Feasibility study of electrified heavy trucks for city distribution

- Exploring the impact of key cost drivers on the financial and practical viability of electrified heavy trucks.

Jon Williamsson, University of Gothenburg, School of Business, Economics and Law.
Johan Lodin, Volvo Group Trucks Technology.
Sofia Löfstrand, Volvo Group Trucks Technology.

Project background

The study is based on parts of the results that were generated from a 2 year project conducted with Volvo Trucks, Viktoria Insitute, Gothenburg City, The Swedish Transportation Agency, Schenker and TGM Bäckebol.

Goal is to write a short concise paper and get it published asap.

Research background

Electrical heavy trucks have been tested and are used for delivery in a few urban freight scenarios where customers are less price sensitive and more environmental conscious (e.g.. Paris, Deret – Modec, Smith Newton).

However, the adoption of electrified heavy distribution trucks (gross vehicle weight rating, GVWR, 7,5+ tonnes) in urban freight settings has been slow.

The trend in Sweden has been encourage private actors to find solutions to environmental challenges i.e. there is a need for *working business models* for the market to solve the situation.

Research purpose

EVs still have a comparatively high TCO but the most radical differences lies in the distribution of fixed and variable costs.

Electrical Vehicles (EVs) exhibit radically different cost characteristics (2-3 times higher fixed costs and 50-75% lower variable costs) and require adaptations of both local facilities and infrastructure.

The change in cost structure means that it is one way to increase the cost competitiveness of EVs is to increase the utilization rate of the vehicle. Due to charging requirements the increasing utilization rate can mainly be achieved through the use of two-shift solutions.

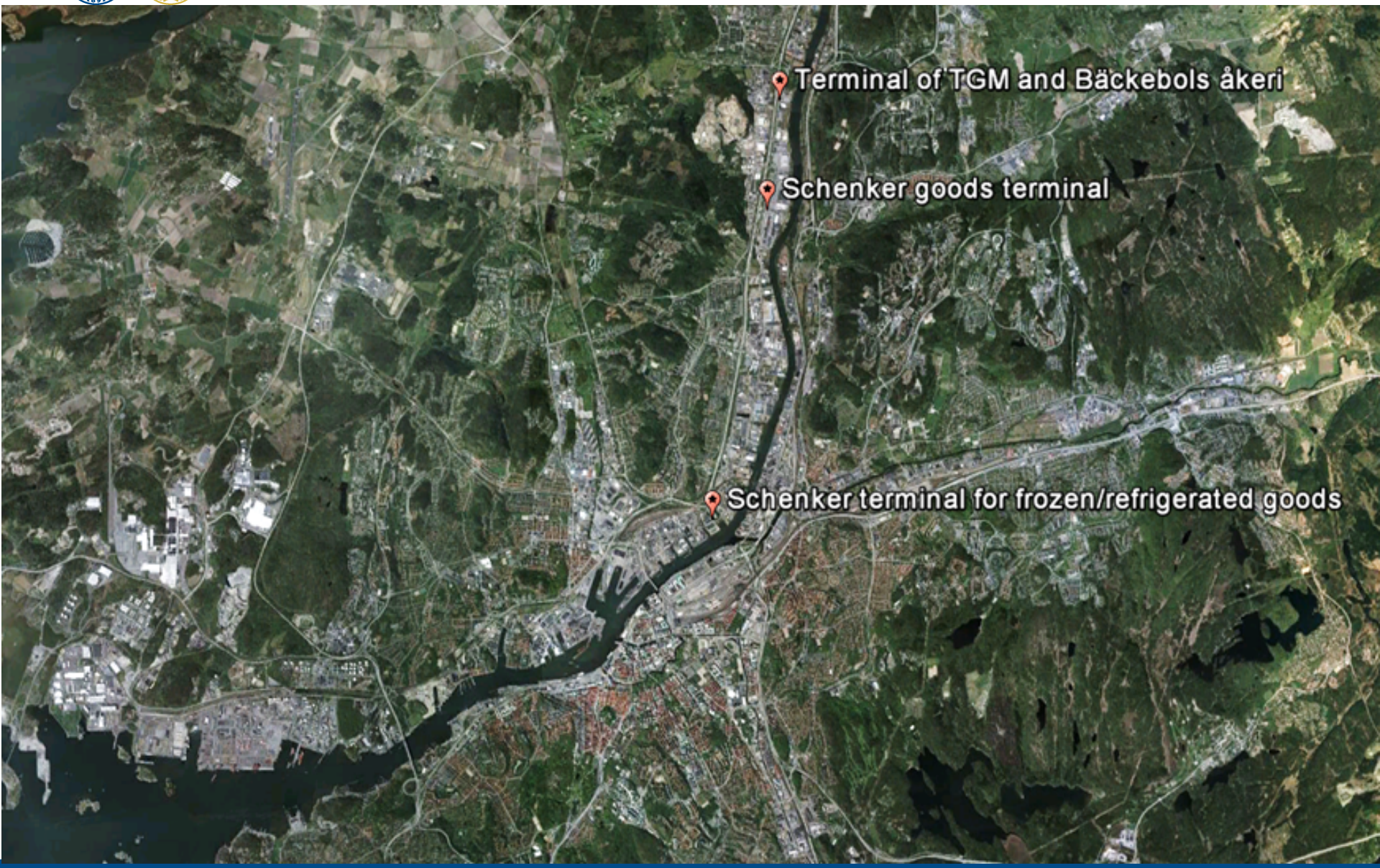
This study sets out to explore how the introduction of two-shift delivery would impact the financial viability of EVs and what changes would be necessary to the business models of involved firms.

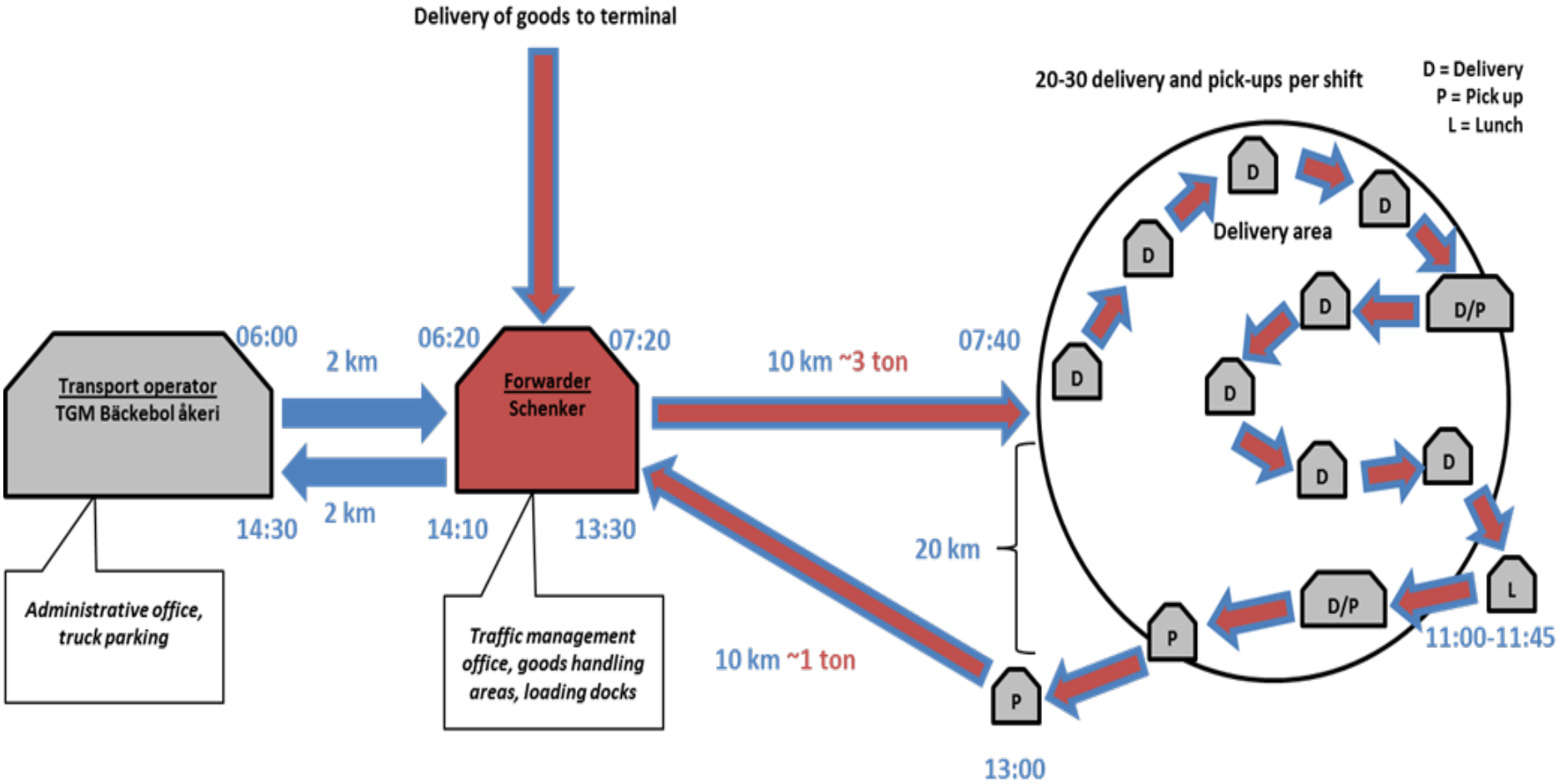
Research method

Business models are complex and often emerge through a process of trial and error (cf. Teece, 2010) so the study relied on an action research based approach in which stakeholders were deeply involved in the development of the empirical material.

The study compares four different cases that are based on data gathered from the distribution fleet of DB Schenker and their contractor TGM/Bäckebol in Gothenburg.

Data comes from actual transport assignments, i.e. the distribution deliveries and pick-ups, during one week were used as basis for the study.


Terminal of TGM and Bäckebols åkeri
Schenker goods terminal
Schenker terminal for frozen/refrigerated goods


Delivery of goods to terminal
20-30 delivery and pick-ups per shift
D = Delivery
P = Pick up
L = Lunch
Delivery area
Transport operator
TGM Bäckebol åkeri
Forwarder
Schenker
06:00
2 km
06:20
07:20
10 km ~3 ton
07:40
14:30
2 km
14:10
13:30
20 km
10 km ~1 ton
13:00
11:00-11:45
Administrative office, truck parking
Traffic management office, goods handling areas, loading docks

The routes used for the different cases were based on addresses that were geo-located using different software and the NAVTEQ map database provided estimated speed and distance of roads in the road network. The data is then used as a basis for the creation of four case scenarios.

Case	Description
D1	Diesel vehicle run in one shift distribution
E1	All-electric vehicle run in one shift distribution
D2	Diesel vehicle run in two shift distribution
E2	All-electric vehicle run in two shift distribution

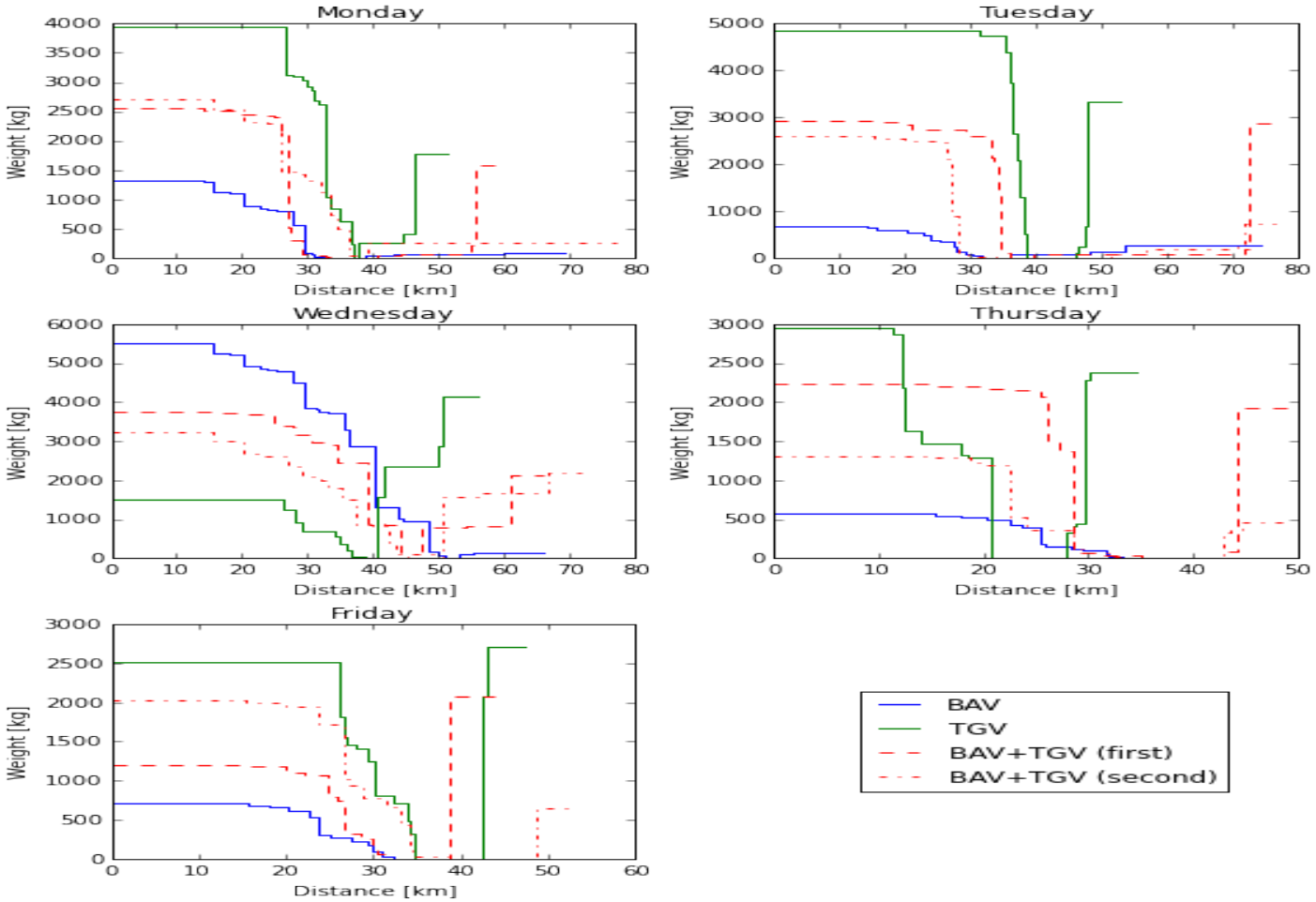
Day	Route	Number of stops	Average time per stop (m)	Total distance (km)		Total drive time (h)		Average weight (kg)	Total delivery weight (kg)
Monday	1	17	12.7	69.2	= 120.6	2.9	= 4.8	510.3	1323
	2	16	17.4	51.4		1.9		2678	3936
	1+2 first	17	13.0	60.6	= 137.7	2.8	= 5.9	1276.2	2551
	1+2 second	16	12.8	77.1		3.1		1150.7	2708
Tuesday	1	19	10.8	74.4	= 127.2	3.1	= 4.9	322.9	671
	2	13	21.5	52.8		1.8		3721.5	4858
	1+2 first	17	11.8	77.8	= 154.2	3.2	= 6.3	1465.9	2932
	1+2 second	16	12.6	76.4		3.1		1013.5	2597
Wednesday	1	27	7.5	65.8	= 121.6	3.1	= 5.2	3070.7	5500
	2	15	17.5	55.8		2.1		1641.8	1496
	1+2 first	21	9.3	66.1	= 137.7	3.3	= 6.7	2432.9	3757
	1+2 second	20	9.4	71.6		3.4		2015.5	3239
Thursday	1	14	19.3	45.4	= 80.0	2	= 3.5	326.1	579
	2	12	25.2	34.6		1.5		1747.3	2951
	1+2 first	13	19.9	49.2	= 98.3	2.2	= 4.4	1447.6	2230
	1+2 second	13	19.7	49.1		2.2		698.3	1300
Friday	1	12	23.3	45.7	= 93.1	1.8	= 3.5	395.2	716
	2	12	24.1	47.4		1.7		1848.2	2519
	1+2 first	12	22.8	43.8	= 96.9	1.9	= 4.3	961.1	1206
	1+2 second	12	20.5	53.1		2.4		1158.4	2029

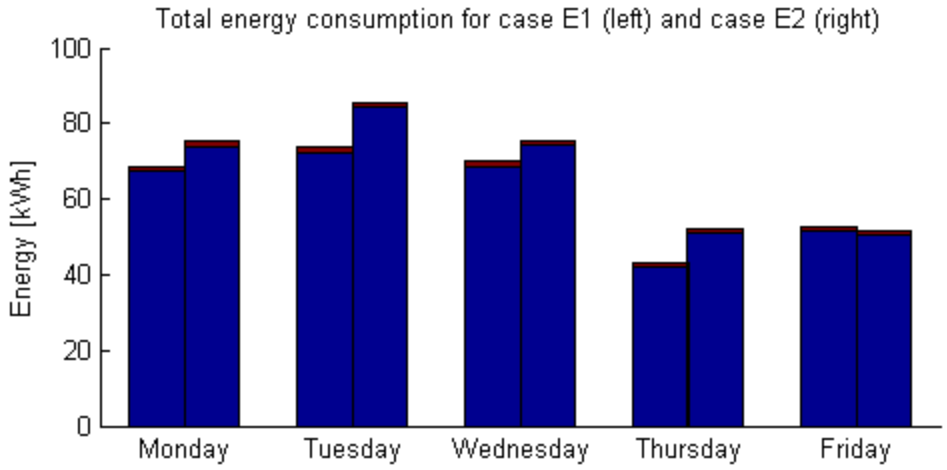
The first case is the base case of two diesel vehicles performing the distribution transport in the current route set-up of TGM and Bäckebol.

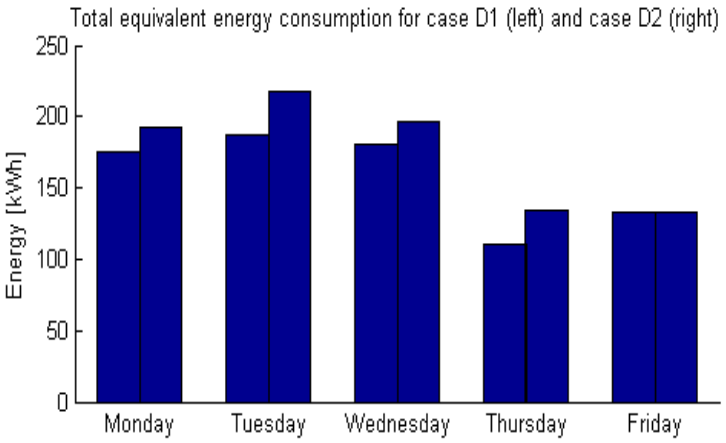
The second case is a simple replacement of the diesel trucks with all-electric trucks.

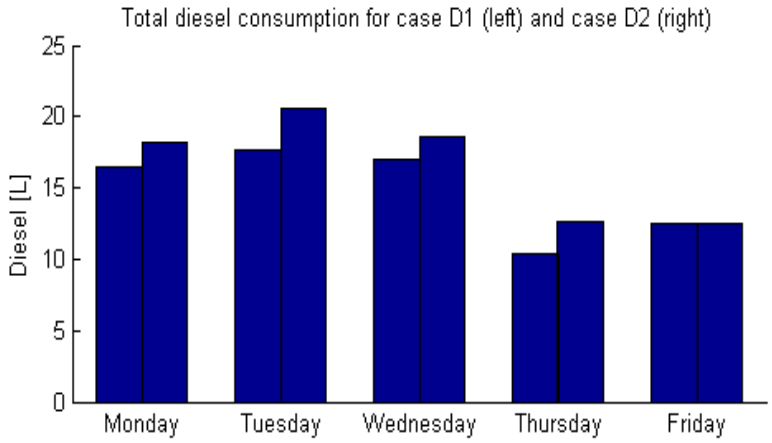
The third and fourth cases rely a routing and fleet managing application of the knowledge gained from the first two cases. The routing and loading of the vehicle is changed so that the deliveries that were previously carried out during one single shift now can be conducted in two shifts per working day. This means that we only use one vehicle but increase the utilization of that vehicle. The switch from one shift to two shifts influences the deliveries, environmental performance and costs.

The distribution of weights during the transport missions




Total energy consumption for case E1 (left) and case E2 (right)
Energy [kWh]
0
20
40
60
80
100
Monday
Tuesday
Wednesday
Thursday
Friday


Total equivalent energy consumption for case D1 (left) and case D2 (right)
Energy [kWh]
0
50
100
150
200
250
Monday
Tuesday
Wednesday
Thursday
Friday


Total diesel consumption for case D1 (left) and case D2 (right)
Diesel [L]
0
5
10
15
20
25
Monday
Tuesday
Wednesday
Thursday
Friday

Fuel/energy consumption

	2015	2020	2025
Amount of fuel (liters) for one year (D1)	3 358	3 193	3 037
Amount of fuel (liters) for one year (D2)	3 739	3 555	3 381
Amount of kWh for one year (E1)	14 163	14 005	13 902
Amount of kWh for one year (E2)	15 290	15 145	15 032
Cost of fuel for one year (D1)	5 742	6 323	6 833
Cost of fuel for one year (D2)	6 393	7 040	7 608
Cost of energy for one year (E1)	1 467	1 721	1 976
Cost of energy for one year (E2)	1 584	1 861	2 137

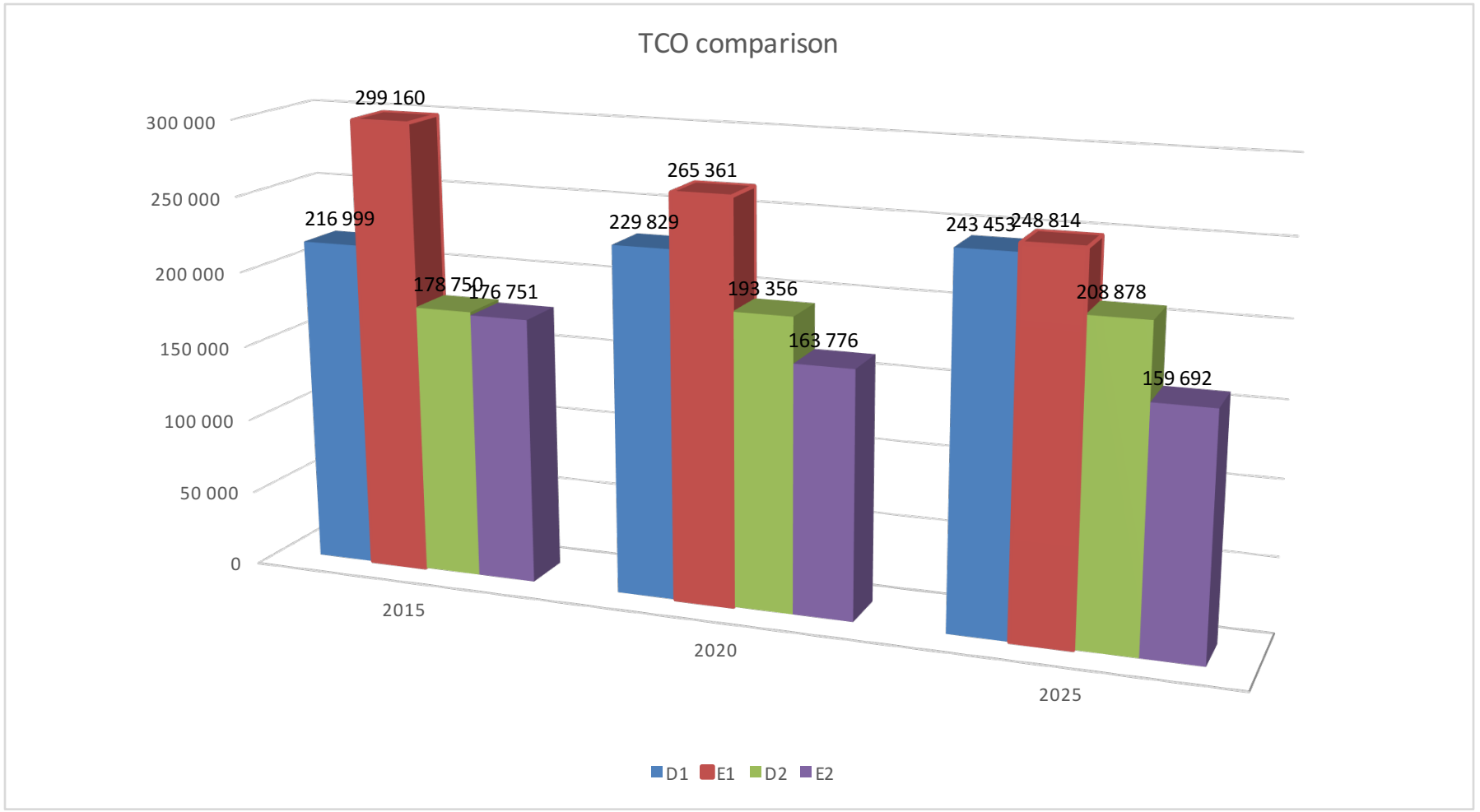
Price prognosis for input variables

Production year	Total cost of EV	Cost of EV powertrain	Cost of Battery	Total cost of ICE vehicle	Cost of ICE engine
2015	128 000	25 500	72 900	53 100	14 300
2020	108 000	24 000	57 500	53 100	14 300
2025	96 400	22 500	45 400	53 100	14 300

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Expected fuel price (Euro/liter)	1,71	1,76	1,82	1,87	1,93	1,98	2,03	2,09	2,14	2,20	2,25
Expected electricity price (Euro/kWh)	0,10	0,11	0,11	0,12	0,12	0,12	0,13	0,13	0,13	0,14	0,14
Salary (Euro/h)	25,00	25,28	25,98	26,79	27,57	28,34	29,10	29,86	30,63	31,40	32,22
Pay supplement (Euro/h)	5,25	5,31	5,46	5,63	5,79	5,95	6,11	6,27	6,43	6,59	6,77
CPI (source NIER)		1,10	2,80	3,10	2,90	2,80	2,70	2,60	2,60	2,50	2,60

Resale value/Age	1	2	3	4	5	6	7	8	9	10
D1, E1 (10 years)	80%	73%	67%	60%	53%	47%	40%	33%	27%	20%
D2, E2 (5 years)	73%	60%	47%	33%	20%					

		Costs (€)			Share (%)		
		2015	2020	2025	2015	2020	2025
D1	Vehicle	106 200	106 200	106 200	48,9%	46,2%	43,6%
	Maintenance	59 783	68 174	77 409	27,6%	29,7%	31,8%
	Fuel	51 015	55 455	59 844	23,5%	24,1%	24,6%
	Total	216 999	229 829	243 453	100,0%	100,0%	100,0%
E1	Vehicle	256 000	216 000	192 800	85,6%	81,4%	77,5%
	Maintenance	29 892	34 087	38 704	10,0%	12,8%	15,6%
	Fuel	13 269	15 274	17 310	4,4%	5,8%	7,0%
	Total	299 160	265 361	248 814	100,0%	100,0%	100,0%
D2	Vehicle	53 100	53 100	53 100	29,7%	27,5%	25,4%
	Maintenance	68 853	78 517	89 152	38,5%	40,6%	42,7%
	Fuel	56 797	61 740	66 626	31,8%	31,9%	31,9%
	Total	178 750	193 356	208 878	100,0%	100,0%	100,0%
E2	Vehicle	128 000	108 000	96 400	72,4%	65,9%	60,4%
	Maintenance	34 426	39 258	44 576	19,5%	24,0%	27,9%
	Fuel	14 325	16 517	18 716	8,1%	10,1%	11,7%
	Total	176 751	163 776	159 692	100,0%	100,0%	100,0%


TCO comparison
300 000
250 000
200 000
150 000
100 000
50 000
0
299 160
216 999
178 750
176 751
265 361
229 829
193 356
163 776
248 814
243 453
208 878
159 692
2015
2020
2025
D1
E1
D2
E2

Including salaries for two shifts

	2015	2020	2025
D1 wages and TCO for 8 years	973 066	1 096 980	1 232 858
E1 wages and TCO for 8 years	1 005 330	1 095 937	1 209 373
Net value of electrification to operator	-32 263	1 043	23 485
D2 wages and TCO for 8 years	1 025 219	1 161 114	1 310 123
E2 wages and TCO for 8 years	998 271	1 113 246	1 246 514
Net value of electrification to operator	26 947	47 868	63 609
Net value from shifting between D1 and E2	-25 205	-13 409	-7 329

- The cost of unsocial hours was greater than the benefit of increased utilization of the EVs. Keeping the amount of unsocial hours down, while maximizing the utilization rate of the EV is therefore paramount.
- Considering these results, a shift to electric trucks seems feasible in the coming years.
- However, an introduction of EVs might require other changes in the logistics value chain. Changes that need to be introduced in cooperation with relevant stakeholders.

Things to consider

Shifts work would, for example, influence the entire distribution chain (Holguín-Veras et al., 2014) and probably also incur extra costs in form of supplementary pay for personnel at depot etc. Furthermore it is necessary to keep in mind that higher utilization rate incurs increased maintenance etc.