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Quantifying the benefits of car-free days and home working in European Cities

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1 Introduction

Ricardo Energy and Environment has been commissioned by the Clean Cities Campaign to carry out an analysis of the potential benefits of measures to reduce fuel consumption in cities in the EU and UK. The Clean Cities Campaign is a European coalition that is hosted by "Transport & Environment" and unites more than 60 organisations campaigning for active, shared and electric mobility for a more liveable and sustainable urban future.

This pilot study was commissioned to quantify the potential reduction in consumption of petroleum products from two measures which have recently been the subject of discussion as part of a wider effort around reducing oil consumption:

- Car-free days. These are days where the metropolitan area is closed to private vehicle traffic. Typically, public vehicles continue to operate and exemptions are available for some citizens based on need.
- Home working initiatives, where employees within the metropolitan area work from home rather than commuting into their typical place of work. This analysis does not include commuting into the metropolitan area from outside.

The impact of these measures on fuel consumption has been calculated for a shortlist of four cities in the EU and UK, comprising Brussels, London, Manchester and Prague. The shortlist of cities to be included in the study was led by an initial literature review to identify cities with relevant data, and was decided in discussion with the Clean Cities Campaign. The range of cities included in this analysis could be expanded to include more cities in future.

The results for these four cities were then extrapolated to estimate the potential overall benefits from implementing similar measures in all cities defined as urban nodes in the current proposal for the review of the EU's Trans-European Transport Networks (TEN-T) as well as in all UK cities with more than 200,000 inhabitants. Previous research suggests that in order to have a significant impact on traffic, these policies should not be seen in isolation but be part of a set of complementary policies[1]. The International Energy Agency, for example, has recently put forward a "10-Point Plan to Cut Oil Use" that contains a wide range of measures.[2]

This report describes the general approach taken to calculate fuel reductions (Section 2) and presents the results of the calculations (Section 3). The study conclusions are presented in Section 4.

[1] https://link.springer.com/article/10.1007/s40572-022-00342-y
[2] https://www.iea.org/reports/a-10-point-plan-to-cut-oil-use

2 Methodology

The average reduction in daily fuel consumption from implementing a car-free day for a single day can be calculated using the following formula:

$$Reduction\ in\ fuel\ consumption = Average\ daily\ fuel\ consumption\ by\ cars\ in\ the\ city\ \times$$
$$day\ of\ week\ factor\ \times \%\ reduction\ due\ to\ car\ free\ day$$

There is a significant degree of uncertainty around the impacts of large-scale car-free days on annual average traffic flows, as there are limited examples of car-free days covering entire cities. Furthermore, it is to be expected that these days are associated with some degree of temporal and/or spatial trip displacement. For example, if a Sunday is designated a car-free day, shoppers may shift their shopping to the preceding Saturday rather than cancelling it entirely. To reflect this uncertainty, we have calculated reductions for a range of reduction efficiencies from 70% (representing the lower limit of likely efficiency) to 90% (representing a reasonable upper limit for efficiency).

The average reduction in daily fuel consumption from implementing working from home for a single day can be calculated using the following formula:

$$Reduction\ in\ fuel\ consumption = Average\ weekday\ fuel\ consumption\ \times$$
$$\%\ of\ weekday\ trips\ that\ are\ commutes\ \times \%\ reduction\ due\ to\ teleworking\ measures$$

The total reduction in fuel consumption can be scaled up to calculate the reduction from multiple such days in a year. This reduction can then be compared with the annual mean fuel consumption.

Not all jobs can be carried out from home; a study published by the UK Office for National Statistics on home working during the coronavirus pandemic found that 57% of people living in London did some work at home in April 2020. There is considerable uncertainty regarding the effectiveness of home working initiatives in cities; we consider that this value represents a reasonable upper limit, when considering that some individuals were already working from home during the period that relevant traffic statistics are available. We have therefore calculated reductions for a range of reductions in commuting, from 40% reduction (representing a reasonable lower limit of potential effectiveness of this measure) to 60% reduction (representing a reasonable upper limit for the effectiveness of this measure).

In order to estimate the potential total reduction in petroleum product consumption resulting from the implementation of car-free days or home working days within cities across Europe, the simple average per capita reduction across the four cities was calculated. This per capita reduction was then extrapolated to cover the populations of all cities defined as urban nodes in the current proposal for the review of the EU's Trans-European Transport Networks (TEN-T) [3] as well as in all UK cities with more than 200,000 inhabitants. Details of the inputs to these calculations are given below.

2.1 Average daily fuel consumption

In order to calculate the potential reduction in consumption of petroleum products from car-free days and home working, the average fuel consumption by cars in each city was calculated using the approach described in the EMEP/EEA air pollutant emission inventory guidebook 2019 chapter 1.A.3.b.i-iv Road transport.[4] In this methodology, daily fuel consumption from road transport can be calculated using the formula below:

$$Fuel\ consumption = \Sigma_{j,k}\ [M_{d,j,k} \cdot EF_{j,k}]$$

Where:

[3] https://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&lg=EN&type_doc=COMfinal&an_doc=2021&nu_doc=0812

[4] EMEP/EEA air pollutant emission inventory guidebook 2019:1.A.3.b.i-iv Road transport 2019, published 17th October 2019, https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

$M_{d,j,k}$ = total annual distance driven by all vehicles of category j and technology k on day d, and $EF_{j,k}$ = technology-specific fuel consumption factor for vehicle category j and technology k The vehicle categories j are split on the following characteristics:

- Vehicle class (car, LGV, HGV, motorcycles);
- Fuel used (petrol, diesel, LPG);
- Engine size.

2.1.1 Fuel consumption factors

Fuel consumption factors from the latest version of the EMEP/EA air pollutant emission inventory guidebook were used. These factors are presented in Table 1. These average European fuel consumption factors were developed from more detailed calculations including typical values for driving speeds, ambient temperatures, and trip lengths.

Table 1: EMEP Tier 2 average fuel consumption values for petrol and diesel cars (sector 1.A.3.b.i-iv)

Sub-category	Fuel Consumption (g/km)
Petrol Mini	49.0
Petrol Small	56.0
Petrol Medium	66.0
Petrol Large-SUV-Executive	86.0
Diesel Small	38.0
Diesel Medium	55.0
Diesel Large-SUV-Executive	73.0
LPG	57.0

The available fleet data in the selected cities provides the vehicle size in terms of engine displacement, measured in cubic centimetres (cc). For the purposes of this study it was assumed that the following engine displacement ranges correspond to the size categories in Table 1:

- Small: < 1400 cc;
- Medium: 1400 – 2000 cc;
- Large: > 2000 cc.

2.1.2 Activity and trip purpose data

In order to carry out this calculation, estimates of the total annual distance driven by different vehicle categories in each city on weekdays, Saturdays, and Sundays are required. The distance travelled was calculated from available activity and vehicle fleet data for each city using the formula

$$Average\ daily\ traffic\ (veh\ km) = (Total\ annual\ distance\ travelled\ by\ all\ cars\ \times\ proportion\ of\ vehicles\ in\ category\ j\ \times day\ of\ week\ factor)/\ 365$$

For each city, data was acquired from the following sources in order of preference:

- Statistics published by national/local government bodies or organizations reporting to them;
- Results from national traffic surveys;
- European-level statistics published by Eurostat.

Priority was given to data that was local, and which included time series indicating consistency and accuracy of data capture. Where multiple years of data were available, data for the most recent pre-2020 year was used. Data from 2020 and 2021 was eliminated from the study as the impacts of the coronavirus pandemic on global traffic flows renders data for these years unrepresentative of typical traffic conditions.

The key input data used in the activity data calculation are summarised in Table 2. Data quality ratings are provided for each input on a scale ranging from A (best quality) to E (worst quality); these were determined using professional judgment, based on the criteria described above.

Table 2: Key input data for each city, including data source, year, region, and overall quality rating

City	Input data	Source	Region	Year	Quality
Brussels	Traffic activity	Service public federal Mobilite et Transports: Kilometres parcourus par les vehicules belges en 2017	Brussels	2017	A
	Fleet data	StatBel	Belgium	2019	B
	Weekly traffic profiles	Cahiers de l'Observatoire de la mobilité: Les pratiques de déplacement à Bruxelles de la Région de Bruxelles-Capitale	Brussels	2014	B
	Trip purpose	Cahiers de l'Observatoire de la mobilité: Les pratiques de déplacement à Bruxelles de la Région de Bruxelles-Capitale	Brussels	2014	B
London	Traffic activity	Department for Transport (DfT): Road traffic statistics	Greater London	2019	A
	Fleet data	Department for Business, Energy and Industrial Strategy: NAEI Emission Factors for Transport	Greater London	2019	A
	Weekly traffic profiles	Department for Transport (DfT): Road traffic statistics	England (national)	2019	B
	Trip purpose	National Travel Survey (published by DfT)	England (national)	2019	B
Manchester	Traffic activity	Department for Transport (DfT): Road traffic statistics	Greater Manchester	2019	A
	Fleet data	Department for Business, Energy and Industrial Strategy: NAEI Emission Factors for Transport	England urban	2019	B
	Weekly traffic profiles	Department for Transport (DfT): Road traffic statistics	England (national)	2019	B
	Trip purpose	National Travel Survey (published by DfT)	England (national)	2019	B
Prague	Traffic activity	TSK-Praha Prague Transportation Yearbook 2020	Prague	2019	A
	Fleet data	Czech Traffic Statistics System: Transport Yearbook 2020	Czechia	2019	B
	Weekly traffic profiles	TSK-Praha Prague Transportation Yearbook 2020	Prague	2020	A
	Trip purpose	Eurostat Passenger Mobility Statistics	Average of EU countries	2019	D

2.2 Population data

Population data were acquired from various data sources for each city; details are provided in Table 3.

Table 3: Population data and sources for study cities

City	Population (1000s)	Source
Brussels (Brussels Capital Region)	1,219.97	Statbel
London (Greater London)	8,866.54	London Datastore
Manchester (Greater Manchester)	2,848.29	UK Office for National Statistics
Prague	1,335.08	Czech Statistical Office

The list of additional urban centres across Europe to be considered in the pan-European reduction calculation was based on the urban nodes in the current proposal for the review of the EU's Trans-European Transport Networks (TEN-T) [5]. This list covers cities in the EU27. Cities in the United Kingdom with more than 200,000 residents were added to the list of EU cities.

Population data for these cities was obtained from statistics for city areas published by Eurostat[6]. Where this database did not include sufficient information, population data was derived from locally-published statistics. The total population of the EU 27 cities is 134 million; the total population including UK cities is 164 million, representing approximately 25% of the population of Europe (not including Turkey or Russia).

2.3 EU fuel consumption statistics

Eurostat publishes statistics for fuel usage by different sectors across Europe[7]. The average reduction from implementing a car-free weekday across the EU27 countries is presented relative to total fuel use across the EU27 in the table below.

Table 4: Total EU oil consumption in 2020, million tonnes of oil equivalent

Sector	Total annual oil consumption 2020
All sectors	600.0
Road transport	289.1

2.4 Other assumptions

In practice, the details of the implementation of car-free days and home working will be highly dependent on the specific circumstances of each city. The effectiveness of the measures would also be expected to vary depending on the details of the implementation. This study is designed to quantify the maximum potential benefit that could result from implementing these measures in cities, and as such in each city, the area encompassed by the measure is assumed to contain the entire city, including all roads within its boundary. This represents the maximum feasible area for any measures implemented on the city level.

To calculate the potential reductions associated with implementing these measures in cities across the European Union and UK, the average per capita fuel reduction across the 4 cities (using a simple average rather than a population-weighted mean in order to avoid overrepresenting larger cities) was scaled to the population of the list of cities defined above.

[5] https://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexplus!prod!DocNumber&lg=EN&type_doc=COMfinal&an_doc=2021&nu_doc=0812
[6] https://ec.europa.eu/eurostat/web/population-demography
[7] Eurostat: Energy statistics - an overview, February 2022

Conversion factors for fuel units were calculated using approximate conversion factors by fuel type from the Statistical Review of Energy[8], published by bp.

3 Results

3.1 Car-free days

Tables 5 and 6 present the predicted potential reduction in fuel usage through the implementation of a single car-free day, provided as litres of fuel saved and barrels of crude oil respectively. Upper and lower bounds, representing a reasonable range of levels of effectiveness, are provided.

Table 5: Reduction in gasoline and diesel usage through the implementation of one car-free day, 10^6 litres, upper (90% effective) and lower (70% effective) bounds

City	Weekday		Saturday		Sunday	
	Upper	Lower	Upper	Lower	Upper	Lower
Brussels	1.29	1.00	1.07	0.83	0.86	0.67
London	5.59	4.35	4.99	3.88	4.50	3.50
Manchester	3.36	2.61	3.00	2.33	2.70	2.10
Prague	1.45	1.13	1.09	0.85	1.00	0.78
All major EU 27 cities	133	104	112	87	98	76
EU27 + UK cities > 200000	163	127	136	106	120	93

Table 6: Reduction in gasoline and diesel usage through the implementation of one car-free day, thousand barrels of oil equivalent, upper (90% effective) and lower (70% effective) bounds

City	Weekday		Saturday		Sunday	
	Upper	Lower	Upper	Lower	Upper	Lower
Brussels	7.5	5.9	6.3	4.9	5.1	3.9
London	31.7	24.7	28.3	22.0	25.5	19.9
Manchester	19.1	14.8	17.0	13.2	15.4	11.9
Prague	8.2	6.4	6.2	4.8	5.7	4.4
All major EU 27 cities	763	593	638	497	562	437
EU27 + UK cities > 200000	932	725	780	607	678	534

Table 7: Reduction in gasoline and diesel usage through the implementation of one car-free day, kilotonnes oil equivalent, upper (90% effective) and lower (70% effective) bounds

City	Weekday		Saturday		Sunday	
	Upper	Lower	Upper	Lower	Upper	Lower
Brussels	1.0	0.7	0.8	0.6	0.7	0.5
London	4.0	3.0	3.6	2.8	3.2	2.5
Manchester	2.4	1.8	2.1	1.7	1.9	1.5
Prague	1.0	0.7	0.8	0.6	0.7	0.6
All major EU 27 cities	104	81	87	68	77	60
EU27 + UK cities > 200000	127	99	106	83	92	73

[8] https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-approximate-conversion-factors.pdf

3.2 Home working

Tables 7 and 8 present the predicted potential reduction in fuel usage through the implementation of a single day of home working, provided as litres of fuel saved and barrels of crude oil respectively. Upper and lower bounds, representing a reasonable range of levels of effectiveness, are provided.

Table 7: Reduction in gasoline and diesel usage through the implementation of a home working day, 10^6 litres, upper and lower bounds

City	Upper (60% effective)	Lower (40% effective)
Brussels	0.30	0.20
London	1.06	0.71
Manchester	0.52	0.34
Prague	0.36	0.24
All major EU 27 cities	27.5	18.4
EU 27 + UK cities > 200000	33.6	22.4

Table 8: Reduction in oil usage through the implementation of a home working day, thousand barrels of oil equivalent, upper and lower estimates

City	Upper (60% effective)	Lower (40% effective)
Brussels	1.8	1.2
London	6.0	4.0
Manchester	2.9	2.0
Prague	2.0	1.4
All major EU 27 cities (mbl)	158	105
EU 27 + UK cities > 200000 (mbl)	193	129

Table 8: Reduction in oil usage through the implementation of a home working day, kilotonnes oil equivalent, upper and lower estimates

City	Upper (60% effective)	Lower (40% effective)
Brussels	0.23	0.15
London	0.75	0.50
Manchester	0.37	0.24
Prague	0.26	0.17
All major EU 27 cities (mbl)	22	14
EU 27 + UK cities > 200000 (mbl)	26	18

3.3 Uncertainty Analysis

The main source of uncertainty in these calculations is the input data, particularly around vehicle activity, traffic fleet, weekly traffic profiles and trip purpose. The level of uncertainty associated with each input varies by city, and is reflected in the quality rating assigned in Table 2.

The traffic activity data has been rated as “A” for all cities. Across all four cities, total distance travelled by cars in the city region is available from statistics published by local government bodies or organisations reporting to them. Data is not always available for 2019; for Brussels, the most recent available dataset is for 2017. However, it is considered that these statistics still provide a robust basis for the calculation, as historic traffic flows in the city are relatively stable over a timescale of a small number of years.[9]

Fleet data for all cities except London has been rated as “B”, as information is available from government statistics on the national level. For London, detailed fleet information covering all the required vehicle categories is published by the UK Department for Business, Energy and Industrial Strategy (BEIS). As such, the data quality for London has been rated as “A”.

Weekly traffic profile data for Prague is available from published statistics; for all other cities, traffic profile data was only available at a national level. The quality rating for Prague is therefore “A”, while the quality rating for other cities is “B”.

National trip purpose information for London and Manchester was taken from National Travel Survey data published by the UK Department for Transport. In Brussels, city-specific data is available, but trip purpose is not split by travel mode, and as such the data quality rating is “B”. However, for Prague, no information was available. Instead, the average of EU27 countries reporting trip intention figures in urban areas has been used, and as a result the home working calculations for Prague are significantly more uncertain than for other cities. The data quality rating for Prague is therefore “D”.

The impacts of car-free days on road transport are subject to a high level of uncertainty, which is reflected in the provision of upper and lower bounds for fuel consumption reductions rather than specific values.

The extrapolation calculation to consider the impacts of the proposed measures across all major EU27 and UK cities are subject to a significantly greater degree of uncertainty. No local data was used in these calculations, and as a result the accuracy of the calculation depends on the following assumptions:

1) impacts across major European cities are likely to be similar, and
2) that the 4 cities chosen are representative of cities across Europe.

The 4 cities in this study are relatively large compared to many of the cities considered in the extrapolation calculations, which may lead to them having more developed public transport infrastructure than other cities across Europe. It is also likely that the demographics of these cities may not represent average conditions across all cities in Europe, and as a result care should be taken when interpreting the results for Pan-European fuel reduction.

Eurostat publishes statistics for fuel usage from road transport across Europe. The average reduction from implementing a car-free weekday across all EU and UK cities included in the study represents 16% of the total daily petroleum product consumption by the transport sector in the EU28. This is a reasonable figure, given that the cities in the study represent 25% of the total population of these countries.

[9] https://mobilit.belgium.be/fr/mobilite/mobilite_en_chiffres/releve_des_kilometres_par_vehicules_belges

4 Conclusions

Across all four cities, implementation of car-free days is the more effective of the two measures analysed on an individual day basis. This is to be expected, as car-free days impact almost all trips in a city, while home working initiatives primarily impact commuting trips. However, an increase in home working could be a permanent and continuous change in travel patterns, whereas car-free days would be limited in time or to certain days of the week. In the longer term, therefore, home working could have the greater effect on fuel use if applied with a high level of ambition.

The implementation of car-free days in major cities across the EU27 and UK is estimated to save between 76 and 133 kilotonnes of oil equivalent per car free day. This represents between 4% and 8% of the average daily oil consumption across all sectors in these countries, and between 9% and 16% of the average daily oil consumption in the road transport sector.

Implementation of car-free days on weekdays is more effective in terms of reducing fuel use compared with Saturdays or Sundays, due to typically higher vehicle use on working days. However, implementing car-free days on weekdays represents a significant implementation challenge, and as a result many of the car-free days which have been implemented to date take place on Sundays, including those in Brussels.

The average barrels of oil equivalent saved per capita in the cities from the implementation of car-free days ranges from 0.002 barrels to 0.007 barrels oil equivalent per person per day, depending on the day of the measure, the city, and the assumed effectiveness of the measure. Effectiveness was higher in Brussels, Manchester and Prague compared to London, potentially reflecting the relatively high levels of public transport usage in London.

Implementing home working within major cities across the EU27 and UK is estimated to save between 18 and 26 kilotonnes of barrels of oil equivalent per day of home working. This represents between 1.1% and 1.6% of the total daily oil consumption in the EU27 + UK across all sectors in 2019, and between 2.2% and 3.3% of total daily oil consumption in the road transport sector in these countries. These calculations do not include commuting into the city from outside the metropolitan area.

The average barrels of oil equivalent saved per capita is significantly lower for home working measures, ranging from 0.0005 to 0.0015 barrels of oil equivalent per person per day. Home working measures are predicted to reduce fuel consumption more efficiently in Brussels and Prague than in Manchester and London, potentially reflecting that a larger proportion of journeys by car are commutes in these cities.