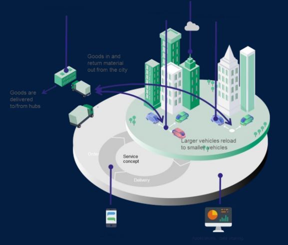


HITS 2024

A COMPARATIVE STUDY BETWEEN EMERGING AND CONVENTIONAL HEAVY-DUTY TRANSPORT VEHICLES IN URBAN LOGISTICS

RAPHAEL ANDREOLLI
Industrial Ph.D. student

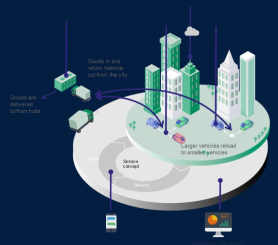
raphael.andreolli@scania.com

KTH VETENSKAP OCH KONST

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

ECO2 VEHICLE DESIGN

SCANIA



Overview

1) Introduction

2) Comparative study

3) Results & Conclusion

RAPHAEL ANDREOLLI
Industrial Ph.D. student

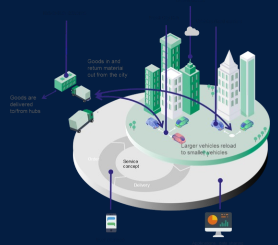
raphael.andreolli@scania.com

KTH VETENSKAP OCH KONST

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

ECO2 VEHICLE DESIGN

SCANIA



INTRODUCTION

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

KTH VETENSKAP OCH KONST

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

ECO2 VEHICLE DESIGN

SCANIA

Driverless multipurpose vehicles (DMVs)

Fig. 1: Leopard by REE Automotive (2022)

Fig. 2: Leopard by REE Automotive (2022)

Fig. 3: U-Shift by DLR (2020)

Fig. 4: U-Shift by DLR (2020)

Fig. 5: NEXT (2022)

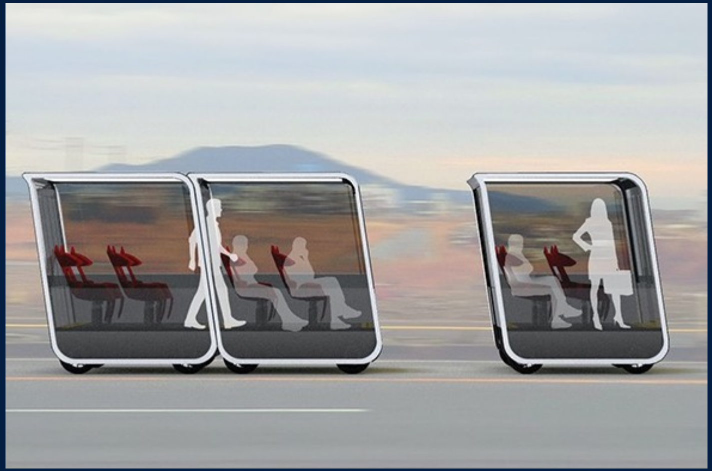


Fig. 6: NEXT (2022)

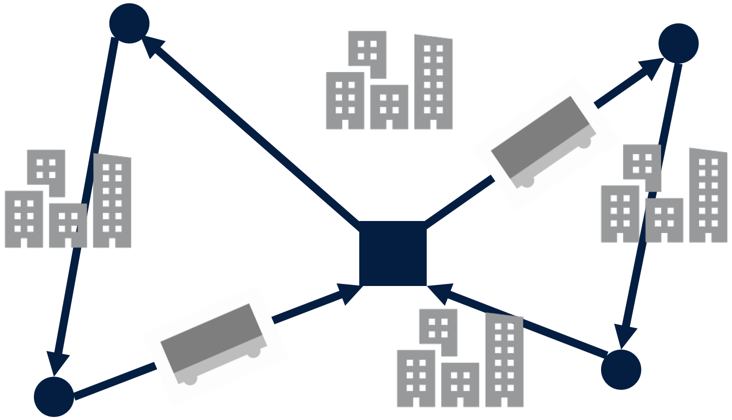
Response to urban challenges

Multipurpose	To minimise →	Energy and resource waste
Electric and silent	To reduce →	Pollution and noise
Self-driven	To handle →	Higher transport demand

Research approach

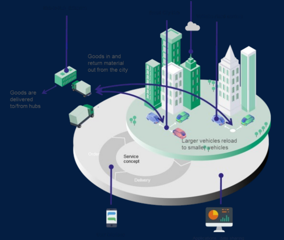
Driverless multipurpose vehicles

City transport



Vehicle level

Transport system level



COMPARATIVE STUDY

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

KTH VETENSKAP OCH KONST

ITRL – INTEGRATED TRANSPORT RESEARCH LAB

ECO2 VEHICLE DESIGN

SCANIA

Aim of study

The aim of this study is to analyse the **total fleet energy consumption** of **DMVs** for specific **transport operations** in urban logistics **compared** to **heavy-duty battery** and **combustion vehicles**

DMV fleet

Driverless Multipurpose Vehicle (DMV)

BEV fleet

Battery Electric Vehicle (BEV)

CV fleet

Combustion Vehicle (CV)

Model overview

Transport system level:

- *Mission*
- *Road*
- *Traffic*
- *Weather*
- *Supply*

Vehicle level:

- *Configuration*
- *Design*
- *Performance*

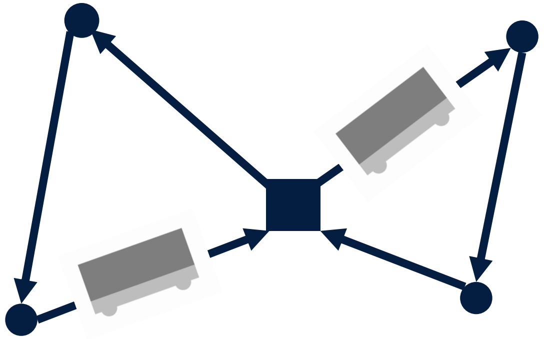
INPUT

MODEL

- Electric vehicle routing problem
- Microscopic vehicle model
- Simple network representation
- Solution approach: Exact

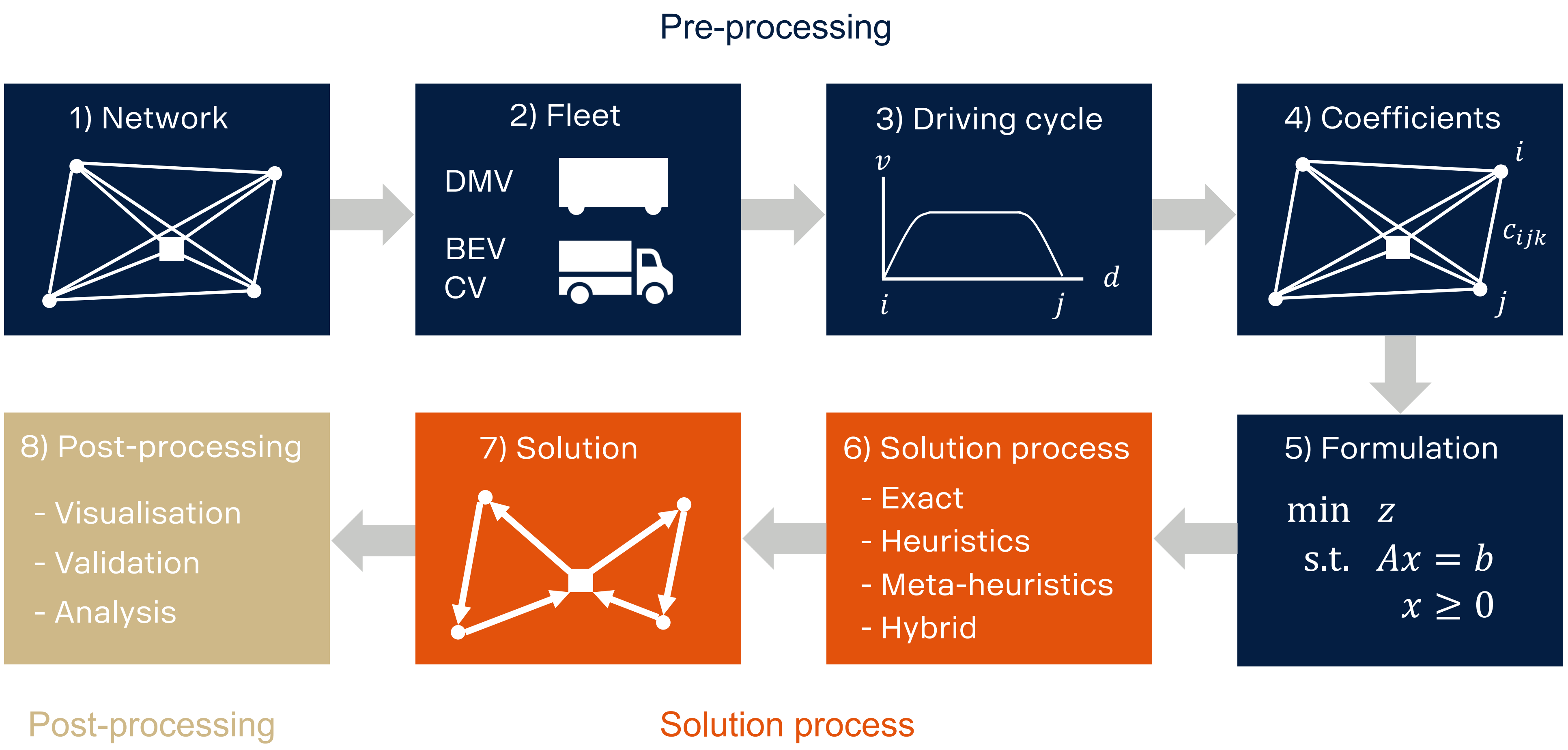
OUTPUT

- Routes
- Fleet size

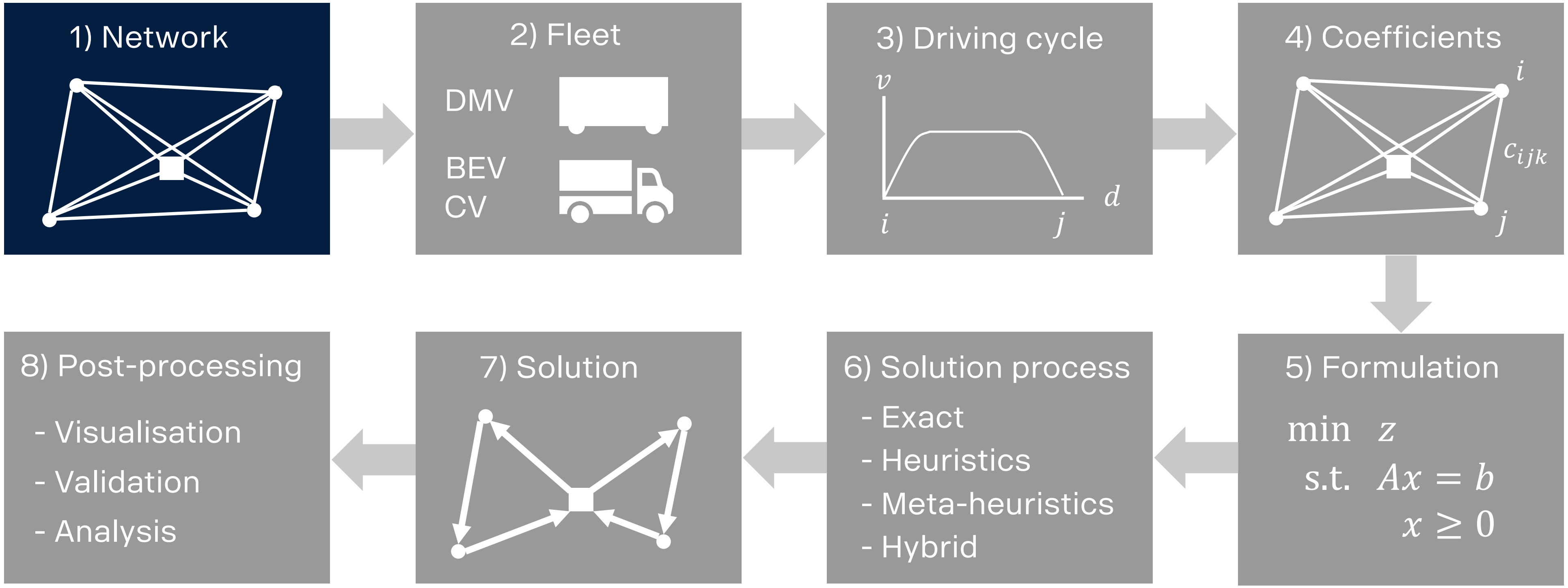


The model finds the most favorable transport routes and fleet size to satisfy network transport demand while minimizing total fleet energy consumption.

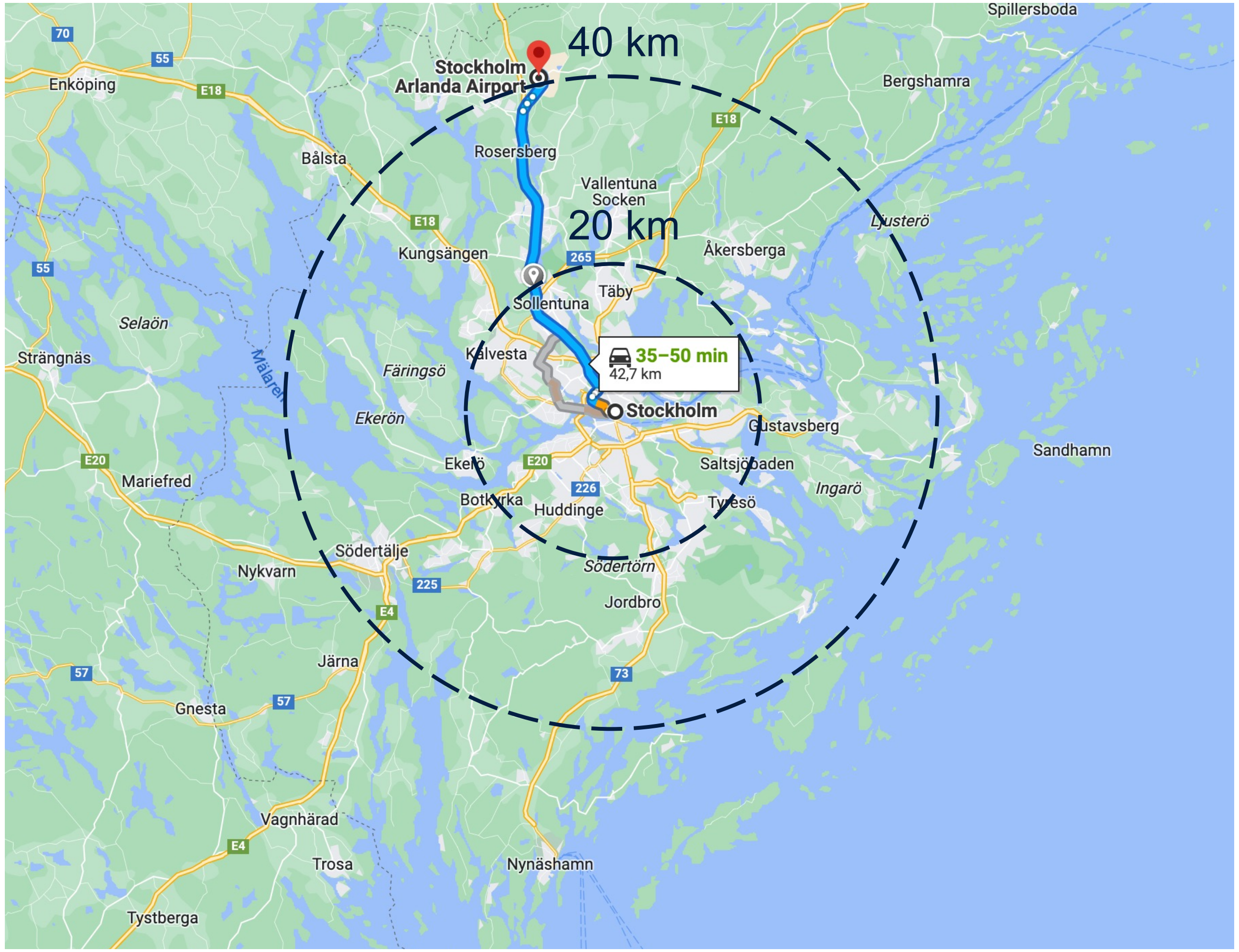
Modelling flow diagram



Modelling flow diagram



Network size



Transport operations

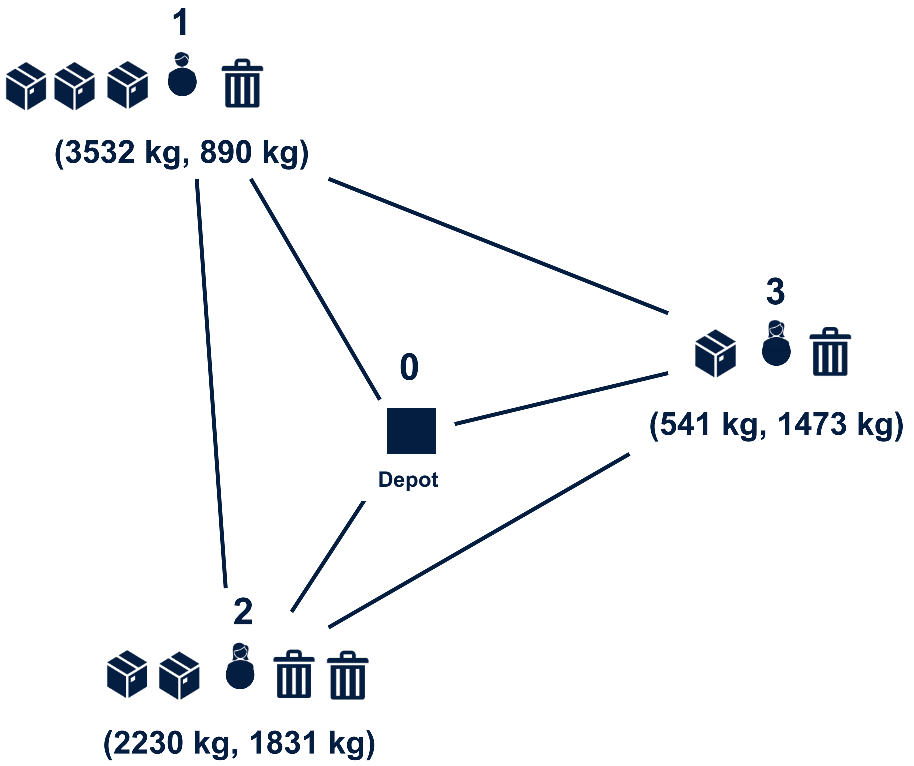
1. Simultaneous freight delivery and waste pickup at each customer in the network

2. Business-as-usual scenario with separate delivery and pickup operations

- Random transport demand at each customer, within case-study limits

- **4D2P** – Max 4000 kg freight delivery demand and max 2000 kg waste pickup demand at each customer

Case-study limit: **4D2P**



Transport demand measured in (kg)

Case-studies – 96 cases

6C-20KM	DMV(7.5)-L	DMV(7.5)-H	BEV(7.5)-L	BEV(7.5)-H	CV(7.5)-L	CV(7.5)-H
01D01P						
3D1P						
1D05P						

3 demand types | 20 km | 6 customers | 7.5 tons

12C-20KM	DMV(7.5)-L	DMV(7.5)-H	BEV(7.5)-L	BEV(7.5)-H	CV(7.5)-L	CV(7.5)-H
01D01P						
3D1P						
1D05P						
1D0P						
0D05P						

5 demand types | 20 km | 12 customers | 7.5 tons

6C-40KM	DMV(18)-L	DMV(18)-H	BEV(18)-L	BEV(18)-H	CV(18)-L	CV(18)-H
1D1P						
8D1P						
4D2P						

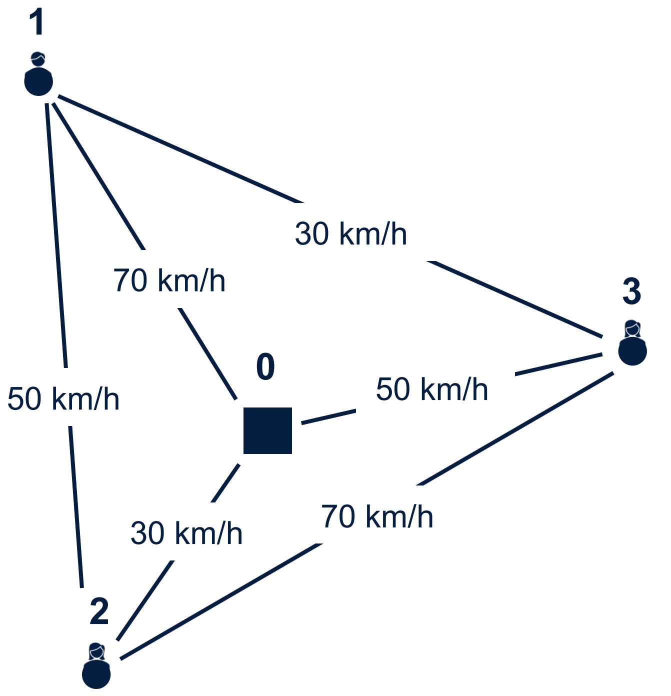
3 demand types | 40 km | 6 customers | 18 tons

12C-40KM	DMV(18)-L	DMV(18)-H	BEV(18)-L	BEV(18)-H	CV(18)-L	CV(18)-H
1D1P						
8D1P						
4D2P						
4D0P						
0D2P						

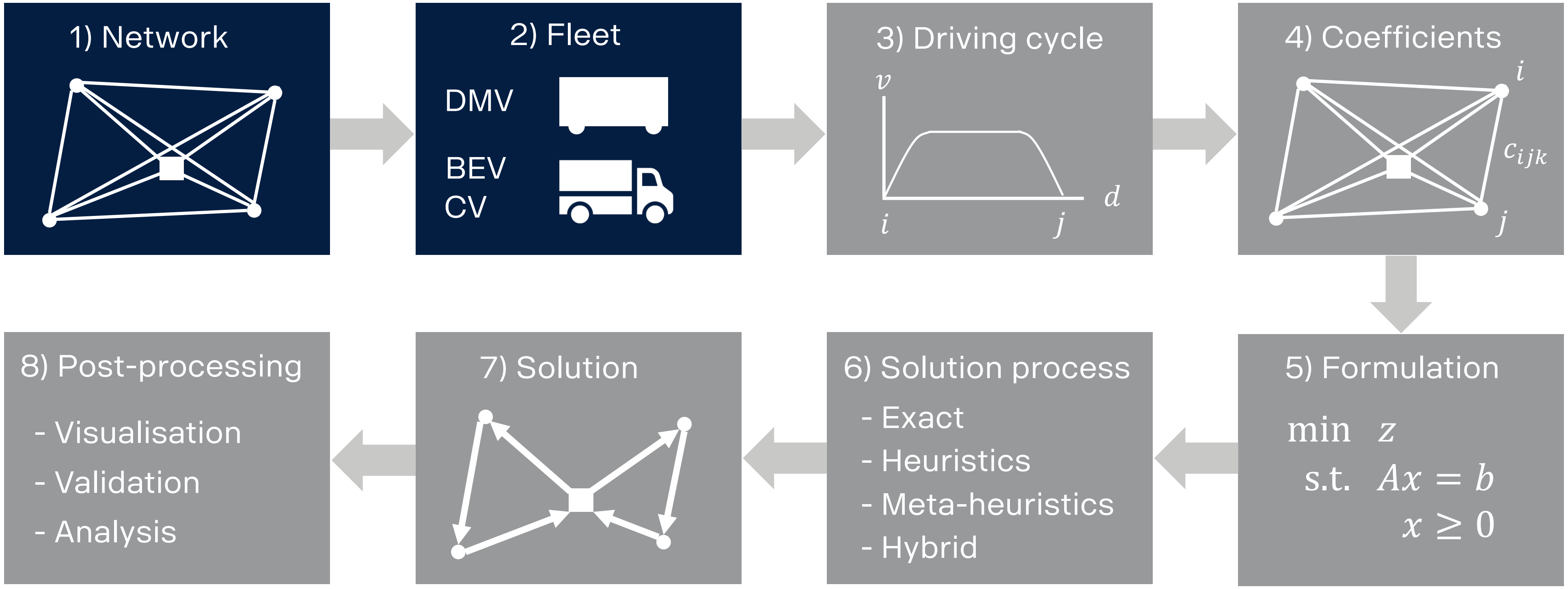
5 demand types | 40 km | 12 customers | 18 tons

Network properties

- All vehicles start and end at the depot
- No terrain considered
- Speed limits on edge (30, 50, 70 km/h)
- Same road pavement on all edges
- Ambient temperature at 20 degree Celsius
- No charging stations or service time considered



Modelling flow diagram



Fleet classes

DMV
7.5 tons

BEV
7.5 tons

CV
7.5 tons

DMV
18 tons

BEV
18 tons

CV
18 tons

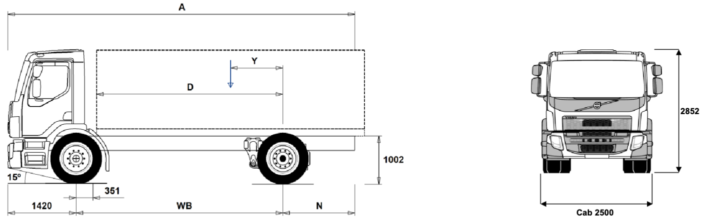
Fleet information derived from OEMs

BEV
18 tons

VOLVO

MODEL RANGE

FE Battery Electric 4x2 Platform 18 tonne - Rear Air Suspension - Contact Sales



Chassis Dimensions [mm]

		3900	4100	4300	4500	4750	5000	5250	5500	5800	6100	6450	6800
WB	**Wheelbase**	**3900**	**4100**	**4300**	**4500**	**4750**	**5000**	**5250**	**5500**	**5800**	**6100**	**6450**	**6800**
A	Overall Chassis Length	7360	7560	7760	7960	8210	8460	8710	8960	9260	9560	9910	10260
D	Center of rear axle to front of body	3475	3675	3875	4075	4325	4575	4825	5075	5375	5675	6025	6375
N	Rear Overhang	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040	2040
Y	Center of Gravity for Payload (Min.)	658	670	678	690	704	718	739	753	778	787	807	824
Y	Center of Gravity for Payload (Max.)	1230	1273	1315	1358	1410	1464	1520	1573	1640	1699	1773	1846

Chassis Weights [kg]

Front Axle	4775	4835	4905	4950	5005	5055	5080	5120	5145	5205	5245	5290
Rear Axle	3000	2980	2970	2935	2910	2890	2835	2815	2760	2760	2735	2725
Kerb Weight	7775	7815	7875	7885	7915	7945	7915	7935	7905	7965	7980	8015
Payload (including body, driver, fuel, etc.)	10225	10185	10125	10115	10085	10055	10085	10065	10095	10035	10020	9985

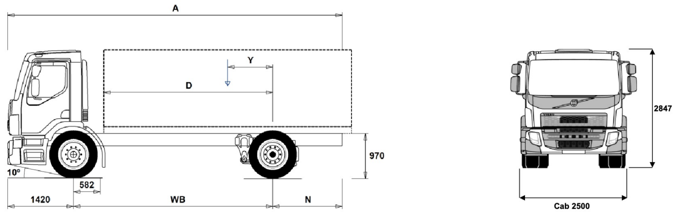
Volvo Trucks (2023).

CV
18 tons

VOLVO

MODEL RANGE

FE818 4x2 Platform 18 tonne - Rear Air Suspension FE 42 R A



Chassis Dimensions [mm]

WB	**Wheelbase**	**3500**	**3700**	**3900**	**4100**	**4300**	**4500**	**4750**	**5000**	**5250**	**5500**	**5800**	**6100**	**6450**	**6800**
A	Overall Chassis Length	6610	6910	7260	7560	7910	8210	8610	9010	9410	9810	10310	10760	11310	11560
D	Center of rear axle to front of body	2844	3044	3244	3444	3644	3844	4094	4344	4594	4844	5144	5444	5794	6144
N	Rear Overhang (Min.)	640	640	640	640	640	640	640	2590	2740	2890	3090	3240	3440	3340
N	Rear Overhang (Max.)	1690	1790	1940	2040	2190	2290	2440	2590	2740	2890	3090	3240	3440	3340
Y	Center of Gravity for Payload (Min.)	706	747	790	829	871	912	964	1015	1067	1118	1178	1237	1310	1375
Y	Center of Gravity for Payload (Max.)	877	928	980	1030	1082	1134	1198	1262	1327	1392	1468	1543	1634	1717

Chassis Weights [kg]

Front Axle	4020	4020	4015	4035	4035	4030	4035	4040	4040	4045	4060	4070	4075	4090
Rear Axle	1685	1700	1720	1765	1780	1795	1815	1845	1865	1880	1925	1960	1980	1985
Kerb Weight	5705	5720	5735	5800	5815	5825	5850	5885	5905	5925	5985	6030	6055	6075
Payload (including body, driver, fuel, etc.)	12295	12280	12265	12200	12185	12175	12150	12115	12095	12075	12015	11970	11945	11925

Volvo Trucks (2023).

Fleet class 18 ton performance levels

Lower performance

Vehicle type	DMV(18) - L	BEV(18) - L	CV(18) - L
Vehicle mass (tons)	6.5	8.3	6.2
Payload mass (tons)	11.5	9.7	11.8
Energy content (kWh)	200	200	1800
Power auxiliary (kW)	5.0	4.0	0.4
Powertrain efficiency (-)	0.6	0.6	0.1
Acceleration (m/s^2)	0.6	0.6	0.6
Braking (m/s^2)	-0.7	-0.7	-0.7
Drag coefficient (-)	0.9	0.9	0.9
Frontal area (m^2)	10	10	10

Higher performance

Vehicle type	DMV(18) - H	BEV(18) - H	CV(18) - H
Vehicle mass (tons)	5.5	7.3	5.2
Payload mass (tons)	12.5	10.7	12.8
Energy content (kWh)	375	375	2200
Power auxiliary (kW)	3.0	2.0	0.2
Powertrain efficiency (-)	0.9	0.9	0.3
Acceleration (m/s^2)	1.0	1.0	1.0
Braking (m/s^2)	-1.1	-1.1	-1.1
Drag coefficient (-)	0.6	0.6	0.6
Frontal area (m^2)	7	7	7

Fleet class 7.5 tons performance levels

Lower performance

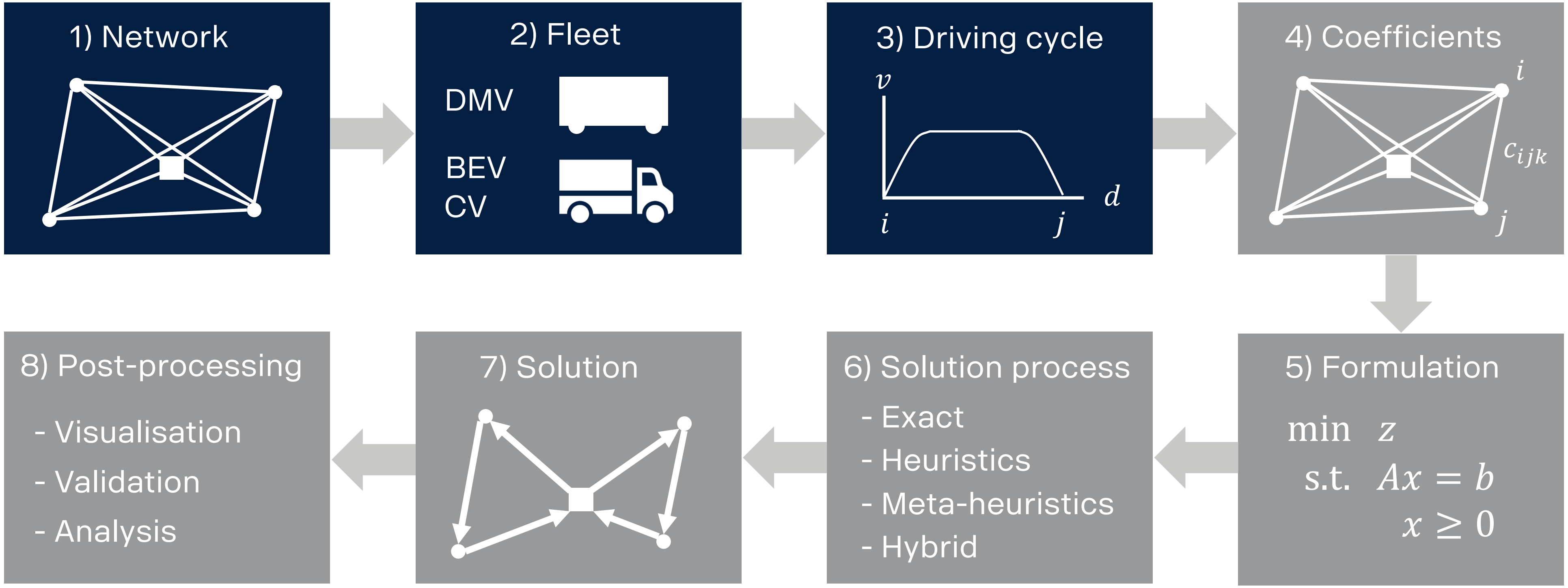
Vehicle type	DMV(7.5) - L	BEV(7.5) - L	CV(7.5) - L
Vehicle mass (tons)	4.0	4.5	4.0
Payload mass (tons)	3.5	3.0	3.5
Energy content (kWh)	60	60	500
Power auxiliary (kW)	5.0	4.0	0.4
Powertrain efficiency (-)	0.6	0.6	0.1
Acceleration (m/s^2)	0.6	0.6	0.6
Braking (m/s^2)	-0.7	-0.7	-0.7
Drag coefficient (-)	0.9	0.9	0.9
Frontal area (m^2)	10	10	10

Higher performance

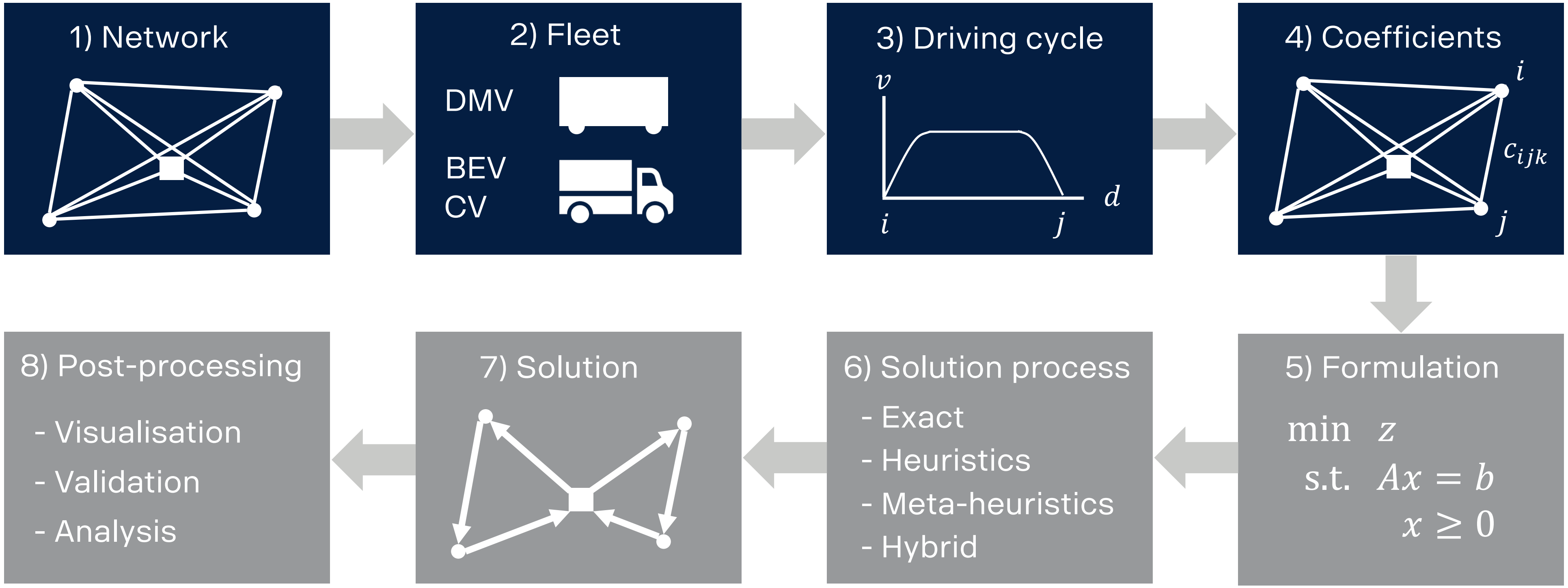
Vehicle type	DMV(7.5) - H	BEV(7.5) - H	CV(7.5) - H
Vehicle mass (tons)	3.0	3.5	3.0
Payload mass (tons)	4.5	4.0	4.5
Energy content (kWh)	100	100	900
Power auxiliary (kW)	3.0	2.0	0.2
Powertrain efficiency (-)	0.9	0.9	0.3
Acceleration (m/s^2)	1.0	1.0	1.0
Braking (m/s^2)	-1.1	-1.1	-1.1
Drag coefficient (-)	0.6	0.6	0.6
Frontal area (m^2)	7	7	7

Innovative consolidation within vehicles

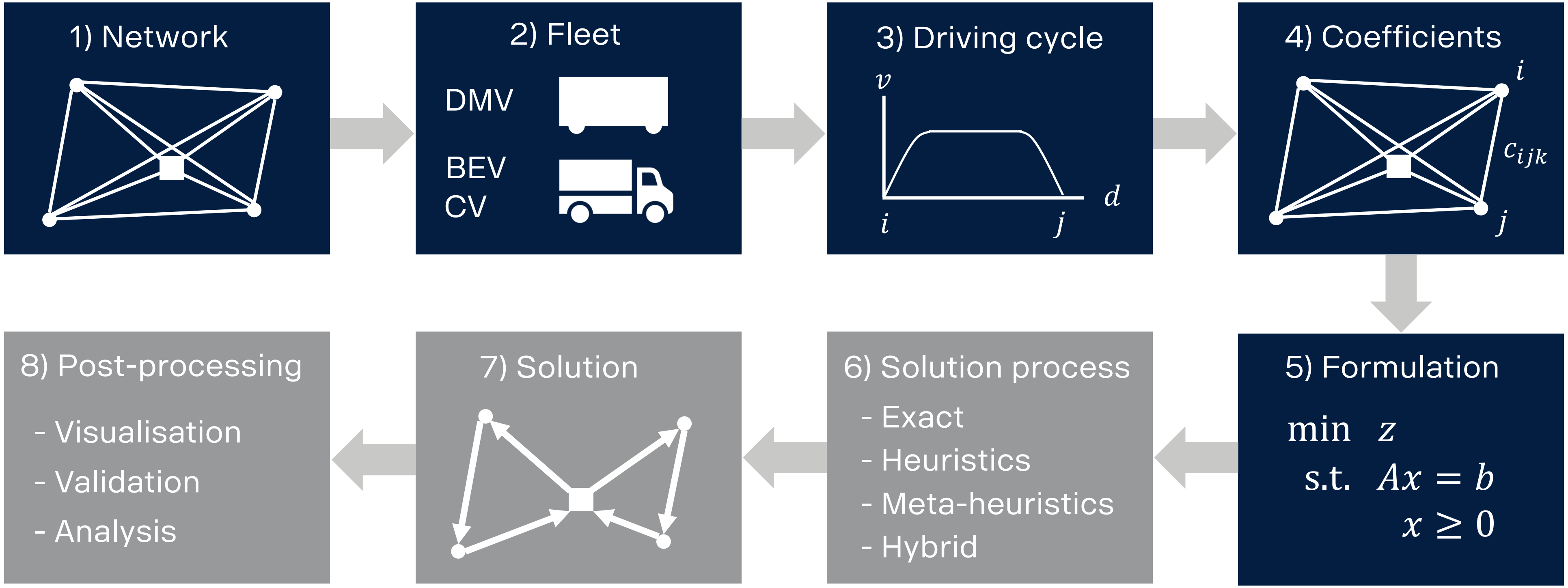
Modelling flow diagram



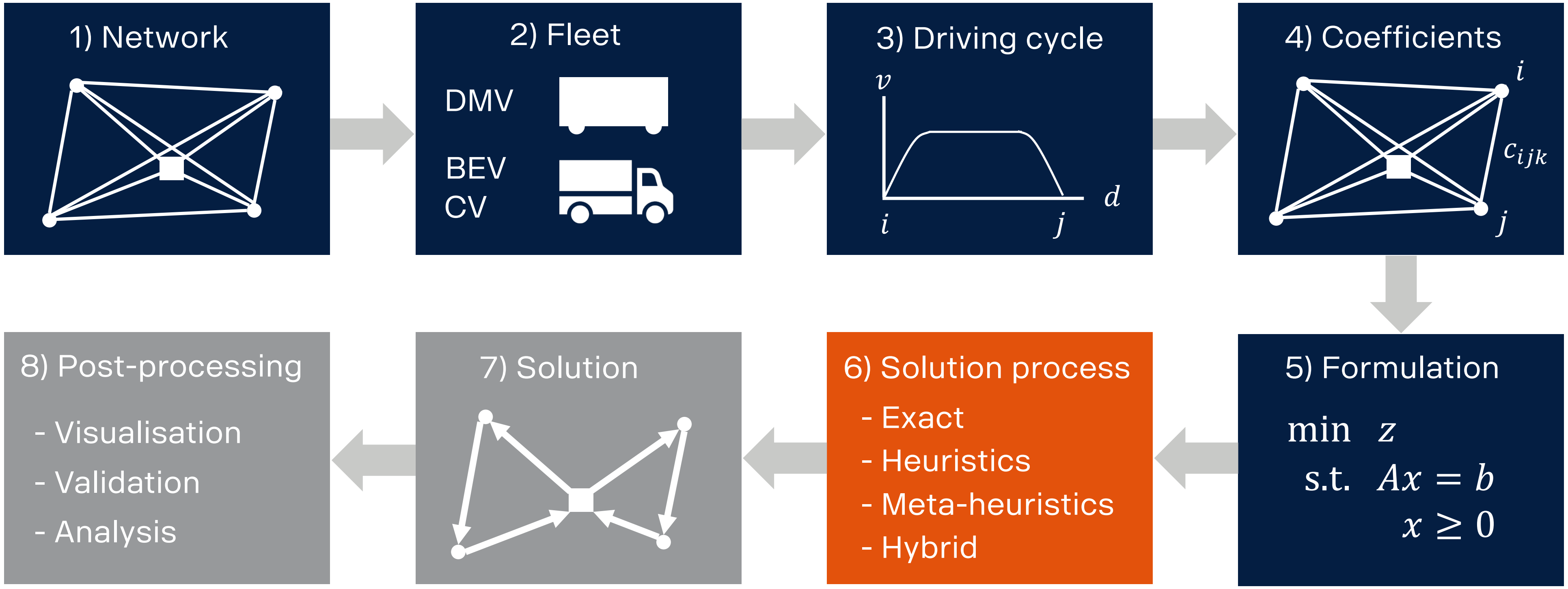
Modelling flow diagram



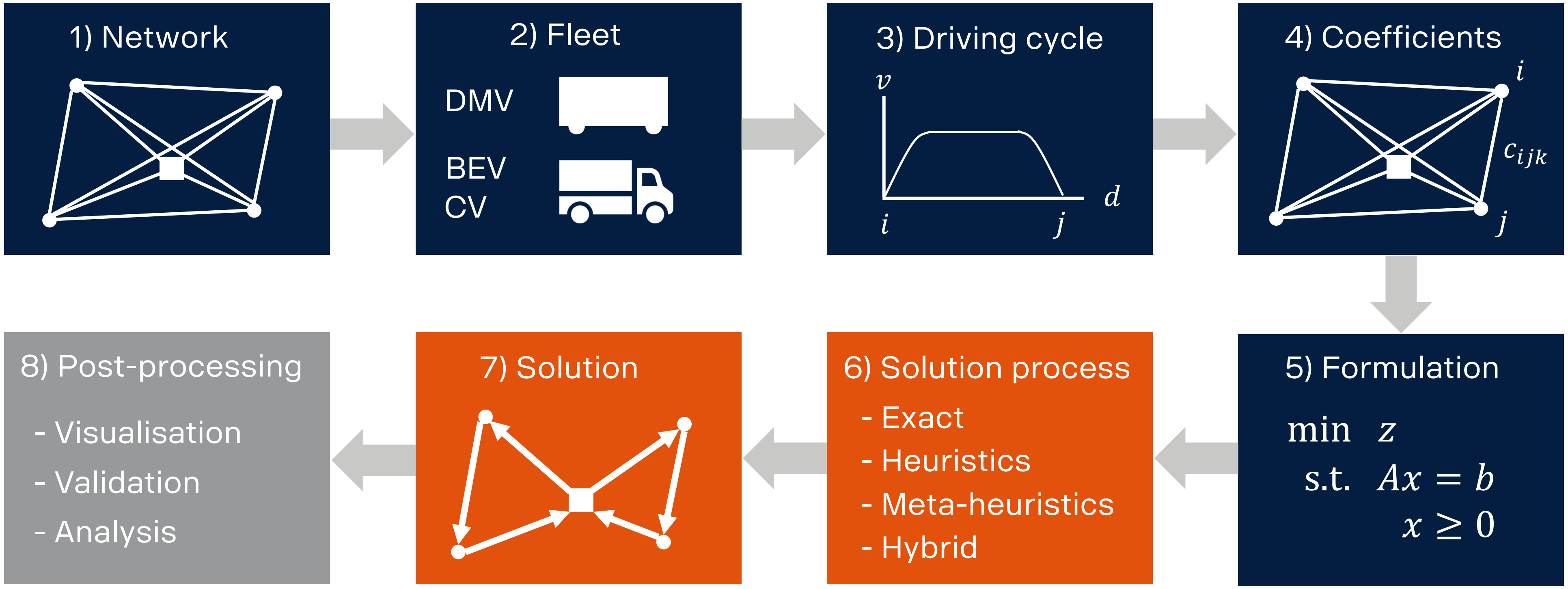
Modelling flow diagram



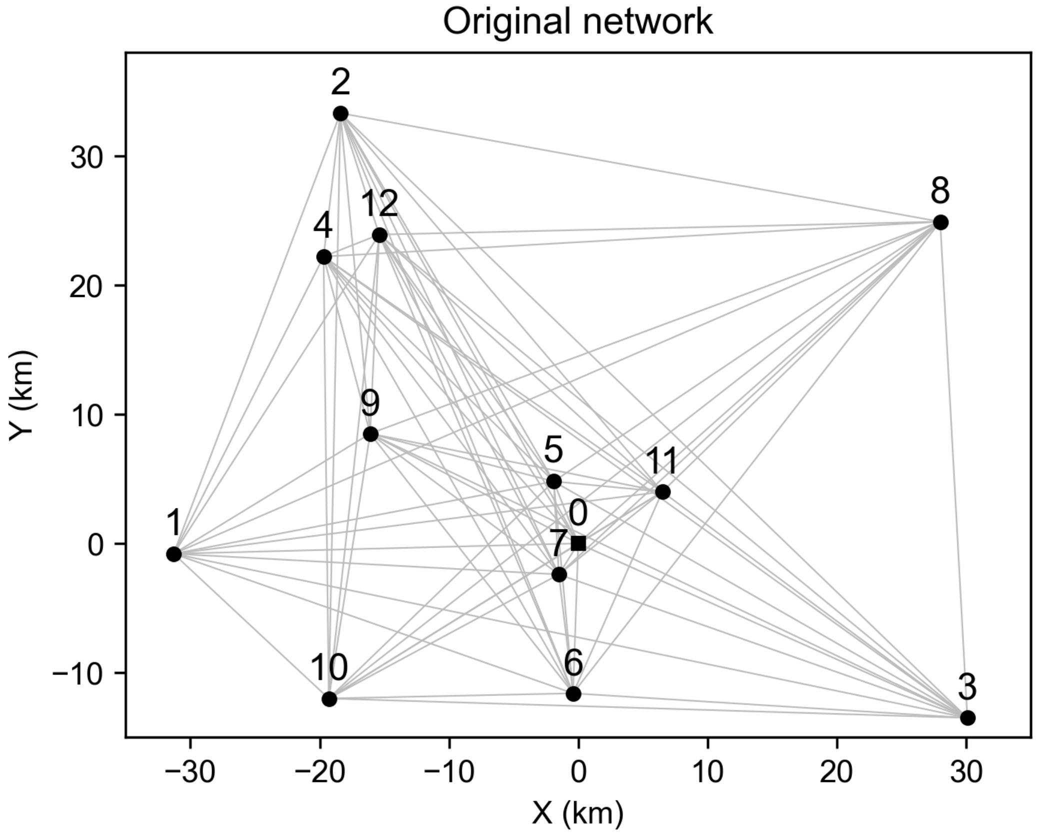
Modelling flow diagram

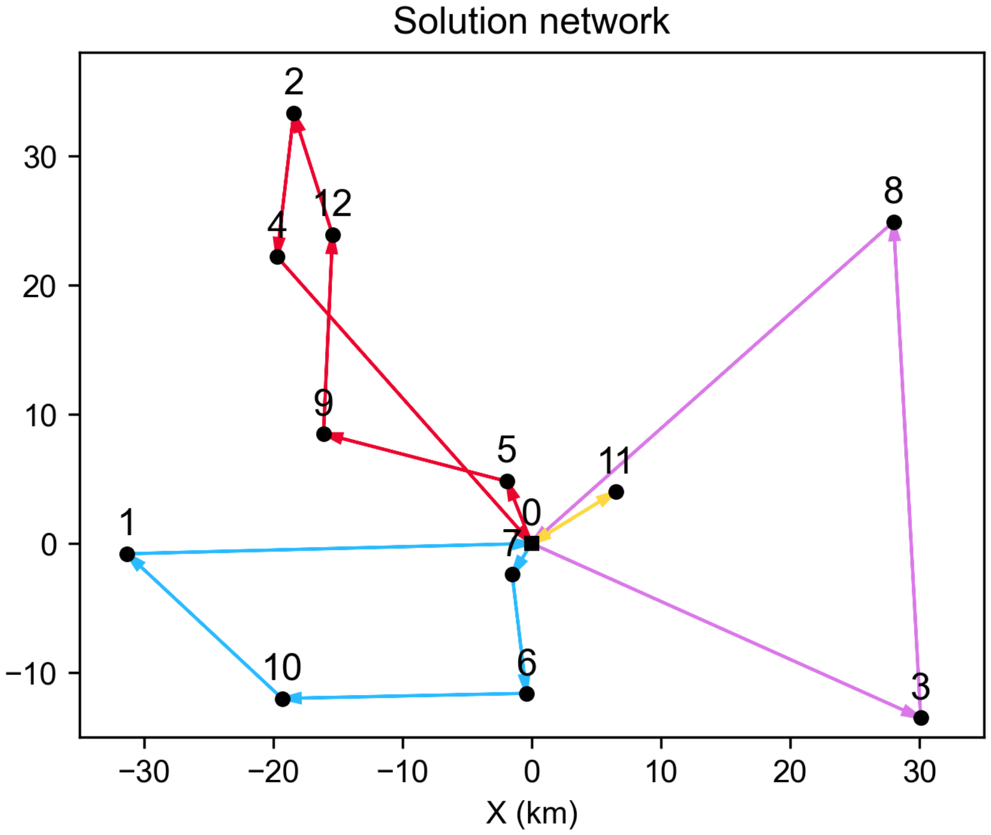


Modelling flow diagram

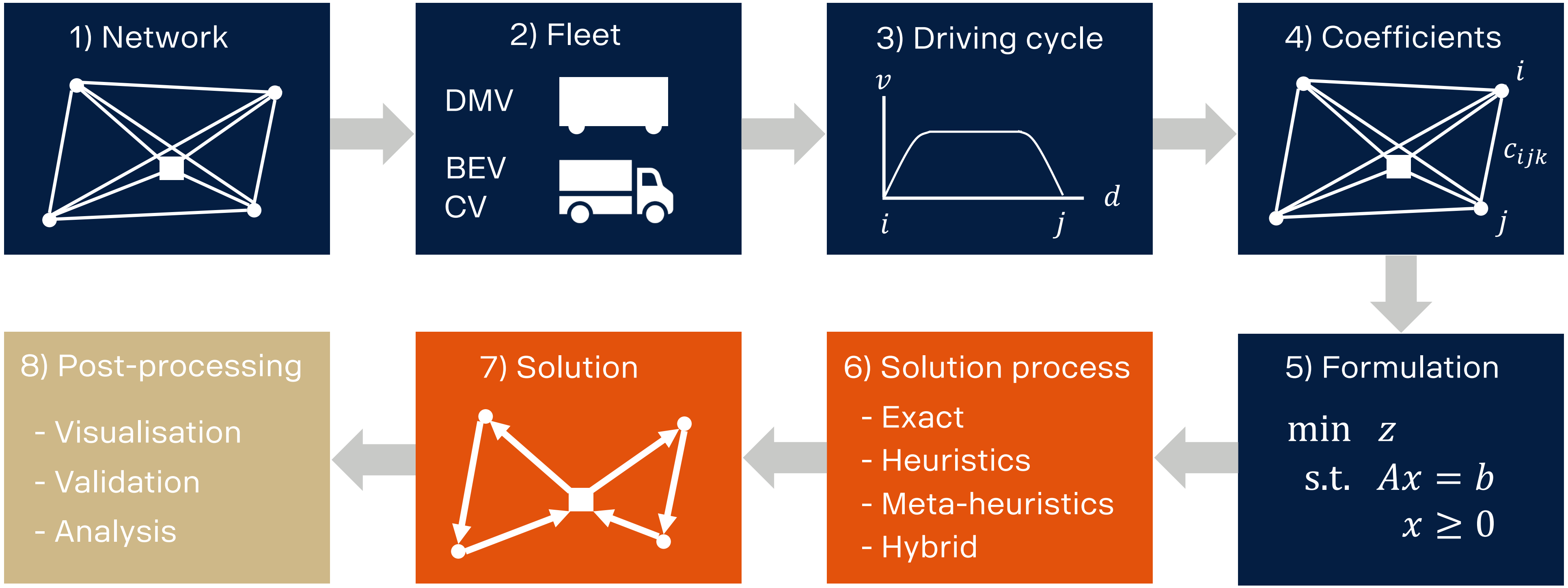


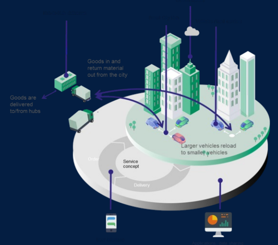
Solutions


Original network
Y (km)
X (km)
30
20
10
0
−10
−30
−20
−10
0
10
20
30
0
1
2
3
4
5
6
7
8
9
10
11
12


Solution network
X (km)
30
20
10
0
−10
−30
−20
−10
0
10
20
30
0
1
2
3
4
5
6
7
8
9
10
11
12

Modelling flow diagram





RESULTS
&
CONCLUSION

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

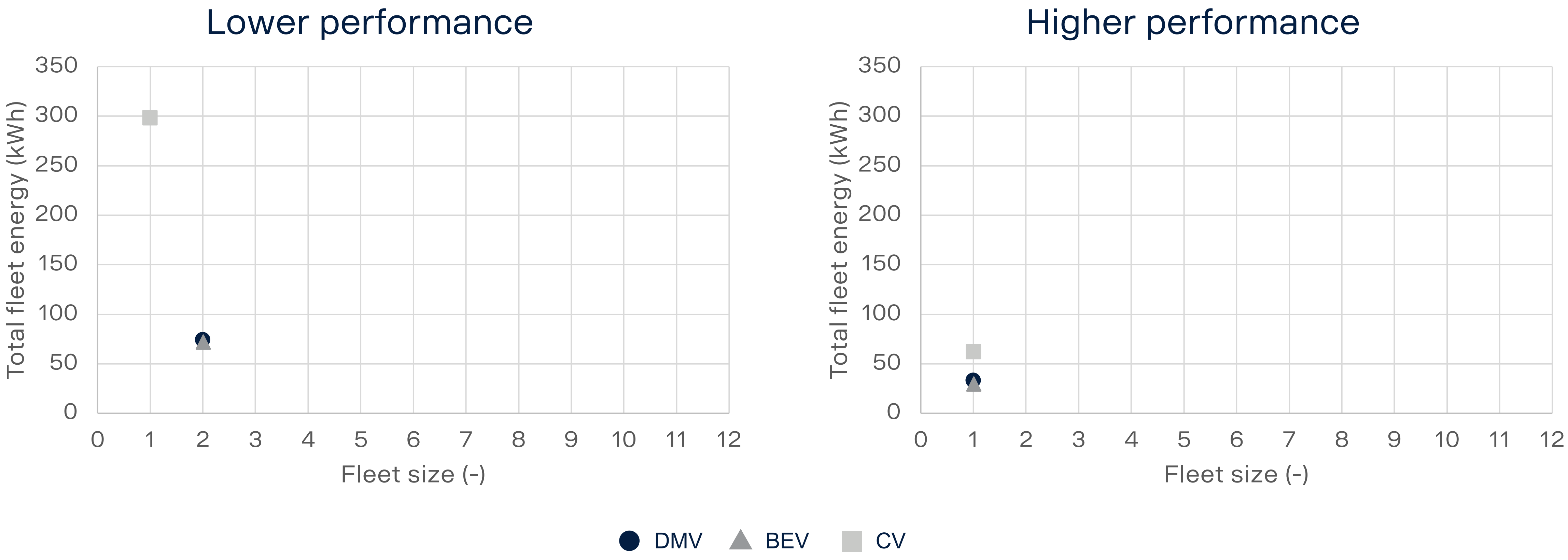
KTH VETENSKAP OCH KONST

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

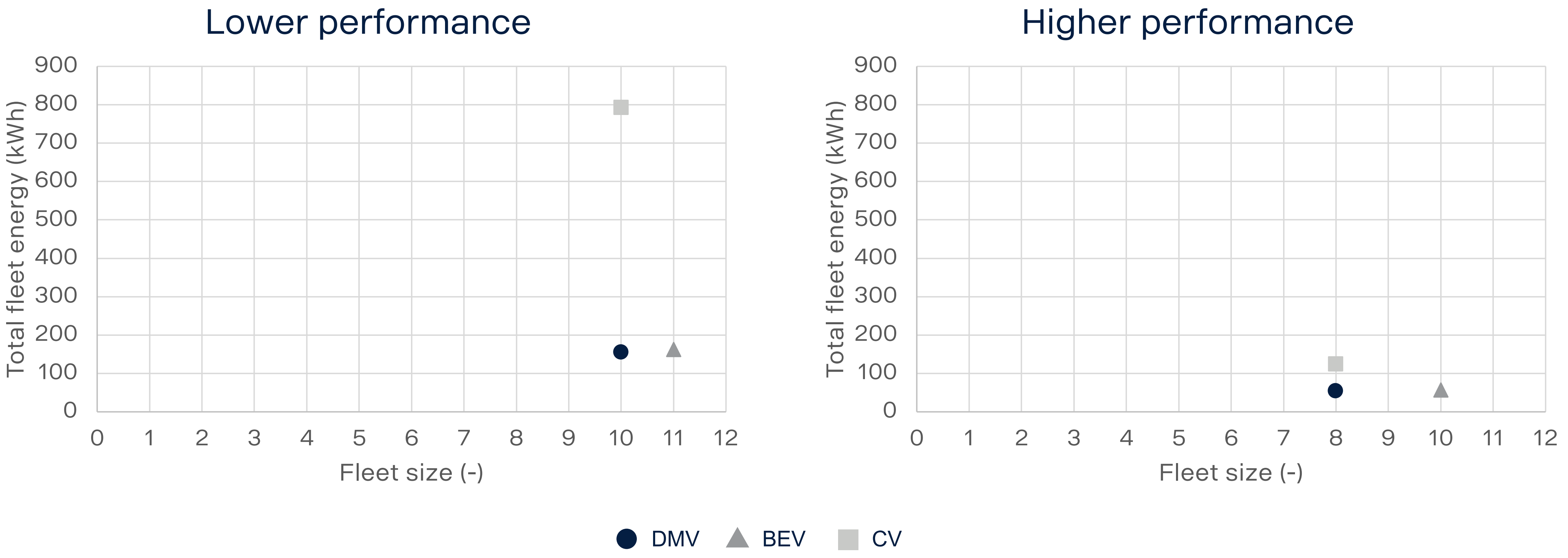
ECO2 VEHICLE DESIGN

SCANIA

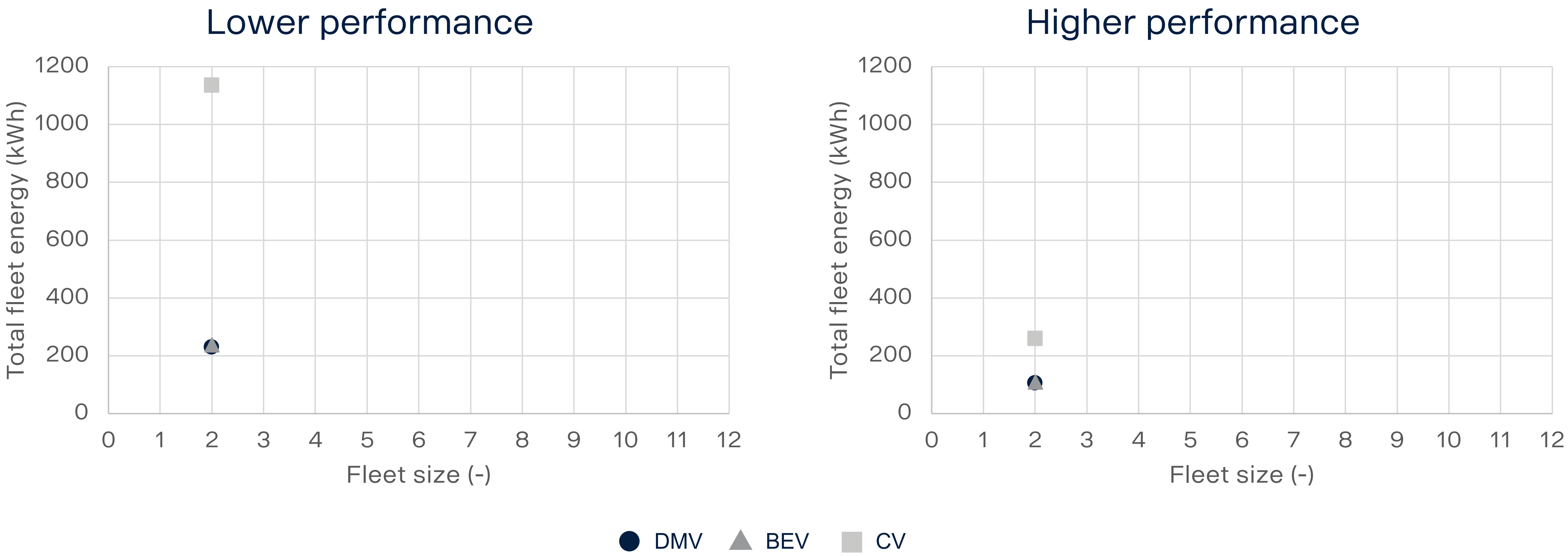
Results – 12C-20KM-01D01P-7.5T



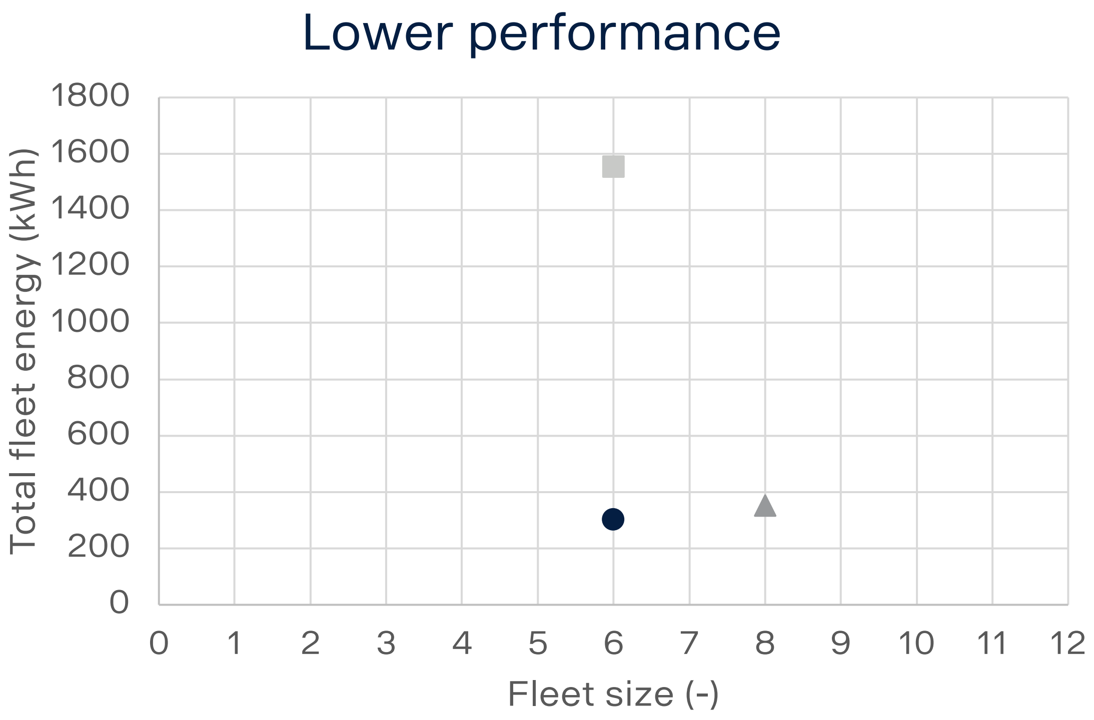
Results – 12C-20KM-3D1P-7.5T

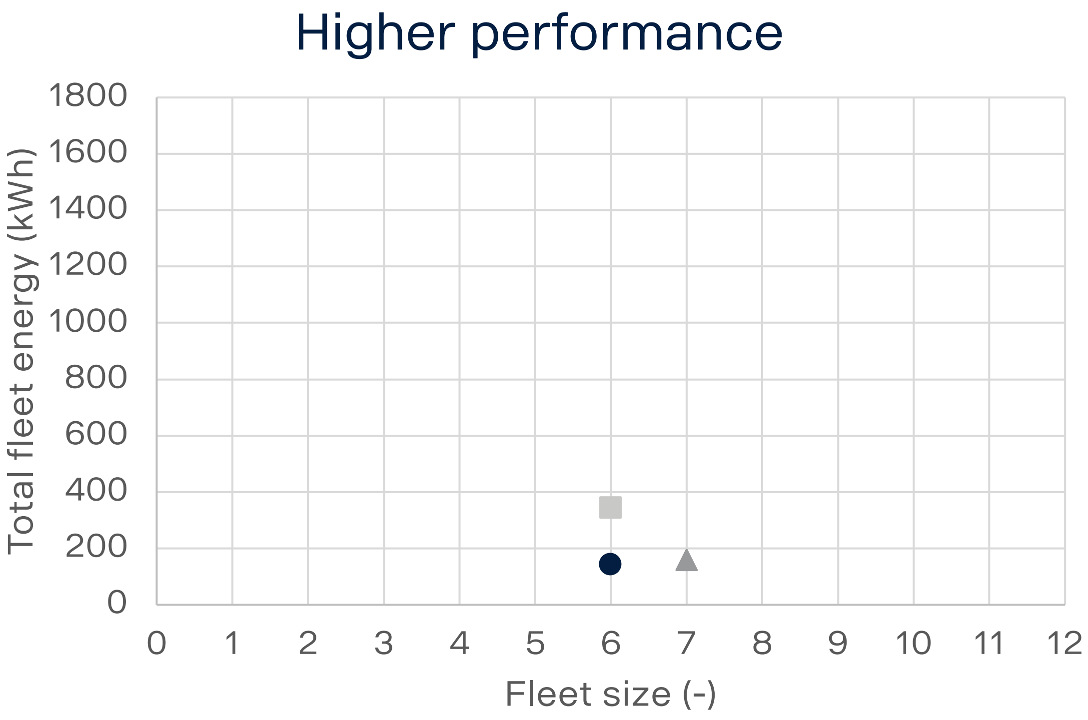


Results – 12C-40KM-1D1P-18T



Results – 12C-40KM-8D1P-18T



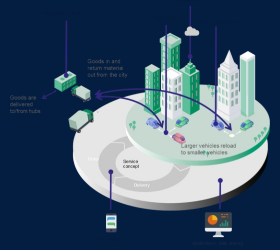


Findings based on 96 case-studies

- CV fleets consumed the most energy for all case studies
- CV fleet consumed 2 to 5 times more energy for the same operation compared to BEV fleet and DMV fleet
- DMV fleet and BEV fleet consumed similar amount of energy for most case-studies
- In a few but important cases DMV fleet consumed less energy and required a smaller fleet size
- Business-as-usual scenario consumes around 50-80% more energy compared to the same operation with simultaneous pickup and delivery

Conclusion

- This study highlights the potential benefits of DMV fleets in urban logistics operations in terms of reducing total fleet energy consumption and fleet size in cases with more than six customers and higher vehicle utilisation operations



HITS 2024

THANKS FOR LISTENING

RAPHAEL ANDREOLLI
Industrial Ph.D. student

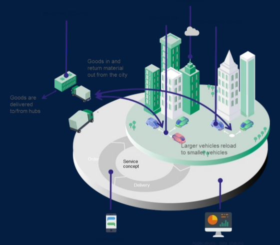
raphael.andreolli@scania.com

KTH VETENSKAP OCH KONST

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

ECO2 VEHICLE DESIGN

SCANIA



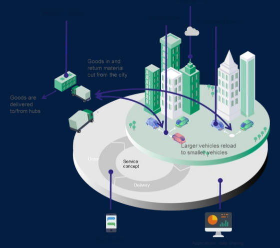
Acknowledgement

- Scania CV AB
- KTH Royal Institute of Technology
- Integrated Transport Research Lab (ITRL)
- Strategic Vehicle Research and Innovation (FFI) funding program
- Centre for ECO2 Vehicle Design
- Strategic research area TRENoP

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

ITRL — INTEGRATED TRANSPORT RESEARCH LAB



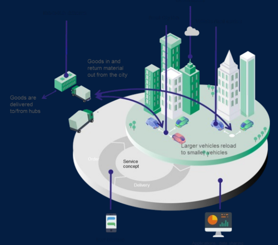
References

- OECD. (2015). The Metropolitan Century: Understanding Urbanization and Its Consequences. OECD Publishing, Paris. https://doi.org/10.1787/9789264228733-en
- International Transport Forum. (2023). ITF Transport Outlook 2023. OECD Publishing. https://doi.org/10.1787/b6cc9ad5-en
- Jaramillo, P., Kahn Ribeiro, S., Newman, P., Dhar, S., Diemuodeke, O. E., Kajino, T., Lee, D. S., Nugroho, S. B., Ou, X., Hammer Strømman, A., Whitehead, J. (2022). Transport. Shukla, P. R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), Climate Change 2022: Mitigation of Climate Change. *Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.012
- Volvo Trucks. (2023). Data Sheets for Volvo FE. https://www.volvotrucks.co.uk/en-gb/trucks/trucks/volvo-fe/specifications/data-sheets.html

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

ITRL — INTEGRATED TRANSPORT RESEARCH LAB



References - Images

Fig. 1: Leopard by REE Automotive (2022), https://ree.auto/leopard/

Fig. 2: Leopard by REE Automotive (2022), https://ree.auto/leopard/tps://ree.auto/leopard/

Fig. 3: U-Shift by DLR (2020), https://verkehrsforschung.dlr.de/en/projects/u-shift

Fig. 4: U-Shift by DLR (2020), https://verkehrsforschung.dlr.de/en/projects/u-shift

Fig. 5: NEXT (2022), https://www.next-future-mobility.com/

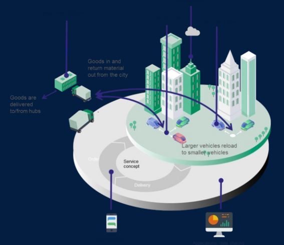
Fig. 6: NEXT (2022), https://www.next-future-mobility.com/ect.org/

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

ITRL — INTEGRATED TRANSPORT RESEARCH LAB

SCANIA



HITS 2024

THANKS FOR LISTENING

RAPHAEL ANDREOLLI
Industrial Ph.D. student

raphael.andreolli@scania.com

ITRL — INTEGRATED TRANSPORT RESEARCH LAB