msa Manchester School of Architecture

Manchester Metropolitan University

Research and Design:
Innovative Digital Tools to Enable Greener Travel

Occupancy / Emissions Sustainability Metric Matrix

12.6.2 Report

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Contents

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Centre for Complexity Planning & Urbanism

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Aim and Objective

This report investigates occupancy/emission metrics for public and private domestic urban transport and develops an emissions/sustainability matrix for the future development of a 'Green Travel Planning Tool'.

The objective of this research is to

1. Review the current methods of estimating occupancy/emissions for various modes of transportation and to update these for accuracy.
2. Produce a sustainability/emissions matrix
3. Compare the metrics developed with results from existing journey planners producing their own estimates. Existing journey planners providing emission estimates typically use distance, estimated travel time and different modes of transpiration as factors. The matrix produced here incorporates multiple additional factors (e.g. travel speed, embodied energy use based on fuel type) in an attempt to accurately estimate emissions per journey.

The study includes the following:-

1. Identification of the latest average emissions for each mode of urban transport (normalised by occupancy)
2. A list of emissions occupancy estimation proxies and conversion factors where applicable
3. Identification of measurements and variables required for emissions and occupancy estimates.
4. A dynamic matrix that can be used to compute emissions results for new journey planners.

Abbreviations

GHG	Greenhouse Gases - Kyoto Protocol (IPCC 2014) covers emission of the seven main greenhouse gases - Carbon dioxide (CO_2), Methane (CH_4), Nitrous Oxide (NOx), Hydroflurocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluride (SF_6), Nitrogen trifluoride (NF_3)
CO_2	Carbon dioxide
BEV	Battery Electric Vehicles
PHEVs	Plug-in Hybrid Electric Vehicles
HEVs	Hybrid Electric Vehicles
IoT	Internet of Things

"What is the most sustainable mode of urban transport?"

On average, tram has the lowest emission (35.1g/pkm) based on average occupancy followed by train (98.76/pkm) followed by bus (101.1g/pkm) followed by car (116.1g/pkm) followed by motorcycle (117g/pkm).

When considering emission per person, the higher the number of passengers in a vehicle, the lower the emission per person.

At maximum capacity, tram has the lowest emission per person (513.8g/pkm), train with the second lowest (1196.2g/pkm), bus as thrid lowest (2425.5g/pkm), car not far off from bus (2587.8g/pkm) and in last place motorcycle with at least 6084.0g/pkm [1]

At minimum capacity - with single occupancy, motorcycle has the lowest emission per person (121.7/pkm), car with the second lowest (181.1g/pkm), tram as thrid lowest (1089.3g/pkm), bus as foruth (1212.8g/pkm) and in last place train (4784.9g/pkm) [2]

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[1] based on average GHG conversion factors
[2] based on average GHG conversion factors

"Which factors affect estimated transport emissions?"

Road specific

- Energy consumption per vehicle
    - Driving mode - acceleration, idling, cruising, acceleration and deceleration
    - Engine load - weight of vehicle plus passenger weight
    - Vehicle age and mechanical condition
    - Temperature and weather condition
    - Road gradients
- Average Travel speed
- Distance

Rail / Tram specific

- Energy consumption per vehicle
    - Type of rail (class) / tram (model)
    - Engine load - weight of vehicle plus passenger weight
    - Gradients/elevation
- Distance

"Is a journey in North Manchester greener than one in South Manchester?"

Potentially, for a car journey comparing two different areas if the average speed is different. For example an average petrol car travelling at average 30mph produces 1114.5g CO_2 per person emission whereas travelling at average 50mph produces a lower 1064.1g CO_2 per person.

In that sense, travelling down one road can be greener than travelling down another road next to it.

Executive summary

This report examines normalised emission metrics by occupancy for multiple modes of urban transportation, allowing a clear comparison of the total emissions produced per journey by mode of transport choices.

The research identifies the different methods of urban transport emission estimation (per journey), accounting for three different variables (proxies) - distance, travel speed and fuel consumption in the order of certainty in the estimation.

Emission conversion factors based on national/local average values and occupancy rates are identified and utilised in the emission/occupancy matrix.

There are limitations in using national/local average values, for example when comparing two roads of equal length with different average speed. An estimation with higher certainty can be produced with average speed data per road segment (link). Emission conversion factors based on average speed are identified and utilised in the emission/occupancy matrix.

Empirical measurements of travel speed, fuel consumption and occupancy per vehicle per journey can be captured and input into the methodology to provide emissions/occupancy estimations with higher certainty for a specific vehicle or service. Fuel consumption based on average speed are identified and utilised in the emission/occupancy matrix.

The produced matrix provides a transparent method of estimating emissions based on multiple variables involved in varied forms of urban transport, such as fuel type, speed, energy, distance and occupancy (averages can be used where specific inputs are missing). This is essential information for any city, transport authority or digital tool developer attempting to incorporate metrics in a ‘green transport App’ or in the longer term to estimate the environmental outcomes of planned urban transport infrastructure.

Emission/Occupancy Matrix

(double spread)

As demonstrated in the table below with the emission/occupancy estimate with a theoretical 100km journey, using the average CO_2 emission conversion factor over travel distance and the average occupancy rate per mode of transport, tram has the lowest emissions with 3514g /person followed by train with 4845g /person followed by bus with 10106g /person followed by car with 11612g /person and the highest emission comes from motorcycle with 11700g emission /person.

The estimate is different when other factors are considered. For example, the emission by bus estimated from average speed and energy consumption (5829g/person at average speed of 30mph and 6052g/person with average fuel consumption at 30mph) is significantly lower than the average emission estimation from the average conversion factor by travel distance (10106g /person).

		Proxy / Measure					Emission estimation gCO2e					
Mode of transport	**Fuel type**	**Speed**	**Energy consumption**	**Travel Distance**	**Occupancy per vehicle**	**travel distance (km)**	**assume average speed**			**assume enegy consumption**		
							30mph	50mph	70mph	30mph	50mph	70mph
							48 km/h	77 km/h	113 km/h	urban	rural	motorway
Passenger Car	Diesel					100.0	14224	13155	15348	5.3	4.9	5.7
	Petrol					100.0	17387	16643	18798	7.1	7.0	7.7
Motorcycle	Petrol					100.0	8859	9218	12180	3.7	4.1	4.7
Bus	Diesel					100.0	69942	65510	84700	27.1	24.0	27.1
Train note 1	Diesel					100.0	N/A	N/A	N/A	234.7		
	Electric					100.0	N/A	N/A	N/A	1038.0		
Tram note 2	Electric					100.0	N/A	N/A	N/A	397.0		

Note 1
Train fuel consumption based on ORR table 2.101 total electricity and diesel usage and train km from DfT rail statistics for 14/15, assuming a split of 40% diesel and 60% electric for vehicle-km

Note 2
According to TfGM "Metrolink switched from hydro power to 100% renewable energy generated by biomass", the calulation above uses the average GHG conversion factor for bioenergy of 16.1 g/kWh

Significant differences can be observed with the emission ranking order between the different mode of transport when other factors are considered. Using the CO_2 emission conversion factor for average speed applicable for road transportation, an average motorcycle has a lower emission (8518g/person, 8863g/person, 11711g/person) than an average petrol car (11145g/person, 10668g/person, 12050g/person) at average speeds demonstrated at 30mph, 50mph and 70mph. Similar results can be observed when using the CO_2 emission conversion factor for energy consumption as a basis for the matrix.

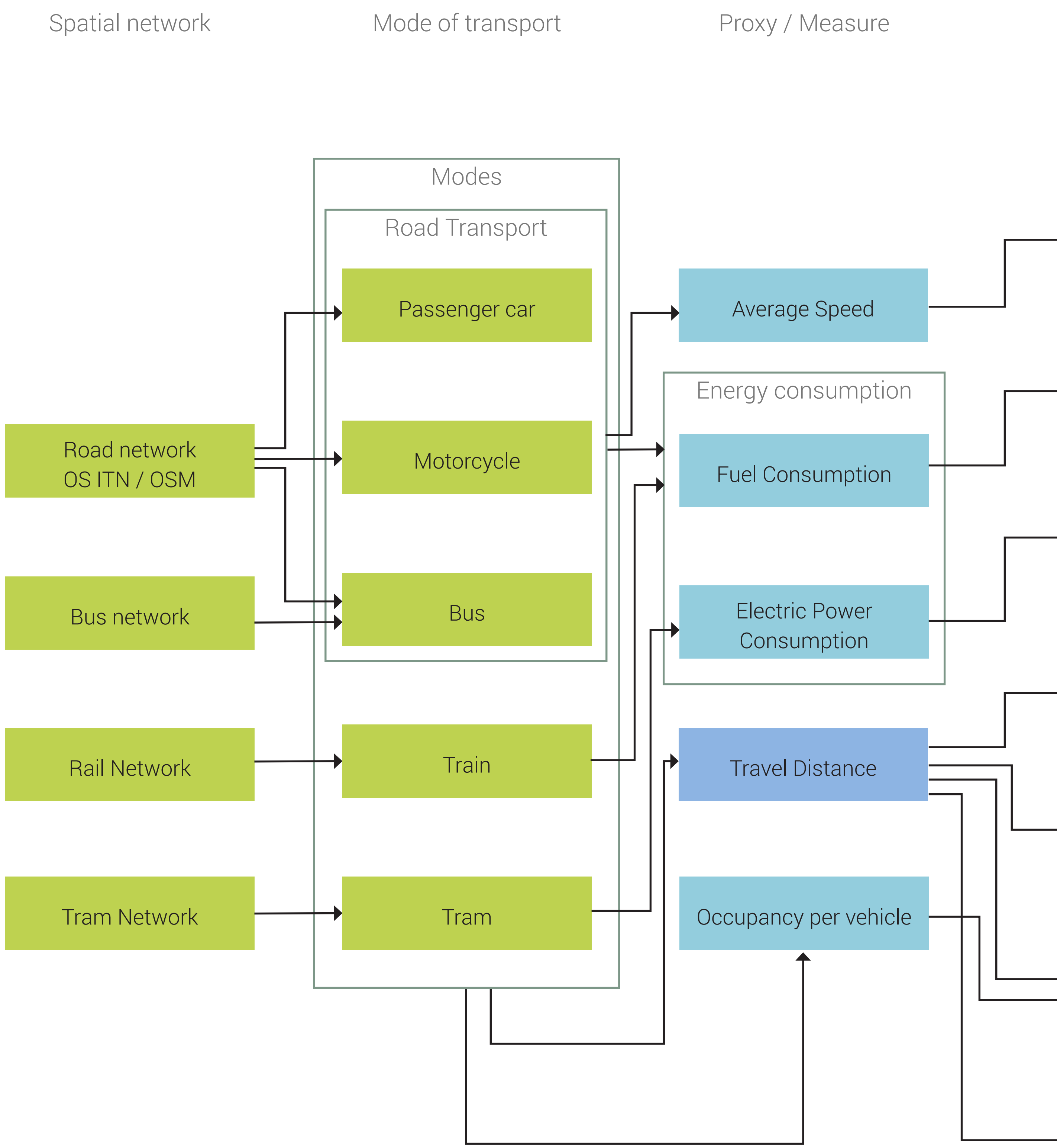
Emission
Low — High

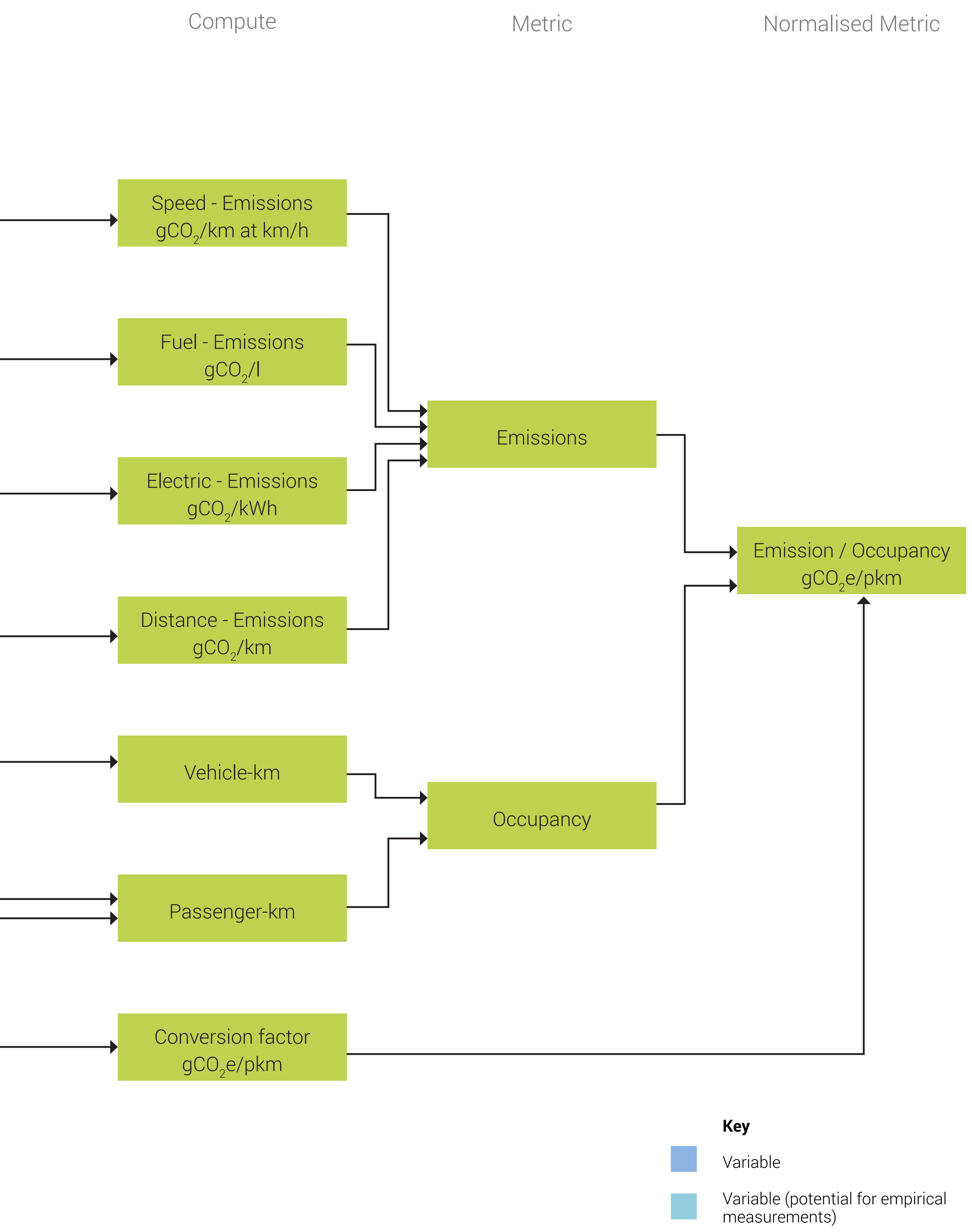
				Occupancy	Emission / Occupancy gCO2e / pkm						
by energy consumed			by travel distance	Occupancy per vehicle (National/Local Average)	by speed over 100km			by energy consumption			by travel distance
					30mph 48 km/h	50mph 77 km/h	70mph 113 km/h	30mph urban	50mph rural	70mph motorway	
14204	13057	15276	18115	1.56	9118	8433	9838	9105	8370	9792	11612
16543	16275	17941	18115	1.56	11145	10668	12050	10604	10433	11501	11612
8621	9485	10951	12168	1.04	8518	8863	11711	8289	9121	10530	11700
72628	64320	72628	121276	12	5829	5459	7058	6052	5360	6052	10106
629076			478492	98.76	N/A	N/A	N/A	6370			4845
427851			478492	98.76	N/A	N/A	N/A	4332			4845
139200			108934	31	N/A	N/A	N/A	4490			3514

Key

Variable

Variable (potential for empirical measurements)


Spatial network
Mode of transport
Proxy / Measure
Modes
Road Transport
Passenger car
Motorcycle
Bus
Train
Tram
Road network
OS ITN / OSM
Bus network
Rail Network
Tram Network
Average Speed
Energy consumption
Fuel Consumption
Electric Power Consumption
Travel Distance
Occupancy per vehicle


Compute
Metric
Normalised Metric
Speed - Emissions
gCO_2/km at km/h
Fuel - Emissions
gCO_2/l
Electric - Emissions
gCO_2/kWh
Distance - Emissions
gCO_2/km
Vehicle-km
Passenger-km
Conversion factor
gCO_2e/pkm
Emissions
Occupancy
Emission / Occupancy
gCO_2e/pkm
Key
Variable
Variable (potential for empirical measurements)

Introduction

According to the UK Department of Energy & Climate Change, domestic transport accounts for 23% of UK greenhouse gas emissions and affects air quality at the roadside. [3]

It is obvious that domestic transport significantly contributes to the overall GHG emission. With the growing trend for the need to travel [4] and that travel related emission reductions due to technological advances overtime [5], what is the most sustainable choice of travel?

The question whether or not "public transport is greener than travel by car" is discussed in a number of publications including:

- Is it greener to travel by rail or car?, Guardian 2013
- How Green is Rail travel?, The New York Times 2009
- Ethical Man blog: Why cars are greener than buses (maybe), BBC 2009
- Is it always greener to take public transportation?, Slate 2008
- Planes, trains, or automobiles: Travel choices for a smaller carbon footprint, International Institute for Applied Systems Analysis 2013
- Which transport is the fairest of them all?, The Conversation 2014

This topic can sometimes raise opposing opinions, depending on the data used, the methods and the scope of the investigation. However, a common factor in attempts to answer the question relies on the ability to compare modes of transportation through an emission per passenger per journey metric. This also needs to account for the indirect factors such as embodied emissions in power generation for electrically powered transportation.

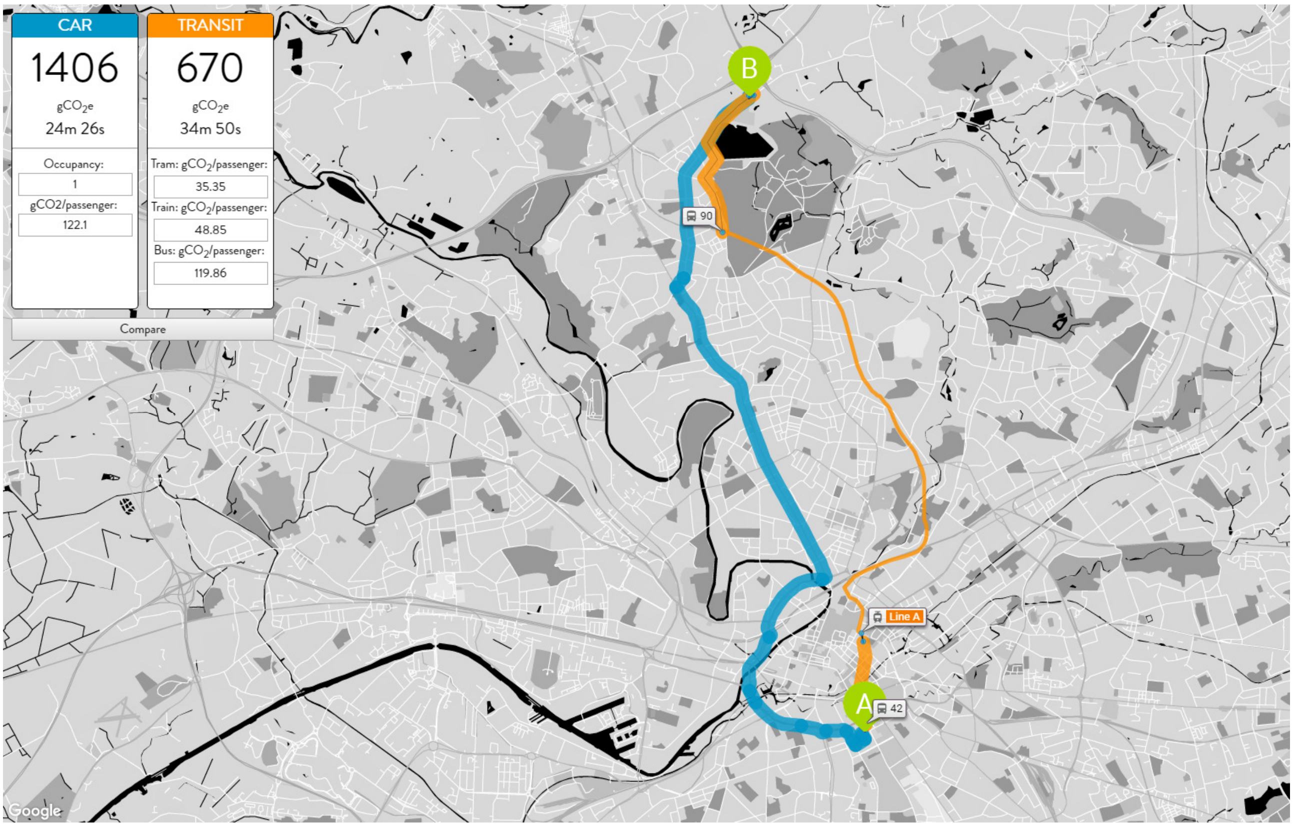
The boarder questions of whether or not all tram or rail or bus journeys are more sustainable than passenger car-based journeys on average; requires the consideration of detailed and specific sets of data, some of which are subject to data availability.

The emission-occupancy matrix developed here to a microscopic comparison of everyday transportation within the context of Greater Manchester, taking key factors into account.

The potential of obtaining key measurements through IoT can provide specific estimations in emissions and occupancy at an unprecedented scale and detail.

In a diverse spatial context, the potential spatial differences remain important - for example, travelling by car might not be 'greener' than tram for certain routes, but the reverse may be true for other routes to and from certain locations. These insights in correlation to other spatial datasets and can lead to new innovative insights and applications.

[3] 2014 UK Greenhouse Gas Emission, Department of Energy & Climate Change
[4] Transport Statistics Great Britain 2016 Modal Comparisons, Department of Transport
[5] For example, with electric vehicles and renewable energy sources



Development: Image above shows an early experimental digital tool made to demonstrate how emission-occupancy factors can be used to compare the gCO_2e/pkm between private automobile passenger per vehicle and public transport for any given origin and destination.

The original prototype was produced by master of architecture students at the Manchester School of Architecture within the CPU (Complexity Planning and Urbanism) atelier[6]. It has been modified and simplified here to illustrate the subject of emission/passenger-km comparison and now up to date in order to reflect the latest emission factors.

As expected, the example shown suggests that a car journey with single occupancy will produce considerably more emissions than public transport. However, when there are three car passenger (468 gCO_2e), the emission per person works out to be lower than average emission per person on the route with public transport. This was a useful starting point to explore journeys at a greater level of scrutiny and with greater accuracy.

The results from the early prototype is based on averaged values and do not take into account key factors in the geographical/imposed conditions including gradients, speed limits and actual conditions including road traffic, occupancy rate on public transport. For example, the prototype will give the same estimated emission for a 100km journey in North Manchester on a road with an average speed of 40mph and the one in South Manchester with average speed of 30mph.

Thus in order to create a context-specific model as a basis for genuine comparison, a more stringent and detailed method estimating emissions is demonstrated in this report.

[6] [6] I. Tosheva, S. Adekunle, L. Weinmann, Transport App, CPU (Manchester School of Architecture) 2015

Average Emission / Occupancy grams per passenger-km (gCO_2/pkm)

The 2016 Government GHG Conversion Factors provide a list of emission conversion factors [7] for CO_2, CH_4 and N_2O emission per passenger-km for buses including coach, tram (estimate for Manchester Metrolink extracted from methodology paper [8]) and rail.

Following table shows extracts and collated gCO_2e/pkm information relevant to Greater Manchester.

Type		**CO_2**	**CH_4**	**N_20**	**Total**
Car (Note 1)	Small car	92.84	0.01	1.22	94.07
	Medium car	112.49	0.01	1.22	113.72
	Large car	142.83	0.01	1.22	144.06
	Average car	116.12	0.01	1.22	117.35
Motorcycle	Small	84.99	2.07	0.30	87.36
	Medium	103.16	2.66	0.60	106.42
	Large	137.24	1.79	0.60	139.63
	Average	117.00	2.20	0.58	119.78
Bus	Local bus (outside London)	119.02	0.08	0.76	119.86
	Local London bus	73.4	0.04	0.36	73.8
	Average local bus	101.06	0.06	0.6	101.72
	Coach	28.29	0.03	0.35	28.67
National rail		48.45	0.05	0.35	48.85
Tram	National average	53.31	0.05	0.27	53.63
	Manchester Metrolink	35.14	0.03	0.18	35.35

Note

1. Assume average car occupancy 1.56 from National Travel Statistics

[7] Conversion factors 2016 - Full set (spreadsheet)

[8] 2016 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors

Occupancy

Average Passenger Occupancy per vehicle = Passenger-Distance / Vehicle-Distance

Vehicle-Distance (Vehicle miles travelled (VMT) or Vehicle-kilometres travelled (VKT))

1. Unit of measurement representing the movement of a vehicle over one kilometre [9]
2. Multiply the number of vehicles in a given road by the average length of journey [10]

Passenger-Distance (Passenger-miles or Passenger-kilometre)

Multiply Unlinked passenger trips by the average length of trips

Unlinked passenger trips

The number of trip made by passenger boarding public transport vehicles. A journey that requires a transfer to another transit vehicle is counted as two trips. [11]

UK Average Passenger Occupancy

Mode of transport		Average passenger occupancy per vehicle	Source
Car / Van		1.56	[12] (Note: 1)
Taxi		1.4	[13]
Bus	Local Bus (outside London)	9.5	[14]
	Average Local Bus	12.0	[8]
	Coach	17.56	[12]
Rail	National average	122.27	[15]
	Manchester (Oxford Road, Piccadilly and Victoria)	98.76	[16]
Tram	National average	45.75	[17]
	Manchester Metrolink	31	[15]

Note:

1. Statistics includes a single occupancy rate of 61% in 2012

[9] http://glossary.eea.europa.eu/terminology/concept_html?term=vehicle-km, EEA
[10] Road traffic (vehicle kilometres) by vehicle type in Great Britain, Department for Transport
[11] http://www.apta.com/resources/statistics/Pages/glossary.aspx
[12] Vehicle mileage and occupancy Table NTS0905 Department of Transport National Travel Survey statistics 2013
[13] 2016 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors
[14] Bus Statistics Table BUS0304, Department for Transport statistics, 2016
[15] Rail Statistics Table RAI0201, Department for Transport statistics, 2015
[16] Rail Statistics Table TSGB0603 (RAI0103), Department for Transport statistics, 2016
[17] Light rail and Tram Statistics Table LRT0108, Department for Transport statistics, 2016

Emission estimation by electrical energy consumption

Applicable mode of transportation:

- Tram (Metrolink)
- Electric Vehicle (including BEVs and PHEVs which charges from external power source)

While there is no in-use/on-site CO_2 emission from vehicles, there are indirect emissions through energy consumption. In order to work out the CO_2 emissions from energy consumed, indirect embodied energy for electric generation is examined.

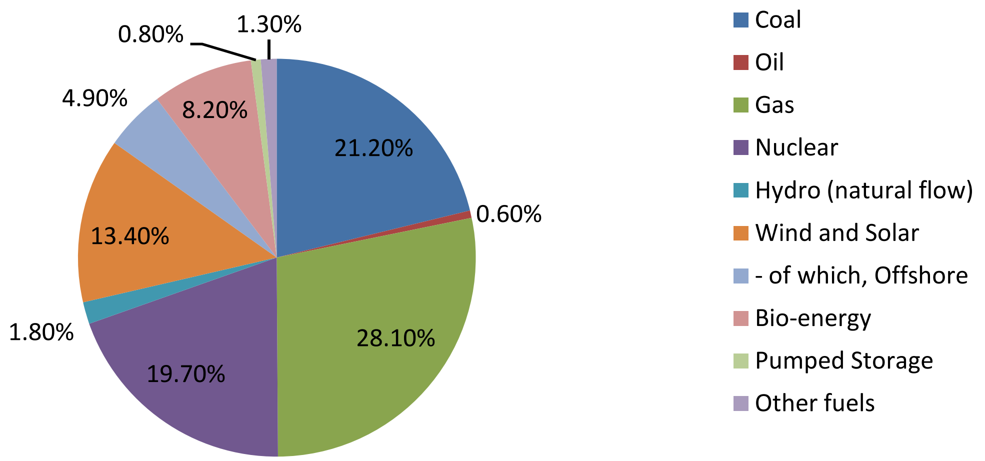
1. Metrolink Tram 2016 electric consumption per passenger-km: 0.078 kWh/pkm [18]

2. The UK Government GHG Conversion Factors provides the following values in grams per kWh:

CO_2	CH_4 (CO_2e)	N_2O (CO_2e)	Total CO_2e
409.57	0.39	2.09	412.05

3. UK electric generation fuel mix and near real-time emission estimation

Electricity in the UK is generated from different fuel sources including fossil fuel, nuclear and renewable resources. [19] According to the UK government statistics, the type of fuel mix differs in each reporting period. Over the past 5 years, a general trend of an increased percentage of renewable energy sources and a decreased percentage in the use of fossil fuel in electric generation. [20]



[18] 2016 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors
[19] Energy UK http://www.energy-uk.org.uk/energy-industry/electricity-generation.html, (accessed 15.11.2016)
[20] UK Government energy statistics, https://www.gov.uk/government/collections/electricity-statistics

The fuel type mix for UK electricity generation in percentage [21]

Fuel type	2011	2012	2013	2014	2015
Coal	29.1%	38.6%	35.2%	28.5%	21.2%
Oil	0.8%	0.7%	0.6%	0.5%	0.6%
Gas	39.3%	27.0%	25.9%	28.7%	28.1%
Nuclear	18.5%	19.0%	19.1%	18.1%	19.7%
Hydro (natural flow)	1.5%	1.4%	1.3%	1.7%	1.8%
Wind and Solar	4.3%	5.7%	8.2%	10.2%	13.4%
- of which, Offshore	1.4%	2.1%	3.1%	3.8%	4.9%
Bio-energy	3.5%	3.9%	4.9%	6.5%	8.2%
Pumped Storage	0.8%	0.8%	0.8%	0.8%	0.8%
Other fuels	0.8%	0.9%	0.9%	1.1%	1.3%

Note: excludes Import from other countries

Near real time data feed (update at 5-minute intervals) electricity generation by fuel type is available for the UK [22]. CO_2 conversion factor can be associated with each fuel type, providing an estimated CO_2 emission based on the fuel mix for a specific time.[23]

Conversion factor for each type fuel for electricity generation [24]

Code	Fuel type	Conversion factor gCO_2/kWh
CCGT	Closed cycle gas turbine	360
OCGT	Open cycle gas turbine	480
COAL	Coal	910
NUCLEAR	Nuclear	0
WIND	Wind	0
PS	Pumped storage	0
NPSHYD	Non-pumped storage hydro	0
OTHER	Other	300
OIL	Oil	610
INTFR	French Interconnector	83
INTIRL	Irish Interconnector	699
INTNED	Dutch Interconnector	550
INTEW	East-West Interconnector	450

There is potential to obtain and record CO_2 emission estimates based on fuel used at a given time in relation to electricity metered readings for the specific use.

[21] National Statistics Energy Trends: electricity Table 5.1. Fuel Used in electricity generation and electricity supplied
[22] Balancing Mechanism Reporting Service, provided by Elexon
[23] RealtimeCarbon.org. (2012, Jan.) CO_2 conversion factors. [Online]. Available: http://www.realtimecarbon.org/resources/RealtimeCarbonMethodology.pdf
[24] Conversion factors for each fuel type for electricity generation in the UK available: http://gridcarbon.uk/

Emission estimation by fuel consumption (FC)

FC = 1/FE

Applicable mode of transportation:

- Car
- Motorcycle
- Bus
- Train (diesel) - note: 40% in the UK has yet to be electrified as of 2016. In the context of Greater Manchester, while there are ongoing plans for rail electrification, currently a limited number of routes are electrified. Majority of rail lines in Greater Manchester has yet to be electrified.

CO_2 conversion factors by fuel type per litre consumed

Petrol 2.33 kg CO_2/l
Diesel 2.68 kg CO_2/l

CO_2 emission is directly related to actual fuel consumption based on the density of fuel and the carbon content of the fuel, there is a higher level of certainty [25] with the estimates of carbon emission from fuel consumption using the corresponding conversion factors per fuel type. This assumes the effect of fuel additives are negligible.

This however does not account for other GHG emissions, and can be different due to different engine type and age of engine. [26]

Fuel efficiency (FE)

FE= 1/FC

Normally reported as miles per gallon (mpg) in a passenger car dashboard in the UK.

Fuel efficiency information for each road vehicle model is reported by the manufacturer and available through DVLA.

Following table shows example fuel efficiency data extracted from "DVLA: fuel consumption and emissions information on a new or used car".

[25] Paulina Golinska, Marcin Hajdul , Sustainable Transport: New Trends and Business Practices, 2012 pg 336
[26] "Carbon emissions are calculated from the fuel consumed and the carbon content of the fuel. Methane (CH4), nitrous oxide (N20) and air quality pollutant emissions are however more difficult to estimate since there is not a direct link between fuel and emissions. Emissions of these gases and pollutants are dependent on a number of factors including vehicle type, age, whether the vehicle has a catalyst and operating characteristics." - A review of data and methods to calculate greenhouse gas emissions from alternative fuel transport, Department for Business, Energy & Industrial Strategy (Department of Energy & Climate Change), January 2014

Vehicle details for VOLKSWAGEN Golf 1.6 TDI 110PS 7speed DSG S, D7

Fuel efficiency under different conditions:

Imperial Urban (cold) mpg	64.2
Imperial Extra Urban mpg	78.5
Imperial Combined (weighted) mpg	72.4
Metric Urban (cold) l/100km	4.4
Metric Extra Urban l/100km	3.6
Metric Combined (weighted) l/100km	3.9

1. NAEI Speed Emission Factor Coefficients and DfT/TRL road vehicle emission factors 2009

Fuel consumption can be estimated by travel speed between 5 - 140 km/h through the fuel consumption factor curve by vehicle fuel type, engine capacity and emission standard.

2. Data through on-board diagnostic (OBD II) interface per vehicle

Applicable mode of transportation:

- Car
- Bus

i. Fuel level data may be available through the OBD II interface and distance can be calculated from GPS location when monitored and record for a journey at time intervals.

ii. Alternatively, real-time fuel consumption and efficiency may be calculated through a combination of readings from the Vehicle Speed Sensor (VSS) and the Mass Air Flow (MAF) sensor.[27]

It is worth noting that there are many factors that affect fuel consumption in a car vehicle including:

- Travel speed - preference, congestions
- Driving mode - acceleration, idling, cruising, acceleration and deceleration
- Engine load - weight of vehicle plus passenger weight
- Vehicle age and mechanical condition
- Temperature and weather condition
- Road gradients

The acquisition of actual real world values will be beneficial in the certainty in the estimation of emissions, and the data can be cross- referenced with other temporal data such as traffic, weather and physical environment dataset such as topography.

[27] Real-Time Fuel consumption monitoring: http://www.windmill.co.uk/obdii.pdf

Emission estimation by travel speed

Applicable mode of transportation:

- Car
- Motorcycle
- Bus

1. Greater Manchester Emissions Inventory 2010 Update

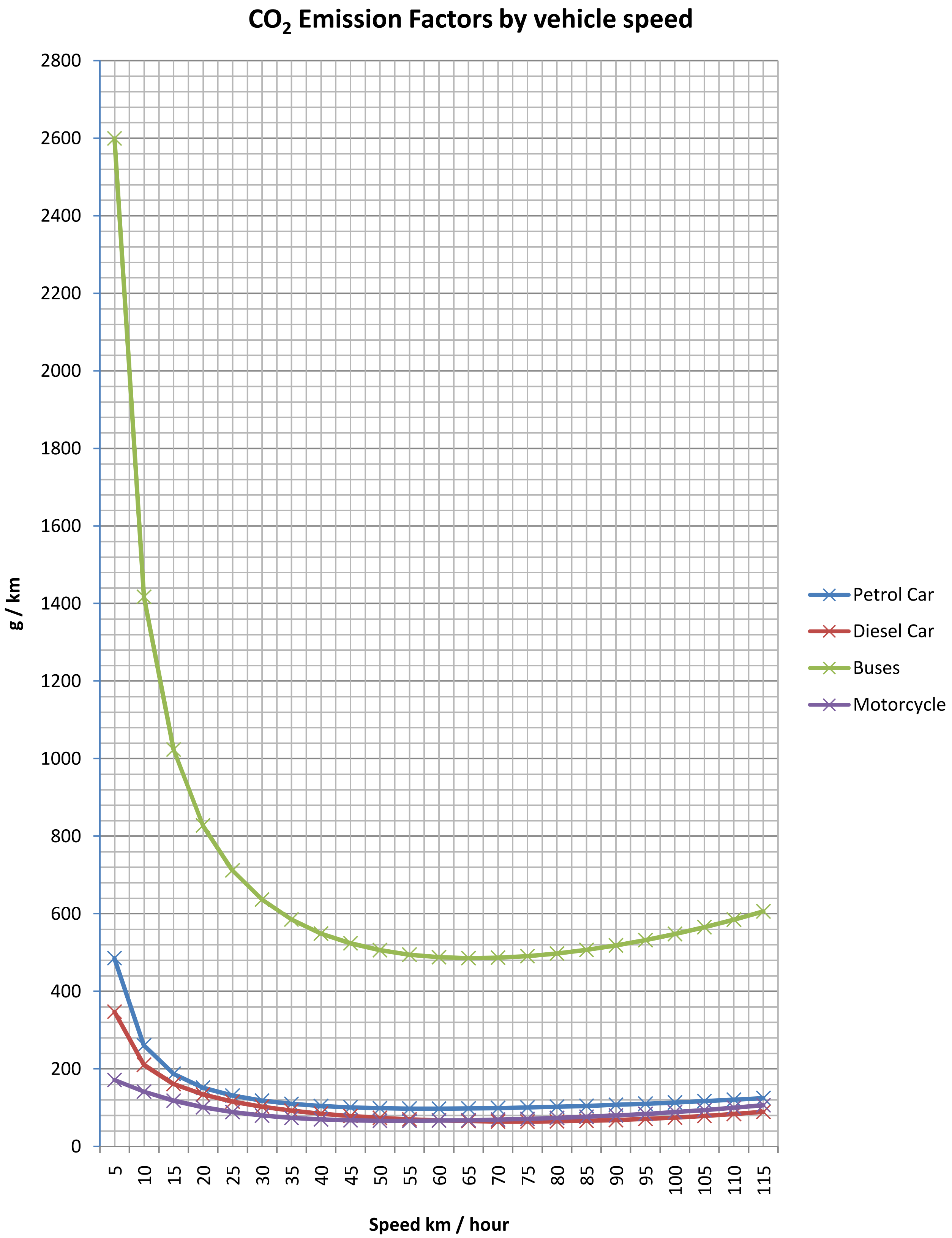
A table of emission factors for different types of road vehicle at an incremental speed of 5km/h from 5 - 115 km/his available through Greater Manchester Emissions Inventory 2010 Update [28]

2. NAEI Speed Emission Factor Coefficients and DfT/TRL road vehicle emission factors 2009

An estimate of emissions by travel speed between 5 - 140 km/h can be obtained through the emission factor curve by vehicle fuel type, engine capacity and emission standard. The dataset vehicle types include car, taxi, LGV, HGV, Bus Coach, Moped, Motorcycle. [29]

"Emissions curves are developed to a common polynomial expression" [30] , this meant emission can be estimated from any speed for the corresponding vehicle type within the limit of 5 - 140 km/h.

A spreadsheet is available online that accounts for 265 types of road vehicles.



Values at 5km/h intervals plotted for different mode of transportation based on average-speed emission factors from DfT/TRL road vehicle emission factors 2009

Emission estimation by travel distance

Applicable mode of transportation:

- Car
- Motorcycle
- Bus

1. 2016 Government GHG Conversion Factors

2016 Government GHG Conversion Factors provides a list of emission conversion factors for road vehicles for CO_2, CH_4 and N_2O emission gCO_2e per km.

Type		CO_2	CH_4	N_20	Total
Car	Small car	144.83	0.01	1.91	146.75
	Medium car	175.49	0.01	1.91	177.41
	Large car	222.81	0.01	1.91	224.73
	Average car	181.15	0.01	1.91	183.07

Motorbike	Small	84.99	2.07	0.30	87.36
	Medium	103.16	2.66	0.60	106.42
	Large	137.24	1.79	0.60	139.63
	Average	117.00	2.20	0.58	119.78

2. DVLA emissions information on a specific car / vehicle

CO_2, CO, HC, NOx and Particulate Matter(PM) (Euro 5/6) data from lab test for specific car model are available through DVLA.

Following table shows an example of emission data for a specific car model extracted from "DVLA: fuel consumption and emissions information on a new or used car".

Vehicle details for VOLKSWAGEN Golf 1.6 TDI 110PS 7speed DSG S, D7

CO_2 emissions (g/km)	102
CO Emissions [g/km or mg/km under Euro 5/6]	94
HC Emissions [g/km or mg/km under Euro 5/6]	N/A
NOx Emissions [g/km or mg/km under Euro 5/6]	37
HC+NOx Emissions [g/km or mg/km under Euro 5/6]	71
Emissions Particles [g/km or mg/km under Euro 5/6]	0.00

Emissions & carbon equivalent

Carbon dioxide is the most common GHG emitted by human activities. The term "Carbon emission" is sometimes used as a shorthand expression for all greenhouse gases.

The unit CO_2 equivalent (CO_2e) is often used to represent the Global Warming Potential (GWP) for the basket of GHG emissions express as a single number for ease of comparison.

GHG to CO_2e Conversion factors by Global Warming Potential [31]

Greenhouse Gas		Global Warming Potential (GWP)
Carbon Dioxide	CO_2	1
Methane	CH_4	25
Nitrous Oxide	NOx	298
Hydroflurocarbons	HFCs	124-14800
Perfluorocarbons	PFCs	7390-12200
Sulphur hexafluride	SF_6	22800
Nitrogen trifluoride	NF_3	17200

[31] Brander M., Greenhouse Gases, CO2, CO2e, and Carbon: What Do All These Terms Mean?, Ecometrica

Analysis of existing journey planner app with CO_2 emission outputs

TripGo

The following table shows the different CO_2 emission results based on three trips grouped by mode of transport:

Mode	CO_2 emission (kg) as output results from TripGo	UK average CO_2 emission from emission x travel distance (kg)
Car	2	0.62
Motorcycle	2	1.97
Bus	0.1	1.01
Train	0.1	1.20

Note: the values from TripGo are actual results from TripGo as displayed on screen rounded up to nearest integer for values above one.

The results between TripGo and own calculations are different. On multiple test, for each mode of transport, dividing CO_2 emission by the travel distance, the number results differs. This suggests there are other factors included in the calculation.

Tripotnik - sustainable travel

The following table shows the different CO_2 emission results based on three trips grouped by mode of transport:

Mode	CO_2 emission (kg) as output results from Tripotnik (Solvenia)	UK average CO_2 emission from emission x travel distance (kg)
Car	1.651	1.161
Motorcycle	1.498	1.170
Bus	N/A	N/A
Train	0.306	0.485

The results between Tripotnik and own calculations are different. On multiple test, for each mode of transport, dividing CO_2 emission by the travel distance, the results is within 0.5. This suggest that Tripotniks uses a fixed average emission conversion factor by distance travel for each mode of transport and it is multiplied to the distance travelled from route to provide the estimated emission.

Conclusion

On average, tram has the lowest emission (35.1g/pkm) based on average occupancy followed by train (98.76/pkm) followed by bus (101.1g/pkm) followed by car (116.1g/pkm) followed by motorcycle (117g/pkm). .[32]

When considering emission per person, the higher the number of passengers in a vehicle, the lower the emission per person.

On average, any car is greener than a bus with less than 6 people, a tram with 6 people and a train with 26 people.[33]

On average, a bus with over 46 people, a tram with 42 people and a train with 184 people is greener than any car.[34]

There can be situations where this differs in reality that affects the variables of travel distance. For example, getting from A to B for a bus with a pre-defined route may have a greater distance to travel than private car. Spatial distance matters.

Based on average occupancy, a 87km car journey has lower emission than a 100km bus journey.

Hence for further work, a more detailed and spatial view of journeys are necessary for comparison between different mode of transport. The estimation by speed and fuel consumption can be used in a spatial -temporal model in response to the changing nature of average speed and fuel consumption over space and time.

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[32] based on average GHG conversion factors

[33] An average car with 1 person produces the same amount of carbon emission per person per km as a bus with 6 people, a tram with 6 people and a train with 26 people.

[34] An average car with 7 people produces the same amount of carbon emission per person per km as a bus with 46 people, a tram with 42 people and a train with 184 people

Appendix

Emission / Average occupancy, varied travel distance

Mode of transport	Fuel type	UK average occupancy									
Average conversion factor			5	10	15	20	25	30	35	40	
Passenger C	Diesel	1.56	580.6	1161.2	1741.8	2322.4	2903.0	3483.6	4064.2	4644.8	5
	Petrol	1.56	580.6	1161.2	1741.8	2322.4	2903.0	3483.6	4064.2	4644.8	5
Motorcycle	Petrol	1.04	585.0	1170.0	1755.0	2340.0	2925.0	3510.0	4095.0	4680.0	5
Bus	Diesel	12	505.3	1010.6	1516.0	2021.3	2526.6	3031.9	3537.2	4042.5	4
Train	Diesel	98.76	242.3	484.5	726.8	969.0	1211.3	1453.5	1695.8	1938.0	2
	Electric	98.76	242.3	484.5	726.8	969.0	1211.3	1453.5	1695.8	1938.0	2
Tram	Electric	31	175.7	351.4	527.1	702.8	878.5	1054.2	1229.9	1405.6	1
Speed	at average 30mph										
Passenger C	Diesel	1.56	455.9	911.8	1367.6	1823.5	2279.4	2735.3	3191.2	3647.1	4
	Petrol	1.56	557.3	1114.5	1671.8	2229.1	2786.3	3343.6	3900.9	4458.1	5
Motorcycle	Petrol	1.04	425.9	851.8	1277.7	1703.7	2129.6	2555.5	2981.4	3407.3	3
Bus	Diesel	12	291.4	582.9	874.3	1165.7	1457.1	1748.6	2040.0	2331.4	2
Speed	at average 50mph										
Passenger C	Diesel	1.56	421.6	843.3	1264.9	1686.5	2108.2	2529.8	2951.4	3373.1	3
	Petrol	1.56	532.1	1064.1	1596.2	2128.2	2660.3	3192.3	3724.4	4256.4	4
Motorcycle	Petrol	1.04	442.3	884.6	1326.9	1769.2	2211.5	2653.8	3096.2	3538.5	3
Bus	Diesel	12	272.9	545.8	818.8	1091.7	1364.6	1637.5	1910.4	2183.3	2
Speed	at average 70mph										
Passenger C	Diesel	1.56	491.9	983.8	1475.8	1967.7	2459.6	2951.5	3443.5	3935.4	4
	Petrol	1.56	602.6	1205.1	1807.7	2410.3	3012.8	3615.4	4217.9	4820.5	5
Motorcycle	Petrol	1.04	586.5	1173.1	1759.6	2346.2	2932.7	3519.2	4105.8	4692.3	5
Bus	Diesel	12	352.9	705.8	1058.8	1411.7	1764.6	2117.5	2470.4	2823.3	3
Average energy consumption											
Passenger C	Diesel	1.56	455.3	910.5	1365.8	1821.0	2276.3	2731.5	3186.8	3642.1	4
	Petrol	1.56	545.2	1090.3	1635.5	2180.6	2725.8	3271.0	3816.1	4361.3	4
Motorcycle	Petrol	1.04	470.5	941.0	1411.4	1881.9	2352.4	2822.9	3293.4	3763.8	4
Bus	Diesel	12	291.5	582.9	874.4	1165.8	1457.3	1748.7	2040.2	2331.6	2
Train	Diesel	98.76	318.4	636.9	955.3	1273.8	1592.2	1910.7	2229.1	2547.6	2
	Electric	98.76	216.5	433.1	649.6	866.2	1082.7	1299.2	1515.8	1732.3	1
Tram	Electric	31	224.5	449.0	673.5	898.1	1122.6	1347.1	1571.6	1796.1	2

Travel Distance

45	50	55	60	65	70	75	80	85	90	95	100
225.4	5806.0	6386.6	6967.2	7547.8	8128.4	8709.0	9289.6	9870.2	10450.8	11031.4	11612.0
225.4	5806.0	6386.6	6967.2	7547.8	8128.4	8709.0	9289.6	9870.2	10450.8	11031.4	11612.0
265.0	5850.0	6435.0	7020.0	7605.0	8190.0	8775.0	9360.0	9945.0	10530.0	11115.0	11700.0
547.9	5053.2	5558.5	6063.8	6569.1	7074.4	7579.8	8085.1	8590.4	9095.7	9601.0	10106.3
180.3	2422.5	2664.8	2907.0	3149.3	3391.5	3633.8	3876.0	4118.3	4360.5	4602.8	4845.0
180.3	2422.5	2664.8	2907.0	3149.3	3391.5	3633.8	3876.0	4118.3	4360.5	4602.8	4845.0
581.3	1757.0	1932.7	2108.4	2284.1	2459.8	2635.5	2811.2	2986.9	3162.6	3338.3	3514.0
102.9	4558.8	5014.7	5470.6	5926.5	6382.3	6838.2	7294.1	7750.0	8205.9	8661.7	9117.6
015.4	5572.7	6129.9	6687.2	7244.5	7801.7	8359.0	8916.3	9473.5	10030.8	10588.1	11145.3
833.2	4259.1	4685.0	5111.0	5536.9	5962.8	6388.7	6814.6	7240.5	7666.4	8092.4	8518.3
622.8	2914.3	3205.7	3497.1	3788.5	4080.0	4371.4	4662.8	4954.2	5245.7	5537.1	5828.5
794.7	4216.3	4638.0	5059.6	5481.3	5902.9	6324.5	6746.2	7167.8	7589.4	8011.1	8432.7
788.5	5320.5	5852.6	6384.6	6916.7	7448.7	7980.8	8512.8	9044.9	9576.9	10109.0	10641.0
980.8	4423.1	4865.4	5307.7	5750.0	6192.3	6634.6	7076.9	7519.2	7961.5	8403.8	8846.2
456.3	2729.2	3002.1	3275.0	3547.9	3820.8	4093.8	4366.7	4639.6	4912.5	5185.4	5458.3
427.3	4919.2	5411.2	5903.1	6395.0	6886.9	7378.8	7870.8	8362.7	8854.6	9346.5	9838.5
423.1	6025.6	6628.2	7230.8	7833.3	8435.9	9038.5	9641.0	10243.6	10846.2	11448.7	12051.3
278.8	5865.4	6451.9	7038.5	7625.0	8211.5	8798.1	9384.6	9971.2	10557.7	11144.2	11730.8
176.3	3529.2	3882.1	4235.0	4587.9	4940.8	5293.8	5646.7	5999.6	6352.5	6705.4	7058.3
097.3	4552.6	5007.8	5463.1	5918.3	6373.6	6828.8	7284.1	7739.4	8194.6	8649.9	9105.1
906.4	5451.6	5996.8	6541.9	7087.1	7632.2	8177.4	8722.6	9267.7	9812.9	10358.0	10903.2
234.3	4704.8	5175.3	5645.8	6116.3	6586.7	7057.2	7527.7	7998.2	8468.7	8939.1	9409.6
623.1	2914.5	3206.0	3497.4	3788.9	4080.3	4371.8	4663.2	4954.7	5246.1	5537.6	5829.0
866.0	3184.5	3502.9	3821.4	4139.8	4458.3	4776.7	5095.1	5413.6	5732.0	6050.5	6368.9
948.9	2165.4	2381.9	2598.5	2815.0	3031.5	3248.1	3464.6	3681.2	3897.7	4114.2	4330.8
020.6	2245.2	2469.7	2694.2	2918.7	3143.2	3367.7	3592.3	3816.8	4041.3	4265.8	4490.3

Emission
Low High

Emission / occupancy, varied occupancy over a fixed distance of 100km

Mode of transport	Fuel type	Travel distance									
Average conversion factor			5	10	15	20	25	30	35	40	
Passenger C	Diesel	100			17252.1	12939.1	10351.3	8626.1	7393.8	6469.5	57
	Petrol	100			17252.1	12939.1	10351.3	8626.1	7393.8	6469.5	57
Motorcycle	Petrol	100									
Bus	Diesel	100	48510.4	24255.2	16170.1	12127.6	9702.1	8085.1	6930.1	6063.8	53
Train	Diesel	100	23924.6	11962.3	7974.9	5981.2	4784.9	3987.4	3417.8	2990.6	26
	Electric	100	23924.6	11962.3	7974.9	5981.2	4784.9	3987.4	3417.8	2990.6	26
Tram	Electric	100	10276.8	5138.4	3425.6	2569.2	2055.4	1712.8	1468.1	1284.6	1
Speed	at average 30mph										
Passenger C	Diesel	100			13546.2	10159.6	8127.7	6773.1	5805.5	5079.8	45
	Petrol	100			16558.8	12419.1	9935.3	8279.4	7096.6	6209.5	55
Motorcycle	Petrol	100									
Bus	Diesel	100	27976.8	13988.4	9325.6	6994.2	5595.4	4662.8	3996.7	3497.1	3
Speed	at average 50mph										
Passenger C	Diesel	100			12528.6	9396.4	7517.1	6264.3	5369.4	4698.2	4
	Petrol	100			15809.5	11857.1	9485.7	7904.8	6775.5	5928.6	52
Motorcycle	Petrol	100									
Bus	Diesel	100	26200.0	13100.0	8733.3	6550.0	5240.0	4366.7	3742.9	3275.0	29
Speed	at average 70mph										
Passenger C	Diesel	100			14617.1	10962.9	8770.3	7308.6	6264.5	5481.4	48
	Petrol	100			17904.8	13428.6	10742.9	8952.4	7673.5	6714.3	59
Motorcycle	Petrol	100									
Bus	Diesel	100	33880.0	16940.0	11293.3	8470.0	6776.0	5646.7	4840.0	4235.0	37
Average energy consumption											
Passenger C	Diesel	100			13527.6	10145.7	8116.6	6763.8	5797.6	5072.9	45
	Petrol	100			16199.0	12149.3	9719.4	8099.5	6942.4	6074.6	53
Motorcycle	Petrol	100									
Bus	Diesel	100	27979.2	13989.6	9326.4	6994.8	5595.8	4663.2	3997.0	3497.4	3
Train	Diesel	100	31449.8	15724.9	10483.3	7862.5	6290.0	5241.6	4492.8	3931.2	34
	Electric	100	21385.4	10692.7	7128.5	5346.3	4277.1	3564.2	3055.1	2673.2	23
Tram	Electric	100	13132.1	6566.0	4377.4	3283.0	2626.4	2188.7	1876.0	1641.5	14

Occupancy %

45	50	55	60	65	70	75	80	85	90	95	100
750.7	5175.6	4705.1	4313.0	3981.3	3696.9	3450.4	3234.8	3044.5	2875.4	2724.0	2587.8
750.7	5175.6	4705.1	4313.0	3981.3	3696.9	3450.4	3234.8	3044.5	2875.4	2724.0	2587.8
		11061.8	10140.0	9360.0	8691.4	8112.0	7605.0	7157.6	6760.0	6404.2	6084.0
390.0	4851.0	4410.0	4042.5	3731.6	3465.0	3234.0	3031.9	2853.6	2695.0	2553.2	2425.5
658.3	2392.5	2175.0	1993.7	1840.4	1708.9	1595.0	1495.3	1407.3	1329.1	1259.2	1196.2
658.3	2392.5	2175.0	1993.7	1840.4	1708.9	1595.0	1495.3	1407.3	1329.1	1259.2	1196.2
141.9	1027.7	934.3	856.4	790.5	734.1	685.1	642.3	604.5	570.9	540.9	513.8
515.4	4063.9	3694.4	3386.5	3126.0	2902.8	2709.2	2539.9	2390.5	2257.7	2138.9	2031.9
519.6	4967.6	4516.0	4139.7	3821.3	3548.3	3311.8	3104.8	2922.1	2759.8	2614.5	2483.8
		8053.6	7382.5	6814.6	6327.9	5906.0	5536.9	5211.2	4921.7	4662.6	4429.5
108.5	2797.7	2543.3	2331.4	2152.1	1998.3	1865.1	1748.6	1645.7	1554.3	1472.5	1398.8
176.2	3758.6	3416.9	3132.1	2891.2	2684.7	2505.7	2349.1	2210.9	2088.1	1978.2	1879.3
269.8	4742.9	4311.7	3952.4	3648.4	3387.8	3161.9	2964.3	2789.9	2634.9	2496.2	2371.4
		8363.6	7666.7	7076.9	6571.4	6133.3	5750.0	5411.8	5111.1	4842.1	4600.0
911.1	2620.0	2381.8	2183.3	2015.4	1871.4	1746.7	1637.5	1541.2	1455.6	1378.9	1310.0
872.4	4385.1	3986.5	3654.3	3373.2	3132.2	2923.4	2740.7	2579.5	2436.2	2308.0	2192.6
968.3	5371.4	4883.1	4476.2	4131.9	3836.7	3581.0	3357.1	3159.7	2984.1	2827.1	2685.7
		11090.9	10166.7	9384.6	8714.3	8133.3	7625.0	7176.5	6777.8	6421.1	6100.0
764.4	3388.0	3080.0	2823.3	2606.2	2420.0	2258.7	2117.5	1992.9	1882.2	1783.2	1694.0
509.2	4058.3	3689.4	3381.9	3121.8	2898.8	2705.5	2536.4	2387.2	2254.6	2135.9	2029.1
399.7	4859.7	4417.9	4049.8	3738.2	3471.2	3239.8	3037.3	2858.7	2699.8	2557.7	2429.9
		8896.4	8155.0	7527.7	6990.0	6524.0	6116.3	5756.5	5436.7	5150.5	4893.0
108.8	2797.9	2543.6	2331.6	2152.2	1998.5	1865.3	1748.7	1645.8	1554.4	1472.6	1399.0
494.4	3145.0	2859.1	2620.8	2419.2	2246.4	2096.7	1965.6	1850.0	1747.2	1655.3	1572.5
376.2	2138.5	1944.1	1782.1	1645.0	1527.5	1425.7	1336.6	1258.0	1188.1	1125.5	1069.3
459.1	1313.2	1193.8	1094.3	1010.2	938.0	875.5	820.8	772.5	729.6	691.2	656.6

Emission

Low High

CO_2 Emission by travel speed

Car - Petrol

Speed	mph	10	15	20	25	30	35	40	45	50	55	60	65	70
	km/h	16	24	32	40	48	56	64	72	80	88	97	105	113
Small < 1400cc	<1993	249.1	205.6	185.9	176.0	171.1	169.3	169.6	171.4	174.3	178.2	182.9	188.4	194.5
	1993	233.6	190.1	170.4	160.4	155.6	153.8	154.0	155.8	158.8	162.7	167.4	172.8	178.9
	1996	226.1	182.6	162.9	153.0	148.1	146.3	146.6	148.4	151.3	155.2	160.0	165.4	171.5
	2000	216.2	172.7	153.0	143.0	138.2	136.4	136.7	138.4	141.4	145.3	150.0	155.4	161.5
	2005	205.4	161.9	142.2	132.3	127.4	125.6	125.9	127.7	130.6	134.5	139.3	144.7	150.8
	2009	190.4	146.9	127.2	117.2	112.4	110.6	110.8	112.6	115.6	119.5	124.2	129.6	135.7
	2014	177.6	134.1	114.4	104.4	99.6	97.8	98.1	99.8	102.8	106.7	111.4	116.8	122.9
Medium 400-2000cc	<1993	305.5	251.7	225.0	209.7	200.5	195.1	192.5	192.0	193.3	196.0	200.1	205.4	211.9
	1993	290.0	236.2	209.5	194.2	185.0	179.6	177.0	176.5	177.8	180.5	184.6	189.9	196.4
	1996	282.0	228.3	201.6	186.3	177.1	171.7	169.1	168.6	169.8	172.6	176.7	182.0	188.4
	2000	270.5	216.7	190.1	174.7	165.5	160.2	157.6	157.1	158.3	161.0	165.1	170.4	176.9
	2005	255.6	201.8	175.1	159.8	150.6	145.2	142.6	142.1	143.4	146.1	150.2	155.5	162.0
	2009	236.8	183.0	156.3	141.0	131.8	126.4	123.8	123.3	124.6	127.3	131.4	136.7	143.2
	2014	221.0	167.2	140.6	125.2	116.0	110.7	108.1	107.6	108.8	111.6	115.6	120.9	127.4
Large > 2000cc	<1993	430.7	349.5	308.5	284.4	269.3	260.1	254.9	252.9	253.6	256.5	261.5	268.3	276.9
	1993	417.6	336.5	295.5	271.3	256.3	247.0	241.8	239.9	240.5	243.4	248.4	255.3	263.9
	1996	407.9	326.7	285.7	261.6	246.5	237.2	232.1	230.1	230.8	233.7	238.7	245.5	254.1
	2000	389.6	308.4	267.4	243.3	228.3	219.0	213.8	211.8	212.5	215.4	220.4	227.2	235.9
	2005	377.8	296.7	255.7	231.5	216.5	207.2	202.1	200.1	200.7	203.7	208.6	215.5	224.1
	2009	350.6	269.5	228.5	204.3	189.3	180.0	174.9	172.9	173.5	176.5	181.4	188.3	196.9
	2014	327.6	246.4	205.4	181.3	166.2	157.0	151.8	149.8	150.5	153.4	158.4	165.2	173.8
Average		288.6	229.2	200.0	183.6	173.9	168.4	165.9	165.7	167.3	170.5	175.1	180.9	188.0

Emission
Low High

CO_2 Emission by travel speed

Car - Diesel

Speed	mph	10	15	20	25	30	35	40	45	50	55	60	65	70
	km/h	16	24	32	40	48	56	64	72	80	88	97	105	113
Small < 1400cc	<1993	199.4	163.9	143.5	130.0	120.8	114.8	111.2	109.9	110.7	113.3	117.8	124.1	132.1
	1993	195.2	159.7	139.2	125.7	116.6	110.5	107.0	105.7	106.4	109.0	113.5	119.8	127.8
	1996	187.3	151.8	131.4	117.9	108.7	102.6	99.1	97.8	98.5	101.2	105.7	111.9	119.9
	2000	176.5	141.0	120.6	107.1	97.9	91.8	88.3	87.0	87.7	90.4	94.9	101.1	109.1
	2005	177.3	141.8	121.3	107.9	98.7	92.6	89.1	87.8	88.5	91.2	95.6	101.9	109.9
	2009	164.8	129.3	108.8	95.4	86.2	80.1	76.6	75.3	76.0	78.7	83.1	89.4	97.4
	2014	153.8	118.3	97.8	84.4	75.2	69.1	65.6	64.3	65.0	67.7	72.2	78.4	86.4
Medium 400-2000cc	<1993	239.8	204.3	183.8	170.4	161.2	155.1	151.6	150.3	151.0	153.7	158.1	164.4	172.4
	1993	234.6	199.1	178.6	165.2	156.0	149.9	146.4	145.1	145.8	148.5	152.9	159.2	167.2
	1996	224.5	189.0	168.5	155.1	145.9	139.8	136.3	135.0	135.7	138.4	142.9	149.1	157.1
	2000	211.3	175.8	155.4	141.9	132.7	126.6	123.1	121.8	122.5	125.2	129.7	135.9	143.9
	2005	205.5	170.0	149.5	136.0	126.8	120.8	117.2	115.9	116.7	119.3	123.8	130.1	138.1
	2009	189.4	153.9	133.4	119.9	110.7	104.7	101.1	99.9	100.6	103.2	107.7	114.0	122.0
	2014	175.8	140.3	119.9	106.4	97.2	91.1	87.6	86.3	87.1	89.7	94.2	100.5	108.5
Large > 2000cc	<1993	312.0	276.5	256.1	242.6	233.4	227.3	223.8	222.5	223.2	225.9	230.4	236.6	244.6
	1993	305.5	270.0	249.6	236.1	226.9	220.8	217.3	216.0	216.8	219.4	223.9	230.2	238.2
	1996	291.5	256.0	235.6	222.1	212.9	206.8	203.3	202.0	202.7	205.4	209.9	216.1	224.1
	2000	273.7	238.2	217.8	204.3	195.1	189.0	185.5	184.2	184.9	187.6	192.1	198.3	206.3
	2005	260.8	225.3	204.9	191.4	182.2	176.2	172.6	171.3	172.1	174.7	179.2	185.5	193.5
	2009	239.0	203.5	183.0	169.5	160.3	154.3	150.7	149.5	150.2	152.8	157.3	163.6	171.6
	2014	220.3	184.8	164.3	150.9	141.7	135.6	132.1	130.8	131.5	134.2	138.6	144.9	152.9
Average		220.8	185.4	164.9	151.4	142.2	136.2	132.6	131.3	132.1	134.7	139.2	145.5	153.5

Emission
Low High

CO_2 Emission by travel speed

Bus - Diesel

Speed	mph	10	15	20	25	30	35	40	45	50	55	60	65	70
	km/h	16	24	32	40	48	56	64	72	80	88	97	105	113
Small < 15t	<1993	1252.8	924.7	769.2	684.8	637.9	614.0	605.7	609.1	621.8	642.3	669.4	702.5	741.2
	1993	934.9	746.5	637.6	567.3	521.9	495.8	485.9	490.6	509.0	540.5	584.6	641.1	709.7
	1996	950.0	707.6	594.8	534.9	502.4	486.4	481.4	484.4	493.5	507.5	525.8	547.7	572.8
	2000	1007.6	746.4	625.8	562.4	528.3	511.8	506.8	509.9	519.4	533.7	552.2	574.3	599.4
	2005	898.3	718.2	613.9	546.5	503.3	478.7	469.9	475.4	494.3	526.0	570.1	626.4	694.6
	2009	970.3	728.3	611.8	547.7	511.4	492.5	485.8	488.3	498.3	514.7	536.8	564.0	595.9
	2014	970.3	728.3	611.8	547.7	511.4	492.5	485.8	488.3	498.3	514.7	536.8	564.0	595.9
Medium 15-18t	<1993	1548.9	1171.9	975.7	858.2	785.2	742.3	722.1	720.5	735.1	764.4	807.3	863.2	931.5
	1993	1319.9	991.1	827.0	732.6	676.3	644.6	630.6	630.6	642.3	664.2	695.5	735.5	783.6
	1996	1180.3	956.4	823.2	734.5	675.0	638.1	620.5	620.4	636.6	668.5	715.6	777.7	854.3
	2000	1361.0	1000.2	830.5	738.9	687.7	660.7	649.9	650.9	660.9	678.1	701.6	730.4	764.0
	2005	1267.2	946.4	789.6	701.3	649.7	621.4	609.4	609.9	620.8	640.5	668.0	702.8	744.4
	2009	1293.8	967.6	807.1	716.1	662.7	633.0	620.3	620.7	631.9	652.5	681.5	718.2	762.2
	2014	1293.8	967.6	807.1	716.1	662.7	633.0	620.3	620.7	631.9	652.5	681.5	718.2	762.2
Large > 18t	<1993	1913.3	1449.6	1211.0	1069.3	982.0	930.6	906.1	903.4	919.3	952.0	1000.2	1063.0	1139.7
	1993	1538.6	1257.9	1082.8	962.0	878.4	824.7	797.1	793.8	813.3	855.0	918.4	1003.0	1108.7
	1996	1479.3	1227.6	1064.7	949.4	868.2	815.1	787.1	782.7	800.9	841.0	902.7	985.5	1089.5
	2000	1533.7	1269.3	1099.2	979.3	895.0	839.9	811.1	806.6	825.5	867.1	931.0	1016.7	1124.2
	2005	1457.0	1196.1	1032.1	918.4	839.4	788.5	762.4	759.1	777.6	817.1	877.2	957.6	1058.1
	2009	1489.2	1220.3	1051.8	935.2	854.4	802.3	775.6	772.3	791.2	831.6	893.0	975.1	1077.6
	2014	1489.2	1220.3	1051.8	935.2	854.4	802.3	775.6	772.3	791.2	831.6	893.0	975.1	1077.6
Average		1292.8	1006.8	853.2	758.9	699.4	664.2	648.1	648.1	662.5	690.3	730.6	782.9	847.0

CO_2 Emission by travel speed

Motorcycle - Petrol

Speed		mph	10	15	20	25	30	35	40	45	50	55	60	65	70
		km/h	342	24	32	40	48	56	64	72	80	88	97	105	113
2-stroke	<= 150cc	<1993	143.1	111.9	94.6	86.0	82.7	82.9	85.8	91.3	99.2	109.1	120.1	129.6	133.9
		1993	132.0	103.3	87.3	79.3	76.3	76.5	79.2	84.2	91.5	100.7	110.8	119.6	123.6
		1996	132.0	103.3	87.3	79.3	76.3	76.5	79.2	84.2	91.5	100.7	110.8	119.6	123.6
		2000	132.0	103.3	87.3	79.3	76.3	76.5	79.2	84.2	91.5	100.7	110.8	119.6	123.6
2-stroke	150-250cc	<1993	209.6	160.1	129.2	110.7	100.1	94.3	91.4	90.7	91.8	95.0	100.6	108.9	119.7
		1993	209.6	160.1	129.2	110.7	100.1	94.3	91.4	90.7	91.8	95.0	100.6	108.9	119.7
		1996	209.6	160.1	129.2	110.7	100.1	94.3	91.4	90.7	91.8	95.0	100.6	108.9	119.7
		2000	209.6	160.1	129.2	110.7	100.1	94.3	91.4	90.7	91.8	95.0	100.6	108.9	119.7
4-stroke	less than 150cc	<1993	92.3	73.6	64.7	61.2	60.5	61.1	62.7	65.5	69.6	74.7	79.8	82.5	78.8
		1993	92.3	73.6	64.7	61.2	60.5	61.1	62.7	65.5	69.6	74.7	79.8	82.5	78.8
		1996	92.3	73.6	64.7	61.2	60.5	61.1	62.7	65.5	69.6	74.7	79.8	82.5	78.8
		2000	92.3	73.6	64.7	61.2	60.5	61.1	62.7	65.5	69.6	74.7	79.8	82.5	78.8
4-stroke	150-250cc	<1993	114.1	90.3	76.5	69.4	66.4	66.1	67.4	70.0	73.7	78.7	85.2	93.4	103.1
		1993	114.1	90.3	76.5	69.4	66.4	66.1	67.4	70.0	73.7	78.7	85.2	93.4	103.1
		1996	114.1	90.3	76.5	69.4	66.4	66.1	67.4	70.0	73.7	78.7	85.2	93.4	103.1
		2000	114.1	90.3	76.5	69.4	66.4	66.1	67.4	70.0	73.7	78.7	85.2	93.4	103.1
4-stroke	250-750cc	<1993	184.0	149.7	129.7	118.9	113.8	112.0	112.2	113.8	116.8	121.5	128.5	138.3	151.1
		1993	169.6	137.8	118.9	108.6	104.0	103.0	104.4	107.5	112.2	118.6	127.0	137.8	151.1
		1996	153.6	124.4	107.3	98.4	94.7	94.2	95.8	98.8	103.3	109.3	117.3	127.7	140.6
		2000	153.6	124.4	107.3	98.4	94.7	94.2	95.8	98.8	103.3	109.3	117.3	127.7	140.6
4-stroke	> 750cc	<1993	217.0	174.9	150.3	137.1	130.9	129.0	129.5	131.6	135.0	140.1	147.4	157.3	170.0
		1993	219.1	175.3	148.8	133.7	125.9	122.2	121.0	121.2	122.8	125.8	130.7	137.8	147.4
		1996	212.3	168.7	142.7	128.5	121.6	119.0	118.9	120.5	123.4	127.9	134.6	143.7	155.5
		2000	212.3	168.7	142.7	128.5	121.6	119.0	118.9	120.5	123.4	127.9	134.6	143.7	155.5
Average			155.2	122.6	103.6	93.4	88.6	87.1	87.8	90.1	93.9	99.4	106.3	114.2	121.8