eHUBS - Smart Shared Green Mobility Hubs

Deliverable 6.1

Midterm report on effects (in terms of CO_2 emission) for blueprint

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This document describes and explains the method used for calculating CO2 emission changes due to eHUBS implementation and presents the results for all pilot cities (for which data is available).

1. Scope of study

Shared mobility can affect CO_2 emission via several mechanisms: it can reduce VMT (Vehicle Miles Travelled) by private car, substitute other travel modes, reduce private car ownership by shedding existing cars and suppressing expected car purchase, and reduce congestion and enable higher speed. In this impact estimation we only consider the CO_2 emission change due to travel mode substitution.

Regarding the emission calculation of electric modes, although their road emission is zero, we account for the CO_2 emission during electricity generation.

eHUBS can include many different types of shared vehicles. In this calculation we will consider electric car, e-bike and e-cargo bike, since there are the modes available in most current eHUBS.

2. Methodology

Since eHUBS consists of multiple types of shared vehicles, we will calculate the emission change brought by each type and then sum it up for the total change.

For each type of shared vehicle, the emission change is calculated by

$$Emission\ change\ = Emission\ of\ shared\ mobility\ trips - Emission\ of\ trips\ replaced\ by\ shared\ mobility \qquad 1)$$

The first term on the right side of the equation 1) can be calculated as below:

$$Emission\ of\ shared\ mobility\ trips\ = Kilometers\ travelled\ with\ shared\ vehicle * Emission\ of\ shared\ vehicle\ per\ km \qquad 2)$$

In which:

$$Kilometers\ travelled\ with\ shared\ vehicle = Number\ of\ shared\ vehicle\ trips * Average\ distance\ of\ shared\ vehicle\ trips \qquad 3)$$

$$Emission\ of\ shared\ vehicle\ per\ km = Shared\ vehicle\ energy\ efficiency\ (kWh) * CO_2\ emission\ factor\ of\ electricity\ generation \qquad 4)$$[1]

If possible, average distance of shared vehicle trips can be obtained from user surveys. For energy efficiency of shared vehicles, we use a general average value from literature. The CO_2 emission factor of electricity generation differs by country (Roukouni and Correia 2021).

The calculation of emission by replaced modes is similar:

$$Emission\ of\ trips\ replaced\ by\ shared\ mobility\ = \sum_{i=car,public\ transport}(Kilometers\ travelled\ with\ replaced\ mode\ i * Emission\ of\ replaced\ mode\ i\ per\ km) \qquad 5)$$

In which:

$$Kilometers\ travelled\ with\ replaced\ mode\ i = Kilometers\ travelled\ with\ shared\ vehicle * Percentage\ of\ replaced\ mode\ i \qquad 6)$$

If the percentage of replaced mode *i* is x%, it means that *x%* of the shared mobility trips used to be conducted by mode *i*. If data allows, this value can be derived from user surveys.

As for the emission of replaced modes: private car CO_2 emission depends on the average age of private car fleet and the location (country) of the city (Roukouni and Correia 2021); public transport

[1] Because all HUBS shared vehicles are powered by electricity.

CO_2 emission depends on the population of the city (Roukouni and Correia 2021); the emission of active modes is zero.

3. Survey data and input parameters

3.1 Data from the user survey

The initial idea is to obtain values of some input parameters from user surveys, such as average frequency of shared mobility use per person, average distance of shared mobility trip, and split of replace modes. In order to do so, we asked people the frequency they use shared mobility and detailed information regarding their last shared mobility trip.
In total we obtained 980 responses from the second survey, of which 247 are shared mobility users.
Table 1 shows the number of shared mobility users from each city and the distribution of the mode they use for their last trip by shared mobility. Since the sample is so small and not necessarily representative, it does not allow us to estimate these input parameter values with high confidence. The values of those input parameters will thus be determined both by survey results and research literature.

Table 1. Number of shared mobility users from each city, categorized by the mode of their last trip by shared mobility

	Shared car	Shared bike	Shared cargobike	Shared e-car	Shared e-bike	Shared e-cargobike	Shared e-scooter	Total
Arnhem/Nijmegen(NL)	4	11	3	7	5	2	2	34
Amsterdam (NL)	25	22	7	20	18	3	9	104
Leuven (BEL)	41	11	8	6	2	11	2	81
Dreux (FRA)	0	3	1	1	5	1	1	12
Kempten (GER)	0	0	0	2	0	0	0	2
Others	2	4	1	2	1	2	1	13
Total	72	51	20	38	31	19	15	246

3.2 Input parameters

3.2.1 Number of daily trips

There are two ways of calculating the total number of daily trips conducted by shared mobility: the first is estimating the average number of daily trips per person then scaling up by the number of users; the second is estimating the average number of daily trips per vehicle then scaling up by the number of shared vehicles. If we were able to obtain a sizeable and representative sample of shared mobility users, we could have applied the first method; however, we cannot use this method because 1) the measurement of the usage frequency of occasional users is not accurate enough: the lowest level of usage frequency in our survey is "once a month or less", while this is still a wide range (ranging from 1-12 day per year); 2) it is uncertain whether our sample is representative in terms of the proportion of occasional and frequent users, which can greatly affect the estimate of average trip per person since the usage frequency of these two groups differ greatly.

Therefore we decided to adopt the second method. We assume that each shared bike/car will be used for 5 trips per day. Table 2 lists the number of shared vehicles in each city. We assume the ratio between e-bikes and e-cargo bike is 3:1. These parameters can easily be adjusted if the cities have updated data or estimate regarding these two parameters.

Table 2. Number of shared vehicles in each city (used in this impact study)[2]

	Nijmegen	Leuven	Manchester	Dreux	Kempten	Amsterdam
Total LEV	134	71	400	18	14	876
E-bike	104	30	55	15	0	62
E-cargo bike	30	41	25	3	14	114
EV	52	7	12	3	4	609

3.2.2 Average distance per trip by shared mobility

The survey respondents answered the distance of their last shared mobility trip. The highest level of response is "7km or longer", therefore we calculate an interval for the average estimate when this response corresponds to 7-10km (we assume eHUBS are mostly used for intra-city short trips not more than 10km). Table 3 lists the values from previous literature, estimates based on the user survey and the values we adopted in the calculation.

Table 3. Average distance per trip by shared mobility

Shared mobility mode	Value from literature	Estimate from survey (km)	Number of survey responses	Value used in this study (km)
Shared car/EV	6-10 km (Rodenbach et al. 2018)	6-8	111	7
Shared e-bike	8.3 km[3] 4.6 km[4] 4.2 km[5]	4.8-5.9	30	5
Shared e-cargobike	15.5 km (Becker and Rudolf 2018)	5-6	19	6

3.2.3 Mode substitution

Table 4 lists the mode split estimate from the survey, values of other comparable services in previous literature, and the values we used in this study. Since we only have a small sample, we contrast the estimates based on the survey with values from previous literature and calibrate when we think it is necessary.

Table 4. Split between modes replaced by shared mobility

		Car	PT	Active modes	Generated trips
Shared (electric) car	Survey (111 responses)	36.0%	33.3%	14.4%	16.2%
	Literature 1, Netherlands (Nijland and van Meerkerk 2017)	39%	39%	6%	16%
	Final values used	**39%**	**39%**	**6%**	**16%**
Shared e-bike	Survey (31 responses)	25.9%	16.1%	48.4%	9.7%
	Literature 1, Poland (Suchanek et al. 2021)	21.8%	40.7%	37.5%	
	Literature 2, UK[6]	46%	20%	34%	
	Literature 3, private e-bike (Bigazzi and Wong 2020)	24%	33%	37%	
	Final values used	**26%**	**30%**	**38%**	**6%**

[2] Some cities also deployed e-scooters and e-mopeds under the eHUBS project, but the impact of these shared vehicles are not accounted for in this study.
[3] https://us.steergroup.com/sites/default/files/2018-10/NABSA%20Presentation_20180609.pdf
[4] https://drive.google.com/file/d/16i7AP14KnLSsbSjlSSNSc050tynykYqI/view
[5] https://sf.streetsblog.org/2018/03/16/data-shows-jump-bikes-are-filling-their-niche/
[6] https://us.steergroup.com/sites/default/files/2018-10/NABSA%20Presentation_20180609.pdf

Shared e-cargobike	Survey (19 responses)	57.9%	5.3%	31.6%	5.3%
	Survey, (non-electric) shared cargobike (20 responses)	40%	10%	30%	20%
	Literature 1, Germany (Becker and Rudolf 2018)[7]	46.6%	9.6%	31%	12.8%
	Final values used	**57%**	**6%**	**31%**	**6%**

3.2.4 Shared vehicle energy efficiency

Table 5 lists the values taken from previous literature.

Table 5. Shared vehicle energy efficiency

Shared mobility mode	Value from literature (Wh/km)	Value used in this study (Wh/km)
Shared car/EV	170 (Roukouni and Correia 2021)	170
Shared e-bike	5-15[8]	10
Shared e-cargobike	9-18 (Narayanan and Antoniou 2022)	13

4. Results for each city

Table 6 presents the results of the CO_2 impact evaluation given the current implementation condition of eHUBS. The first three columns show how much CO_2 change each shared vehicle would bring on a daily basis. We notice that the daily CO_2 reduction of shared EV significantly depends on the emission factor of electricity generation: the benefits of shared EVs are significantly less in Dutch cities due to the high emission factor of electricity generation in the Netherlands. The fourth column is the daily CO_2 change of all deployed shared vehicles (according to Table 2). The fifth column gives an indication of the annual CO_2 emission reduction due to eHUBS implementation.

Table 6. CO_2 emission change due to eHUBS implementation

City	Daily CO_2 change of each shared EV (kg)	Daily CO_2 change of each shared E-bike (kg)	Daily CO_2 change of each shared E-cargo bike (kg)	Daily CO_2 change of planned eHUBS (kg)	Annual CO_2 change of planned eHUBS (t)
Amsterdam	1.85	2.20	3.33	1644.3	600.2
Leuven	3.83	2.45	3.43	241.1	88.0
Nijmegen/Arnhem	1.99	2.28	3.35	440.8	160.9
Manchester	3.11	2.33	3.61	255.4	93.2
Dreux	4.43	2.45	3.41	60.3	22.0
Kempten	2.72	2.55	3.76	63.5	23.2

Table 7 presents the results of the expected CO2 impact if all planned shared vehicles in eHUBS are fully implemented. The number is based on the total number of planned “Shared e-Bikes, e-Cargo / e-Family / e-scooters” and the ratio between shared e-bike and e-cargo bike is assumed to be 3:1. If the number of planned vehicles is lower than the number of actually deployed vehicles, then the actual number is used.

[7] The systems investigated in this study have both non-electric and electric cargo bikes.
[8] https://www.ebikes.ca/documents/Ebike_Energy.pdf

Table 7. Expected CO_2 emission change if eHUBS are fully implemented as planned

City	Number of EVs	Number of e-bikes	Number of e-cargo bikes	Daily CO_2 change of planned eHUBS (kg)	Annual CO_2 change of planned eHUBS (t)
Amsterdam	609	900	300	4110.19	1500.22
Leuven	40	123	41	595.6	217.4
Nijmegen/Arnhem	52	146	49	600.2	219.1
Manchester	12	75	25	301.9	110.2
Dreux	13	30	10	165.2	60.3
Kempten	4	42	14	170.7	62.3

Reference

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