1.000	0.756	0.000
4: Special Vehicles	0.000	0.000	0.000	0.000	0.000
…..					

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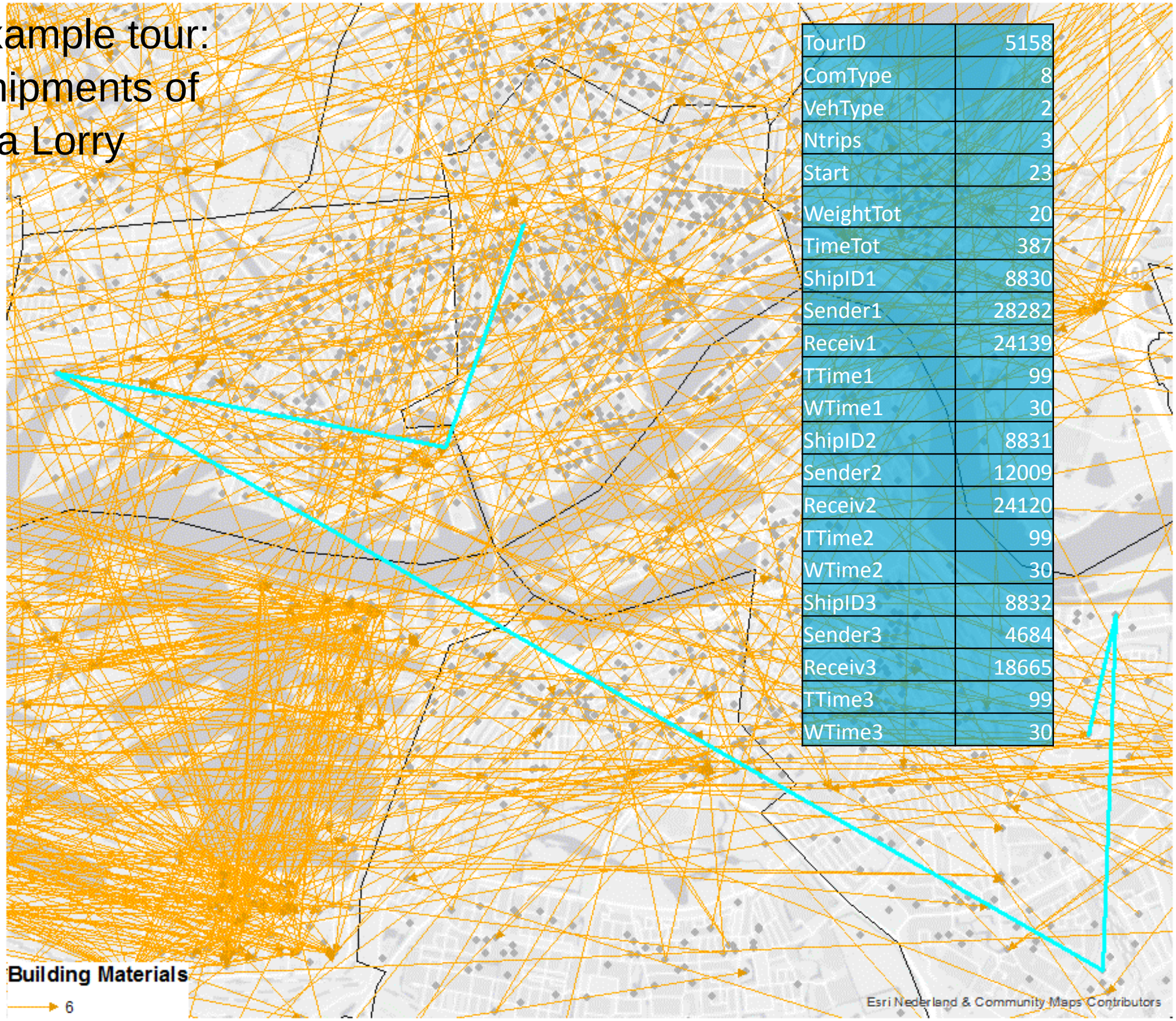
First results

Example of micro result (tour ID 5158)

Highlighted example tour: delivering 3 shipments of NST/R 8 with a Lorry (veh.type 2)



TourID	5158
ComType	8
VehType	2
Ntrips	3
Start	23
WeightTot	20
TimeTot	387
ShipID1	8830
Sender1	28282
Receiv1	24139
TTime1	99
WTime1	30
ShipID2	8831
Sender2	12009
Receiv2	24120
TTime2	99
WTime2	30
ShipID3	8832
Sender3	4684
Receiv3	18665
TTime3	99
WTime3	30

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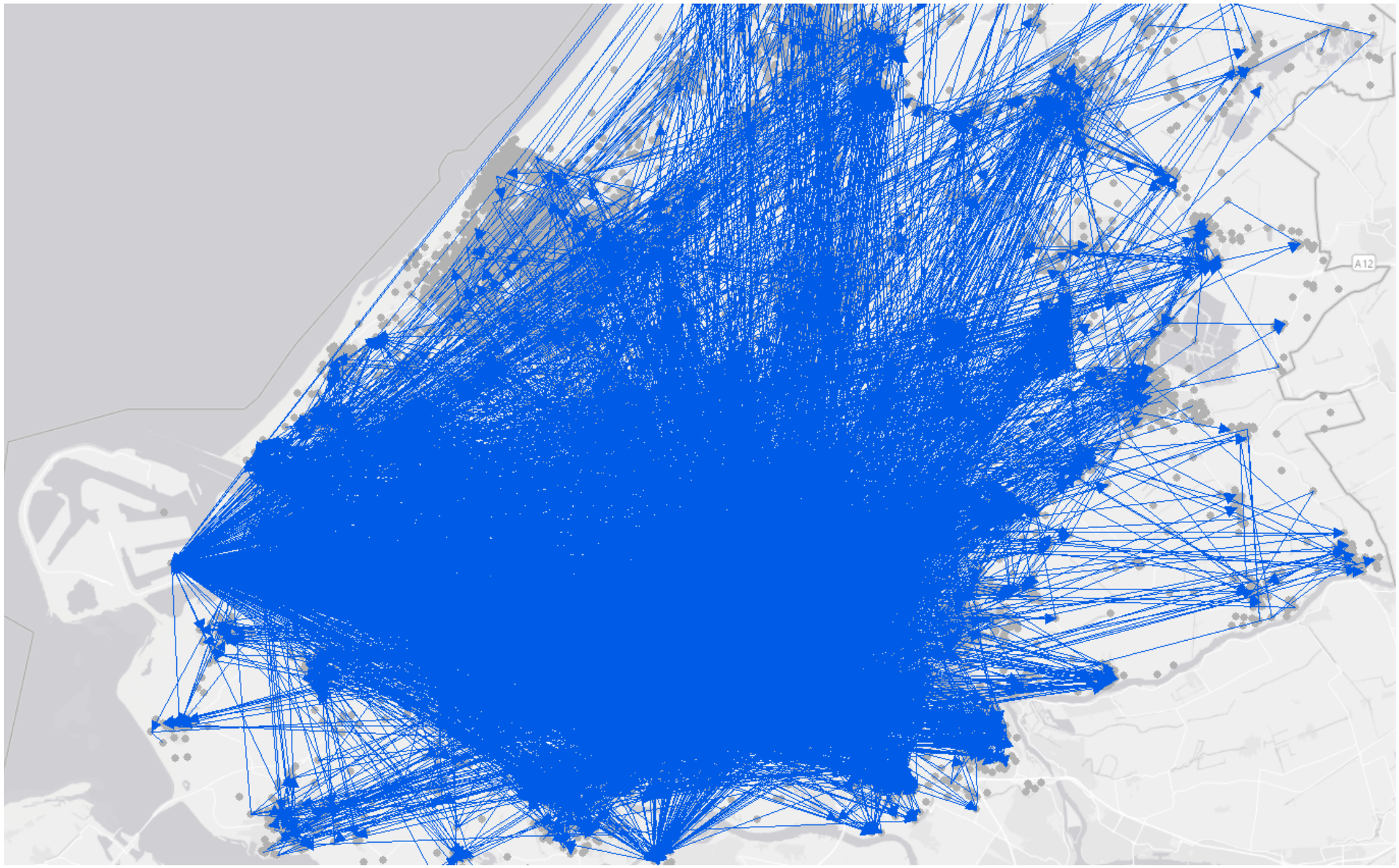
First results

- Synthetic truck patterns for all freight transport to and from Rotterdam
- Results: 8343 tours, delivering 13892 shipments



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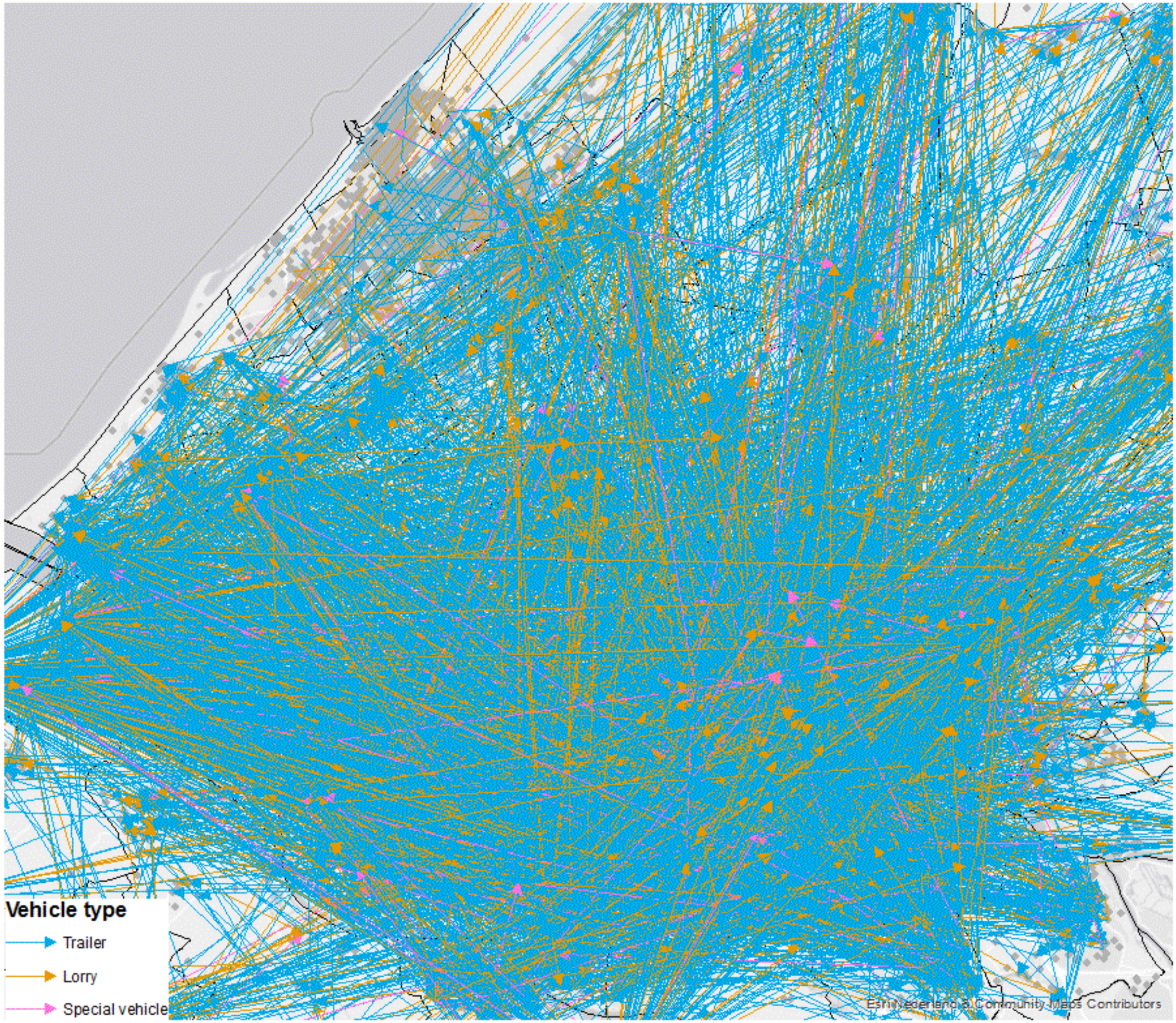
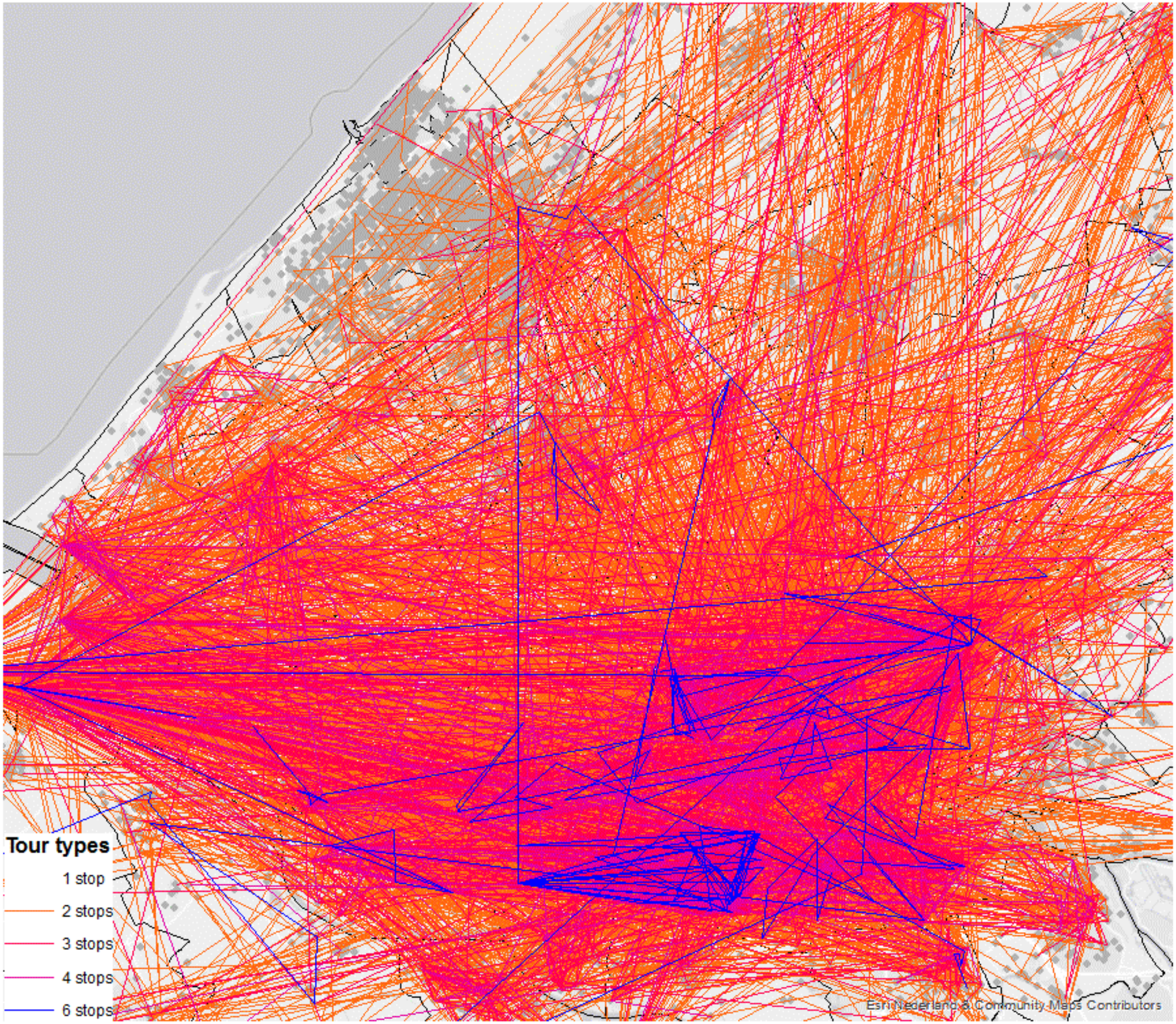
By vehicle type:



By tour types:



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Possible applications

Simple proto-type

- Synthetic truck patterns can be used as a quantitative ‘screenshot’ to explore emerging trends. For instance to quantify:
  - vehicle type specific indicators (safety, emissions)
  - which truck tours will be affected by environmental zoning
  - the potential for last-mile solutions, e.g. pick- up points
  - possible impact of logistic hub’s for urban construction works

Long term

- Agent based model can be used to analyse *behavioural response* to new technologies and logistic trends. For instance to simulate impact of :
  - strategies for road user charges: vehicle types
  - environmental zoning: vehicle type
  - changes in logistic infrastructure: distribution patterns
  - new technologies (IoT): possibilities for horizontal collaboration
  - new vehicle technologies

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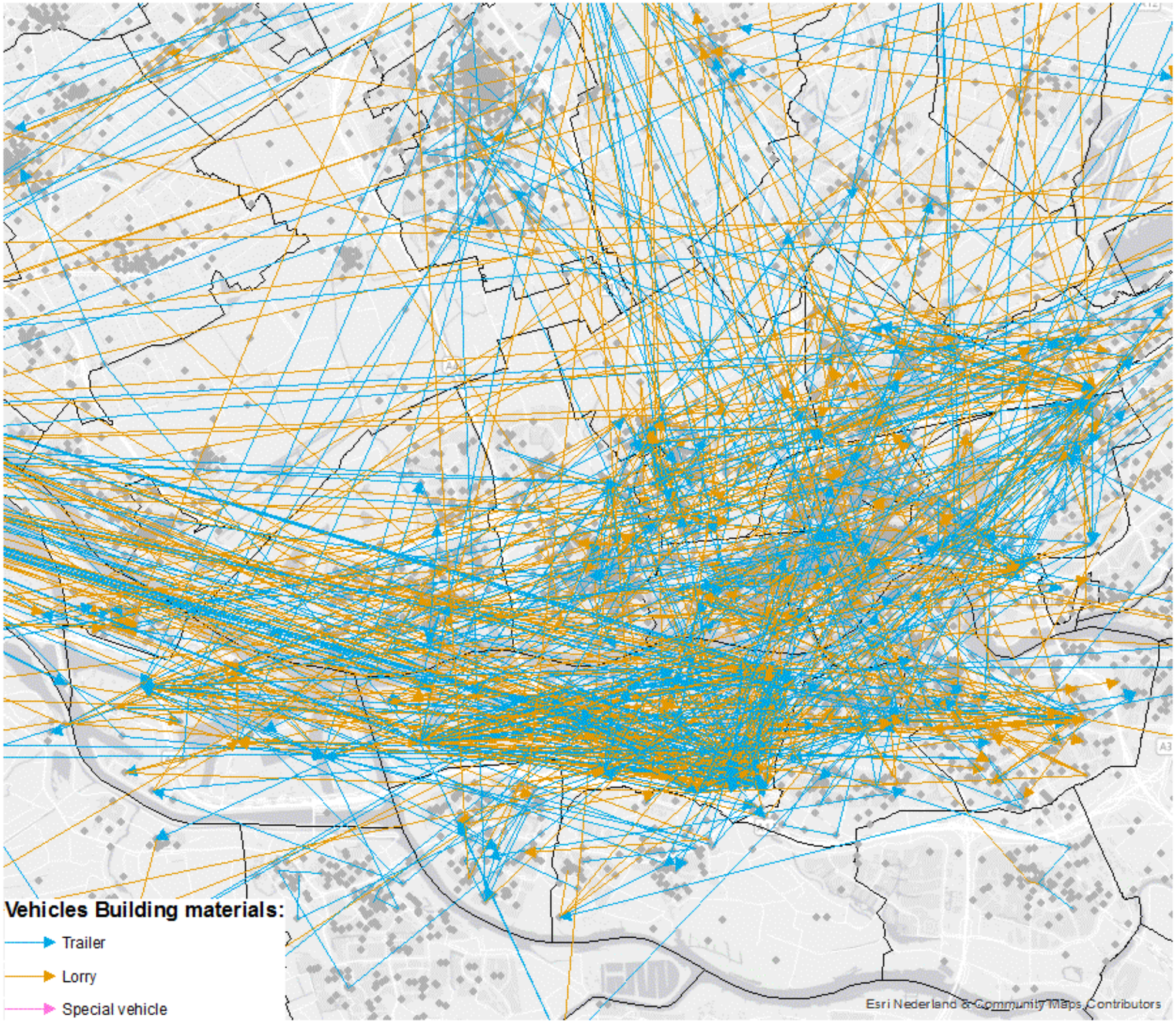
Truck patterns for building materials (NST/R 6)



Conclusions & further research

Conclusions and discussion

- Hardly any analytical **tools** exists that can **support evidence based decision making** for freight transport demand
- Emerging sources of '**big data**' allow the development of such analytical tools
- This first prototype simulating synthetic truck trip patterns can be seen as a **proof-of-concept**. It demonstrates:
  1. simple simulation frameworks can be built
  2. the microscopic results allow intuitive analyses (face-validity)
- For better impact assessment, **agent based choice models** are a promising methodology; it addresses agents and logistic decision making explicitly

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Further research

Analytical phase:

- Data analysis on XML data **CBS:**
  Enrich data by linking XML coordinates to other GIS layers, e.g. Land use, Logistic nodes and the Business register (ABR).
- Develop **Vehicle & shipment size choice** model
- Develop **Tourformation** model

MASS-GT version 2.0:

- Extend dimensions:
  - Study area, include logistic nodes, own account/hired account
- Implement **logistic choice models**
  - vehicle type and shipment size choice
  - tourformation
- Develop interface with **Network Model**

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Questions

Further info see workshop paper:

- de Bok, M, L Tavasszy “An empirical agent-based simulation system for urban goods transport (MASS-GT)”. *Procedia Computer Science*, Volume 130, 2018, Pages 126-133 (https://doi.org/10.1016/j.procs.2018.04.021)

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