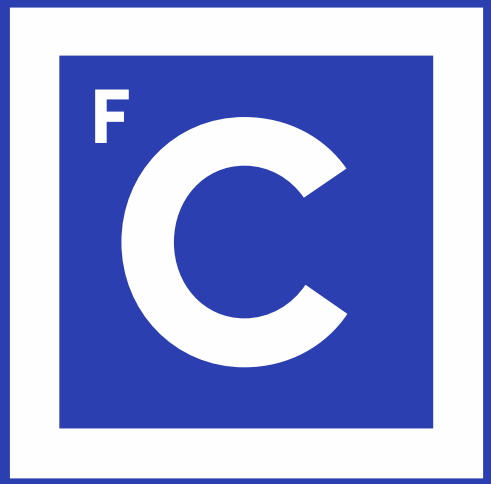

Ciências ULisboa

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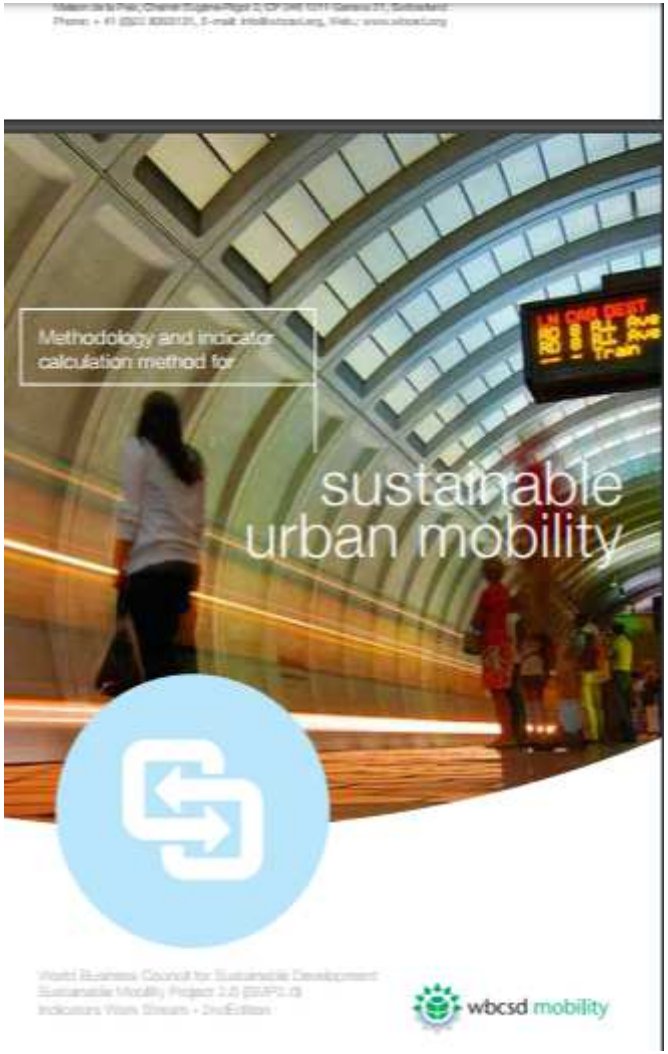
de Ciências
da Universidade
de Lisboa

DISCIPLINA MIEA 2017

Sustainable Mobility

What is sustainable mobility?



World Business Council for Sustainable Development

Sustainable Mobility Project 2.0 (SMP2.0) Indicators Work Stream - 2nd Edition

http://wbcsdpublications.org/wp-content/uploads/2016/01/SMP2.0_Sustainable-Mobility-Indicators_2ndEdition.pdf

What is sustainable mobility?

World Business Council for Sustainable Development

Accessibility for mobility impaired groups	Accessibility for impaired	S	Q
Air polluting emissions	Air pollution	Q	
Noise hindrance	Noise hindrance	Q	
Fatalities	Fatalities	Q	
Access to mobility services	Access	Q	
Quality of public area	Public area	Q	
Urban Functional diversity	Functional diversity	Q	E
Commuting travel time	Travel time	Q	E
Economic Opportunity	Economic Opportunity	Q	E
Net public finance	Public Finance	E	
Mobility space usage	Space Usage	G	E
Emissions of greenhouse gases (GHG)	GHG	G	
Congestion and delays	Congestion	G	S
Energy efficiency	Energy efficiency	G	S
Opportunity for active mobility	Active mobility	G	S
Intermodal integration	Intermodal integration	S	
Comfort and pleasure	Comfort and pleasure	S	Q
Security	Security	S	Q

Table.1: Overview of the 19 Sustainable Urban Mobility Indicators indicating the dimensions of the sustainability of the mobility system. Source: Oran Consulting for WBCSD SMP2.0, 2014

Three dimensions refer to the sustainability of the resource use and/or the impacts of mobility in the city:

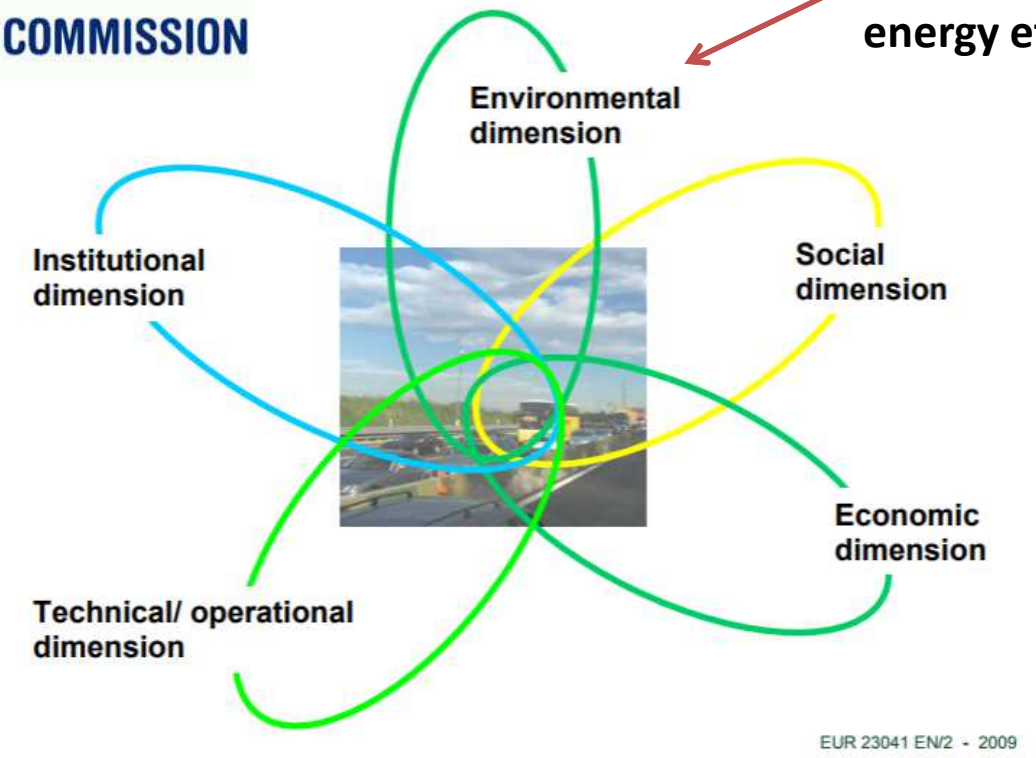
- G — Global environment
- Q — Quality of life
- E — Economic success
- S — Mobility system performance

4 dimensions- 19 Indicators

What is sustainable mobility?

JRC EUROPEAN COMMISSION

Transport emissions and energy efficiency



5 dimensions- 55 Indicators

Indicators of sustainable Mobility

JRC EUROPEAN COMMISSION

ENVIRONMENTAL	***Transport Emissions***	32. NOx emissions (per capita)
		33. VOCs emissions (per capita)
		34. PM_{10} and $PM_{2.5}$ emissions (per capita)
		35. SOx emissions (per capita)
		36. O_3 concentration (per capita)
		37. CO_2 emissions (per capita)
		38. N_20 emissions (per capita)
		39. CH_4 emissions (per capita)
	Energy Efficiency	40. Energy consumption by transport mode (tonne-oil equivalent per vehicle km)
		41. Fuel consumption (vehicles-km by mode)
	Impacts on Environmental Resources	42. Habitat and ecosystem disruption
		43. Land take by transport infrastructure mode
	Environmental Risks and Damages	44. Polluting accidents (land, air, water)
		45. Hazardous materials transported by mode
	Renewables	46. Use of renewable energy sources (numbers of alternative-fuelled vehicles) - use of biofuels

What is sustainable mobility?

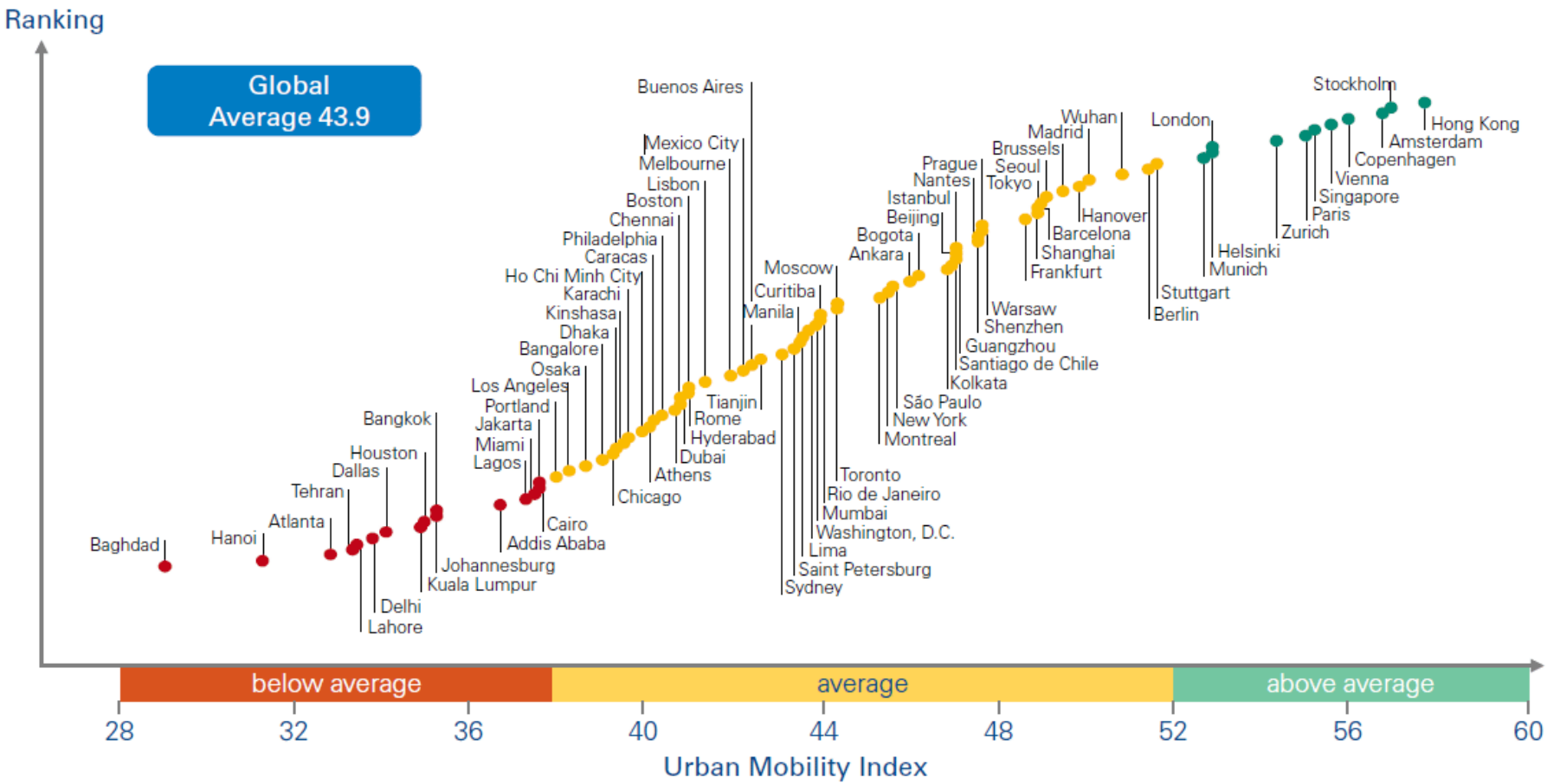
UITP ADVANCING PUBLIC TRANSPORT

International organisation for public transport

What is sustainable mobility?

Figure 6: Arthur D. Little' Urban Mobility Index 2.0

19 INDICATORS



Source: Arthur D. Little Urban Mobility Index 2.0; UITP is independent of this index, which does not necessarily reflect its opinion; 100 index points for city that would achieve best performance on each criteria.

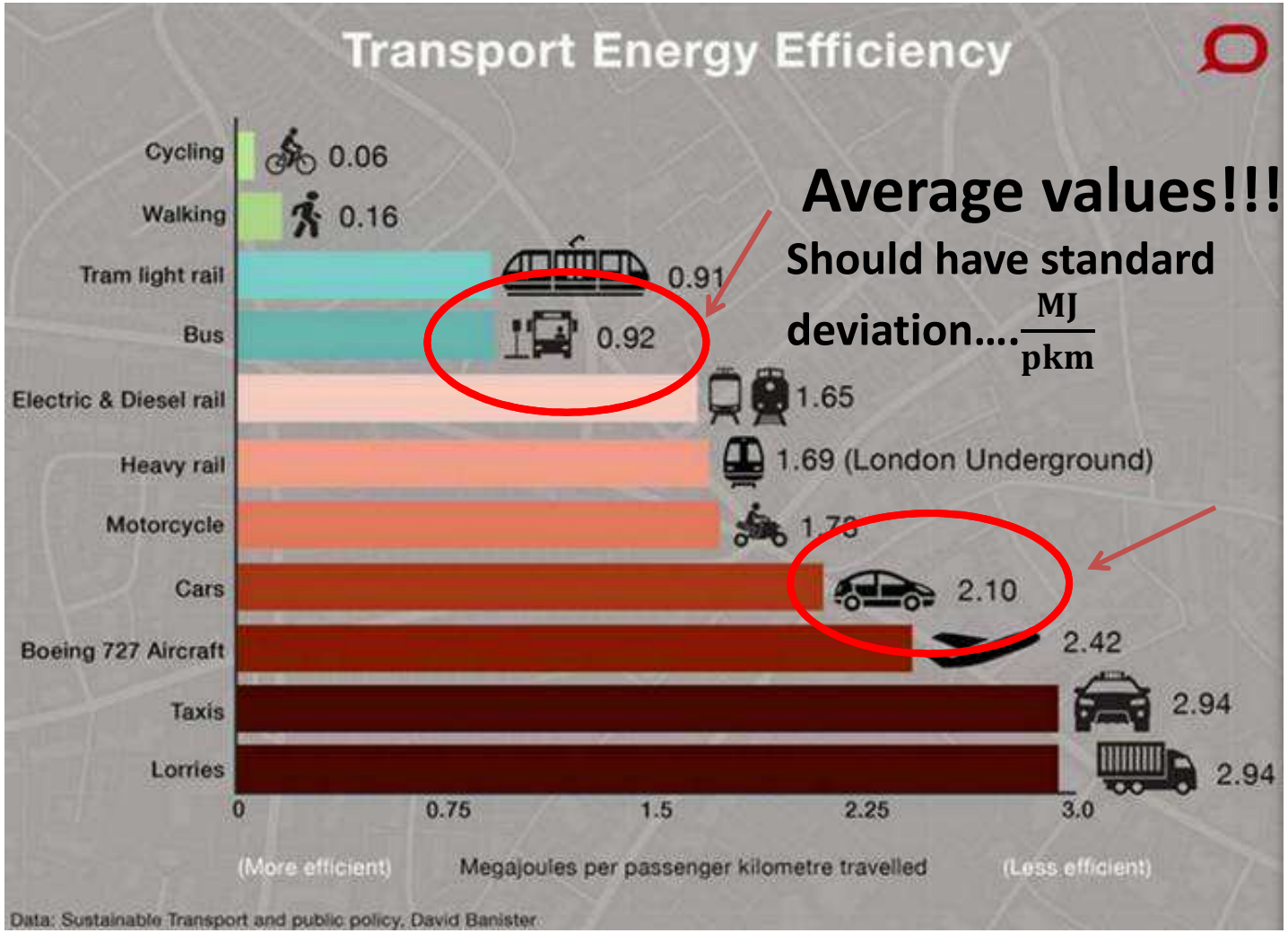
What is sustainable mobility?

Figure 8: Top 11 cities with above average mobility score

		Maturity indicators											Performance indicators							
		Fin. attract. of PT (cost of 5 km PT/ cost of 5 km car)	Share of public transport in modal split [%]	Share of zero-emission modes in modal split [%]	Roads density (deviation from optimum) [km/km^2]	Cycle path network density [km/ths km^2]	Urban agglomeration density [citizens/km^2]	Smart card penetration [cards/capita]	Bike sharing performance [shared bikes/ million citizens]	Car sharing performance [shared cars/million citizens]	Density of vehicles registered [vehicles/capita]	Frequency of the busiest public transport line [times/ day]	Initiatives of public sector (0 to 10 scale)	Transport related CO_2 emissions [kg/capita]	Annual average NO_2 concentration [mcg/m^3]	Annual average PM_{10} concentration [mcg/m^3]	Traffic related fatalities per 1 million citizens	Dynamics of share public transport in modal split [%]	Dynamics zero-emission modes in modal split [%]	Mean travel time to work [minutes]	OVERALL SCORE
1	Hong Kong	1.7	55%	38%	2.0	187	6.5	3.1	0	0	0.07	324	10	776	50.0	50.0	16.2	+20%	0%	36.6	58.2
2	Stockholm	6.7	33%	34%	0.5	4,041	3.7	0.6	852	400	0.40	212	10	1,348	12.5	16.7	9.4	-7%	+89%	33.7	57.4
3	Amsterdam	3.0	8%	50%	1.7	3,502	3.2	0.7	527	1,219	0.32	130	10	844	30.0	24.7	19.5	+12%	+13%	35.5	57.2
4	Copenhagen	4.8	27%	33%	2.7	3,977	2.7	0.1	1,025	246	0.24	238	10	812	56.0	28.0	4.1	+123%	-15%	29.7	56.4
5	Vienna	3.9	39%	34%	0.6	2,948	3.8	0.0	692	415	0.39	277	10	1,111	21.7	21.5	16.1	+15%	+13%	29.3	56.0
6	Singapore	2.6	48%	23%	2.6	280	7.3	2.9	19	57	0.18	233	9	1,381	22.0	29.0	32.5	+17%	+64%	36.8	55.6
7	Paris	2.9	34%	50%	8.8	3,520	3.8	0.6	2,224	219	0.46	267	10	1,163	39.2	38.0	23.9	+7%	0%	38.6	55.4
8	Zurich	3.8	39%	31%	0.7	3,700	4.2	0.0	232	1,064	0.54	149	10	1,200	30.1	19.1	15.4	+15%	+3%	30.4	54.7
9	London	3.9	34%	26%	10.8	254	5.6	3.1	1,012	253	0.39	468	10	1,050	37.0	22.9	26.6	+10%	+4%	44.1	53.2
9	Helsinki	3.6	27%	40%	2.1	4,678	2.3	0.9	0	70	0.48	246	10	1,228	28.0	20.2	13.9	-16%	+8%	28.5	53.2
11	Munich	4.6	21%	42%	0.1	3,862	3.0	0.0	727	640	0.56	210	10	1,351	35.3	21.7	15.3	0%	+11%	30.1	53.0

Source: Arthur D. Little Urban Mobility Index 2.0

Looking to Final energy efficiency



European Environment Agency

TIER 1 ?

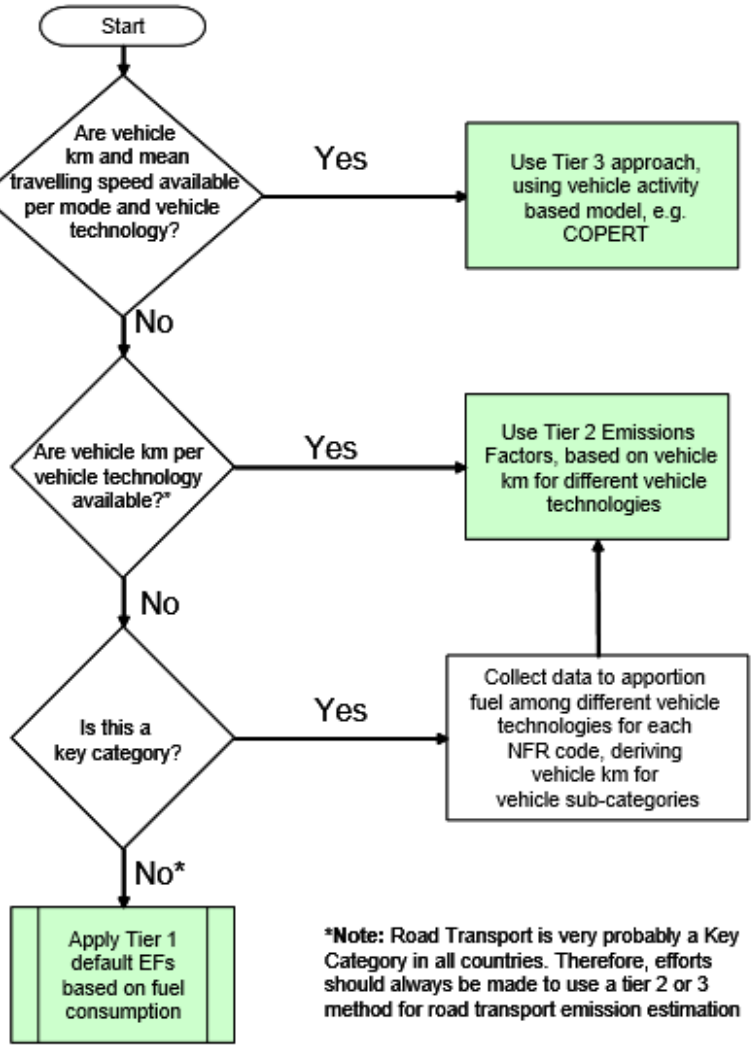
TIER 2 ?

TIER 3 ?

ETOTAL = EURBAN + ERURAL + EHIGHWAY

ETOTAL = EHOT + ECOLD

Figure 3-1 Decision tree for exhaust emissions from road transport



***Note:** Road Transport is very probably a Key Category in all countries. Therefore, efforts should always be made to use a tier 2 or 3 method for road transport emission estimation

European Environment Agency

TIER 1 ?

EF = Emission Factor (g/km) = f(fuel consumption)=g/kg*kg/km

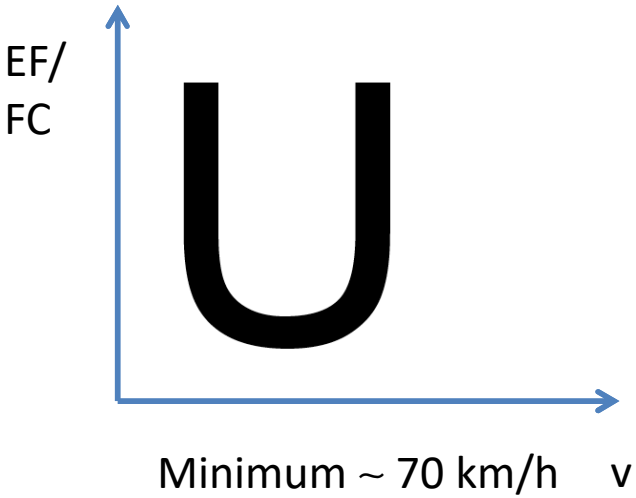
European Environment Agency

TIER 2 ?

EF = Emission Factor (g/km) ≠ f(fuel consumption)

EF = Emission Factor (g/km) = f(vehicle category & standard)

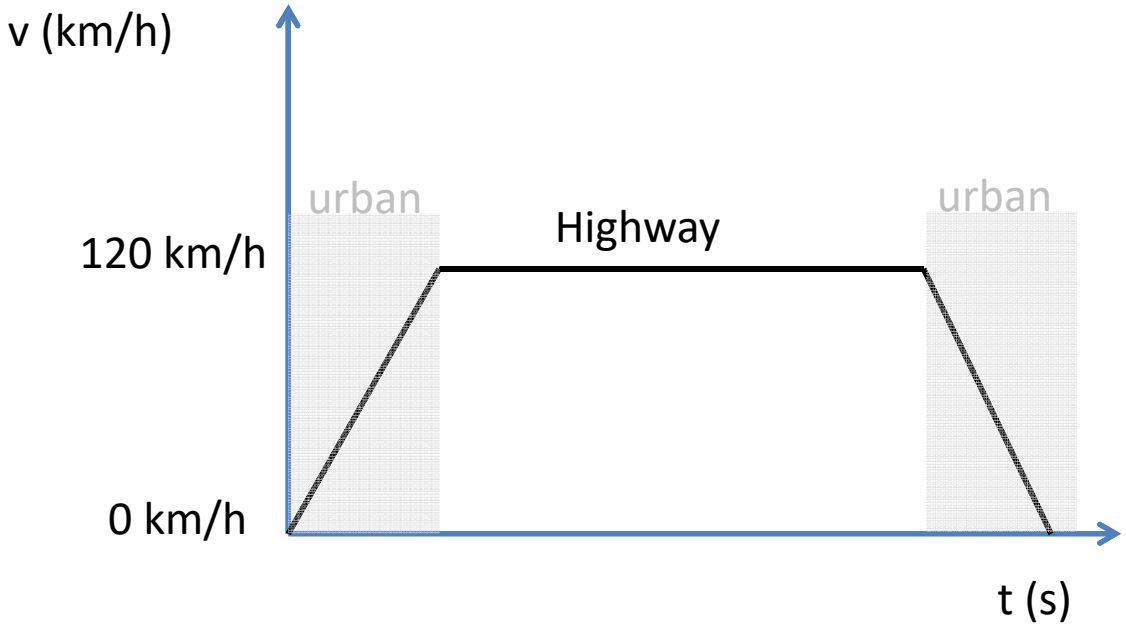
Tier 3



EF = Emission Factor (g/km) = f(vehicle category & standard, **average speed**, ambient temperature, A/C, Road slope, load)

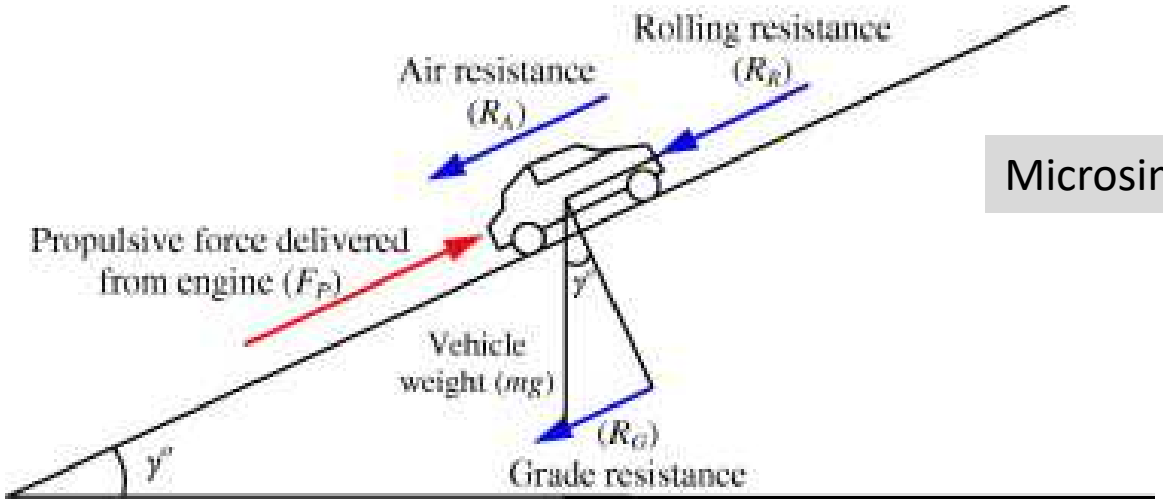
Review

Without refueling info? With GPS info….microsimulation aproach



Driving cycle

Review



Microsimulation approach

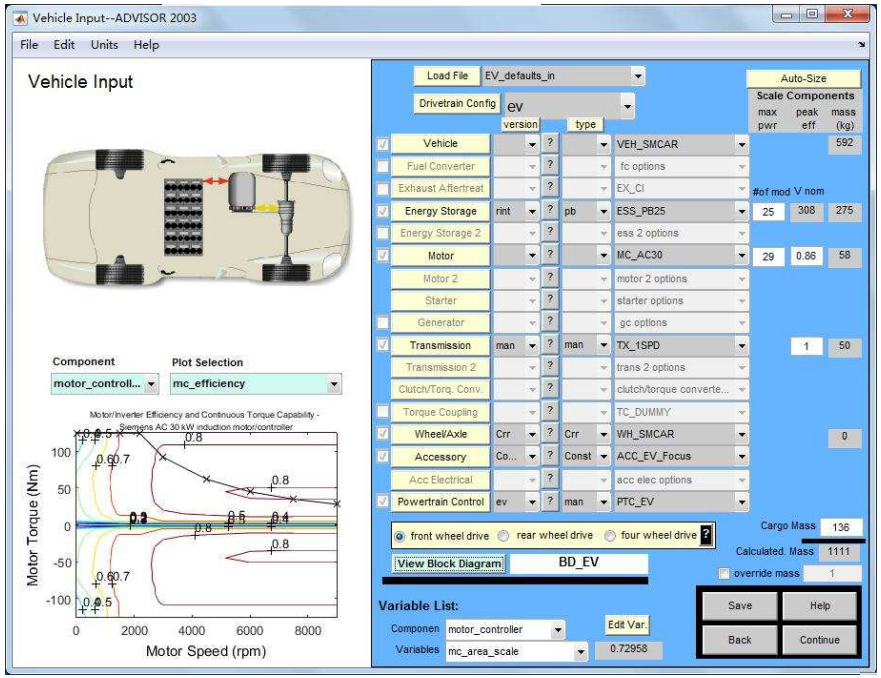
Roling $Rr = k_r(m+m_p)g \bullet \cos\gamma$

Road gradient $Fw = (m+m_p)g \bullet sin\gamma$

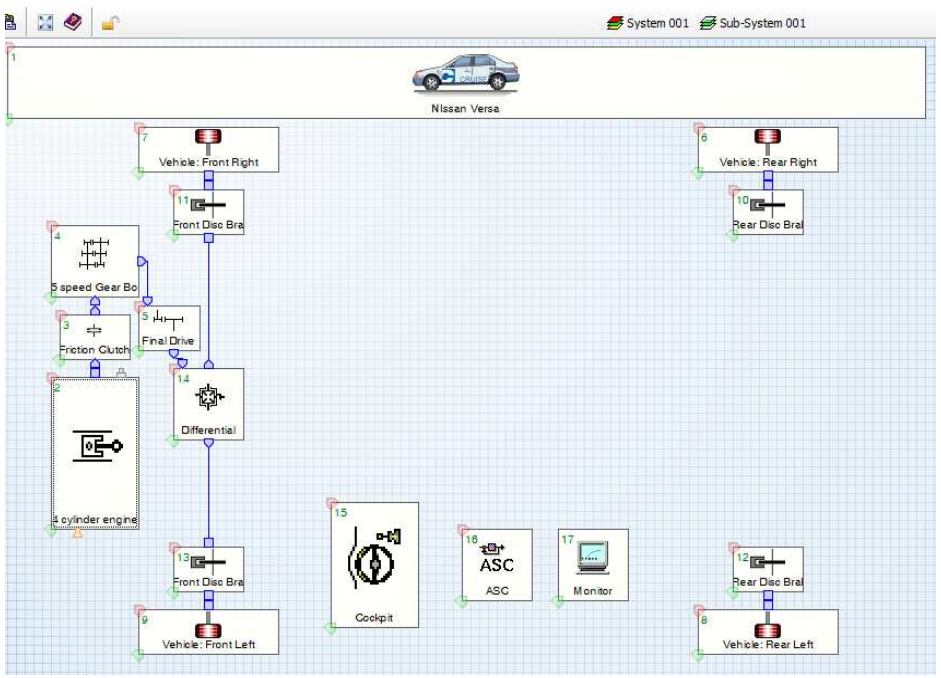
Aerodynamics $Ra = 1/2 \bullet \rho C_d A_f v^2$

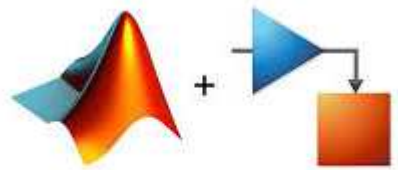
Propultion $Fp = (k_m \bullet m+m_p) \bullet dv/dt$

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



AVL CRUISE





combine MATLAB code and Simulink models together.

python™

Conclusions P#4,P#5,P#6, P#7: Total emissions per year

Emissions/Fleet	Lisbon-Porto TAP 5 roudtrip 	SofLusa Lisboa-Barreiro 	Lisbon-Porto 5 Car fleet 	Lisbon-Porto Alfa pendular (1 roundtrip/day) 
CO_2 (ton/year)	19 000	16 580	140	1750
NOx (ton/year)	32	415	0.2	1.2
PM2.5 (ton/year)	6.5	7.4	0.1	NA

IINAS
International Institute for Sustainability Analysis and Strategy

EN DE

News About Team Work Board Downloads Contact

Themes Projects GEMIS

GEMIS - Global Emissions Model for integrated Systems

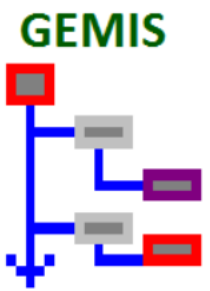
IINAS is the host of GEMIS (**G**lobal **E**missions **M**odel for **i**ntegrated **S**ystems), a public domain **life-cycle** and material flow analysis model and **database** that IINAS **provides freely**.

GEMIS was first released in 1989, and is continuously updated and extended since then. It is used by many parties in more than 30 countries for environmental, cost and employment analyses of energy, materials and transport systems.

IINAS continues networking with GEMIS users on the international level, and extending and improving the model, and its database.

More information on GEMIS is given **here**. There are **reports and data documentation** on GEMIS as well as **Help**.

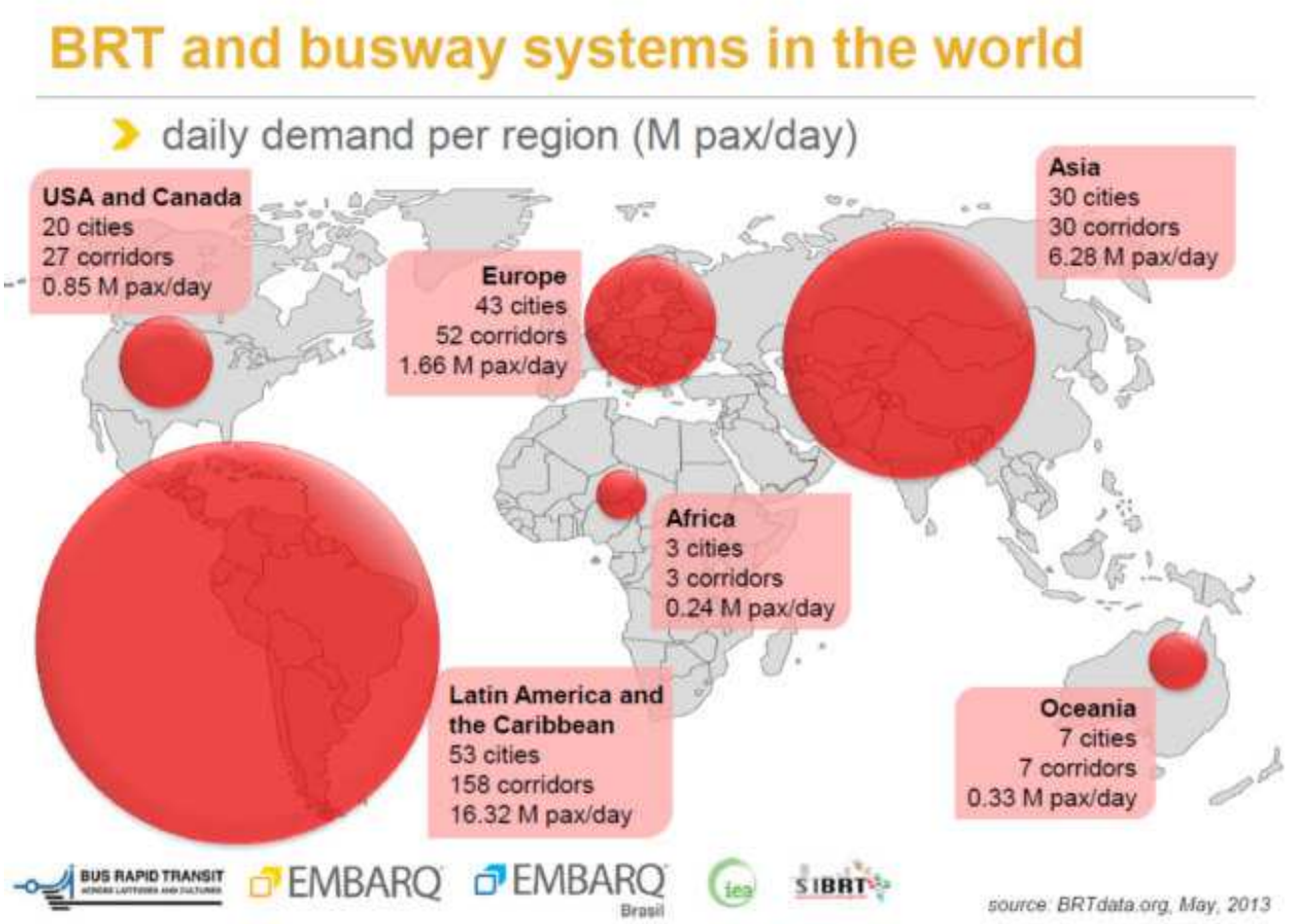
GEMIS is now acknowledged as a tool in the World Bank's **Platform for Climate-Smart Planning**



GEMIS

Emissions/Fleet	Lisbon-Porto TAP Tier 1 	Lisbon-Porto TAP Gemis w/out construction	Lisbon-Porto TAP Gemis w/out construction Scope Local
CO_2 (ton/year)	19 000	5* 4205 = 21025	5*3663 = 18315
NOx (ton/year)	32	5* 15 = 75	5*14 = 70
PM2.5 (ton/year)	6.5	5* 0.2 = 1	5* 0.035 = 0.2

Public transport-BRT systems



Public transport-BRT systems

Avenida 9 de Julio in Buenos Aires, before and after the addition of the Metrobus.

Bus rapid transit system

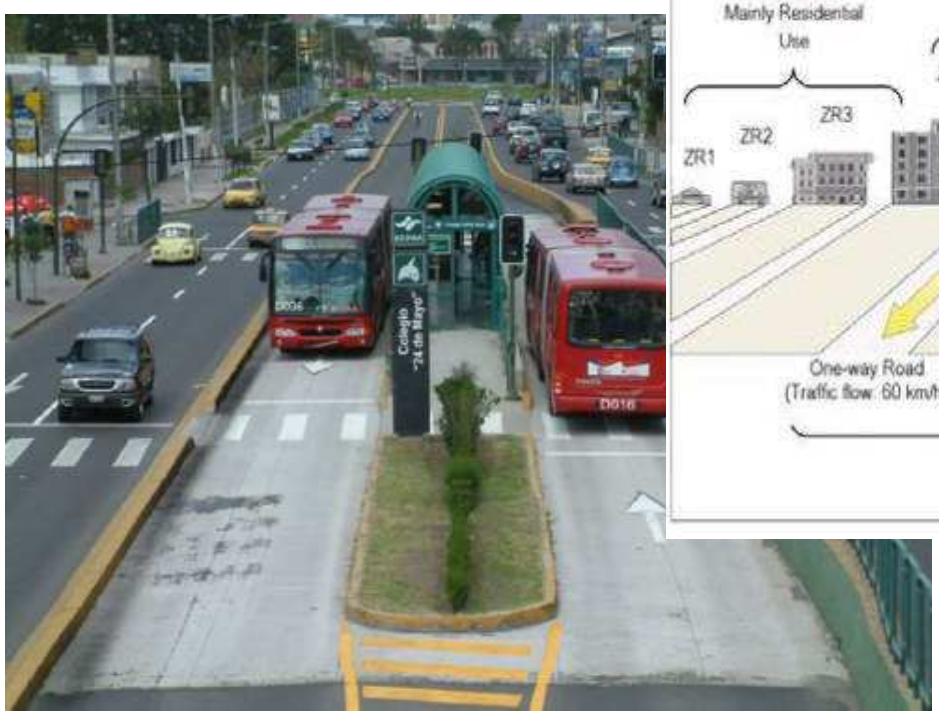
Curitiba and sustainable mobility

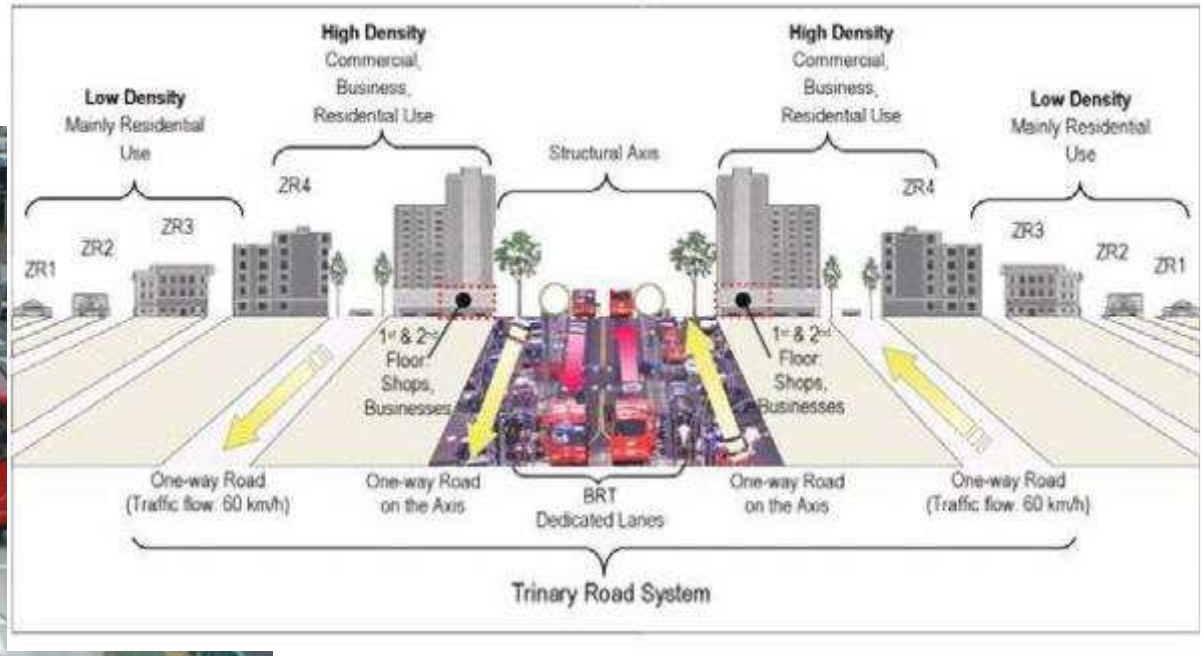
First Bus Rapid Transit system @1974

Bus rapid transit system

Curitiba and sustainable mobility

bus rapid transit (BRT)





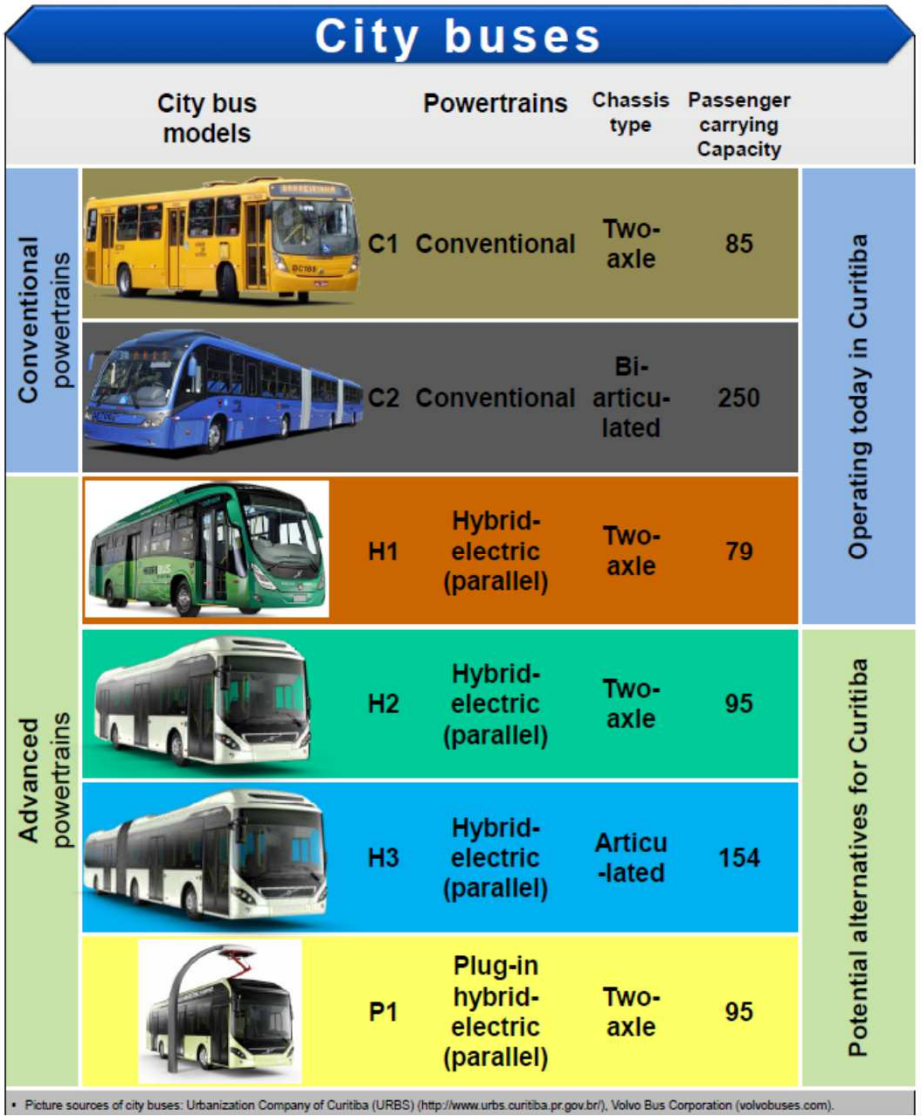
City planned in parallel

Curitiba

Energy use and CO_2 emissions of city buses in Curitiba, Brazil

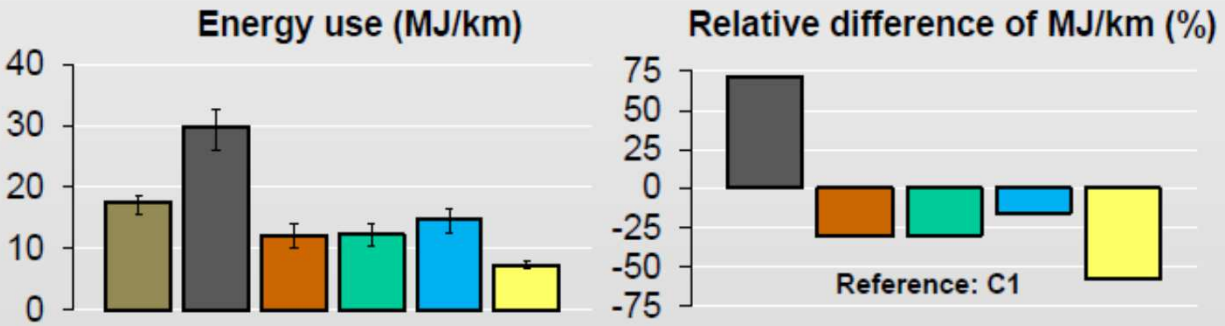
Dennis Dreier [a,*], Semida Silveira [a], Dilip Khatiwada [a],
Keiko V.O. Fonseca [b], Rafael Nieweglowski [c], Renan Schepanski [c]

[a] Division of Energy and Climate Studies, KTH Royal Institute of Technology, Stockholm, Sweden
[b] Federal University of Technology – Paraná, Curitiba, Brazil
[c] Volvo Bus Corporation, Curitiba, Brazil
* Corresponding author (dennis.dreier@energy.kth.se)



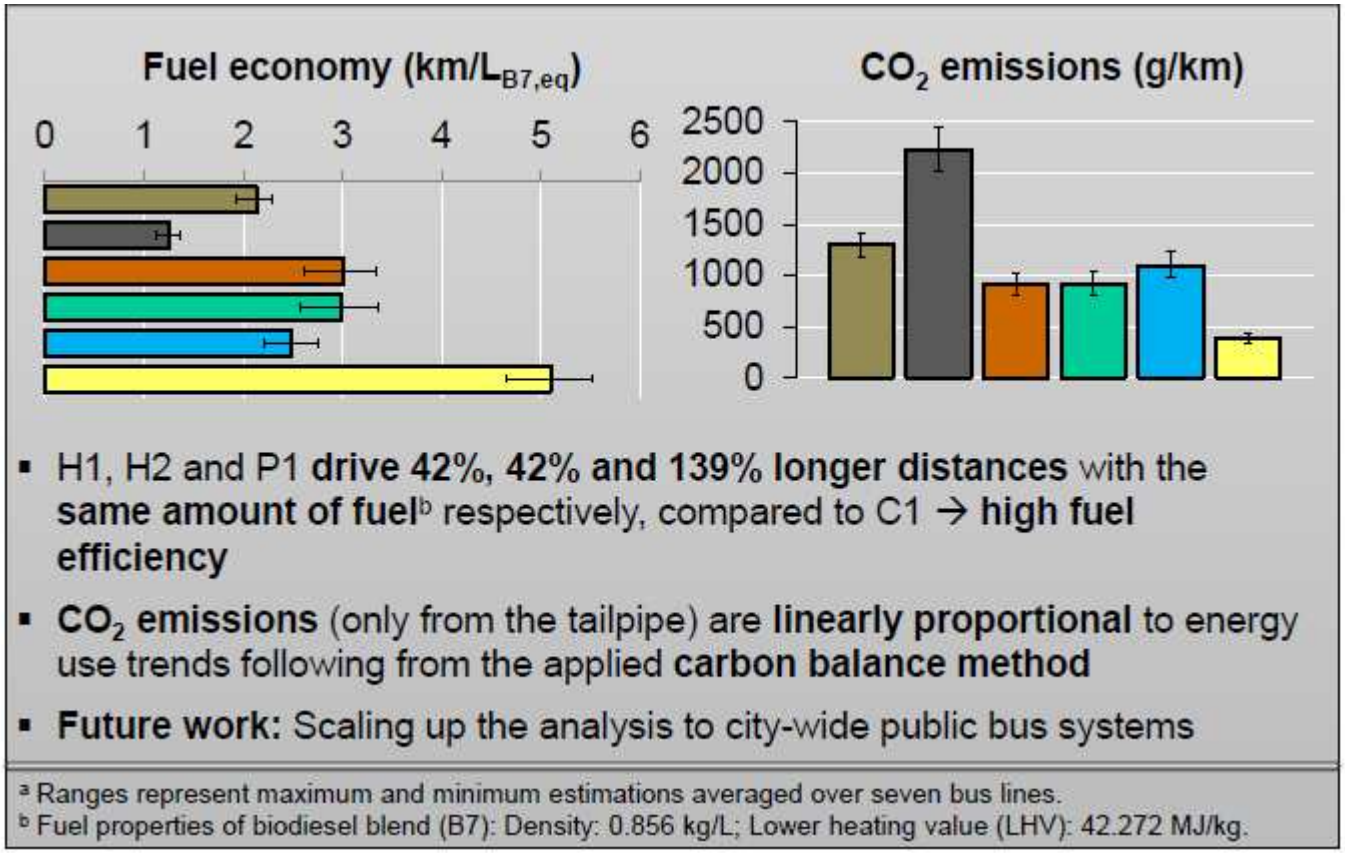
Curitiba

How do advanced powertrains in city buses affect energy use and CO_2 emissions during operation in Curitiba?



- **Advanced powertrains** (hybrid-electric, plug-in hybrid-electric) **can contribute to significant reduction of energy use[a] and CO_2 emissions of city buses**
- H1, H2 and P1 consume **30%, 30% and 58% less energy (MJ/km)** respectively, compared to C1 → **enormous energy saving potentials**

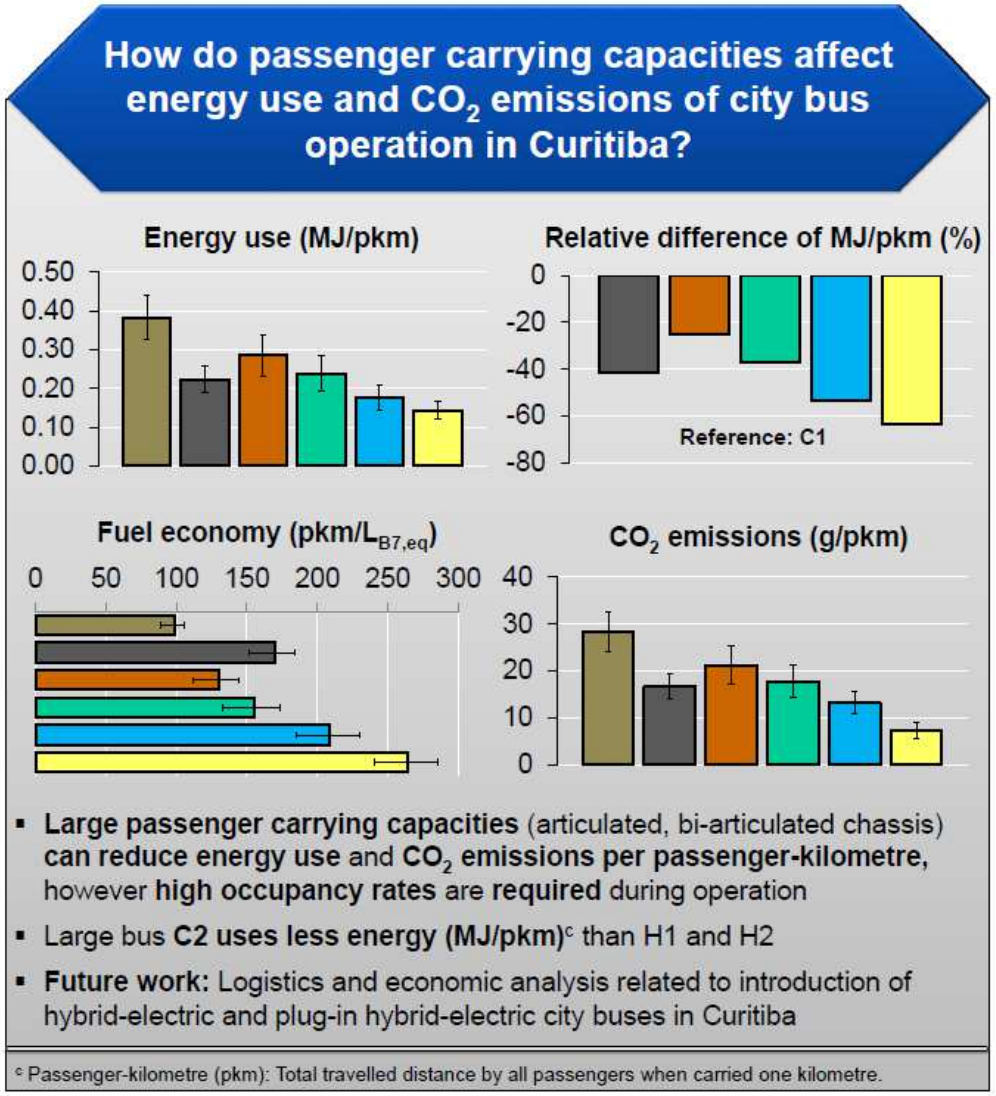
Curitiba



- H1, H2 and P1 **drive 42%, 42% and 139% longer distances** with the **same amount of fuel**[b] respectively, compared to C1 → **high fuel efficiency**
- **CO_2 emissions** (only from the tailpipe) are **linearly proportional** to energy use trends following from the applied **carbon balance method**
- **Future work:** Scaling up the analysis to city-wide public bus systems

[a] Ranges represent maximum and minimum estimations averaged over seven bus lines.
[b] Fuel properties of biodiesel blend (B7): Density: 0.856 kg/L; Lower heating value (LHV): 42.272 MJ/kg.

Curitiba


How do passenger carrying capacities affect energy use and CO_2 emissions of city bus operation in Curitiba?
Energy use (MJ/pkm)
0.50
0.40
0.30
0.20
0.10
0.00
Relative difference of MJ/pkm (%)
0
-20
-40
-60
-80
Reference: C1
Fuel economy (pkm/$L_{B7,eq}$)
0
50
100
150
200
250
300
CO_2 emissions (g/pkm)
40
30
20
10
0
▪ Large passenger carrying capacities (articulated, bi-articulated chassis) can reduce energy use and CO_2 emissions per passenger-kilometre, however high occupancy rates are required during operation
▪ Large bus C2 uses less energy (MJ/pkm)[c] than H1 and H2
▪ Future work: Logistics and economic analysis related to introduction of hybrid-electric and plug-in hybrid-electric city buses in Curitiba
[c] Passenger-kilometre (pkm): Total travelled distance by all passengers when carried one kilometre.

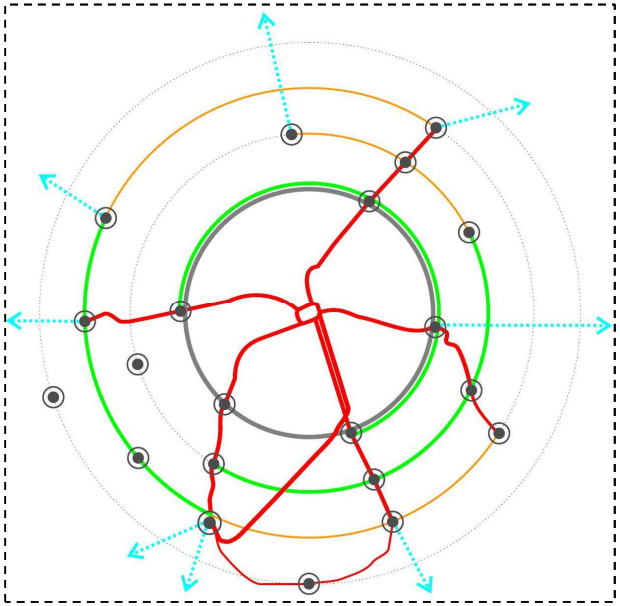
Curitiba

Curitiba has just 35 km of exclusive bicycles lanes (Berlim 620 km)

BRT 82 km
Metropolitan region c.a. 3000000 inhabitants

http://www.biocidade.curitiba.pr.gov.br/biocity/04.html

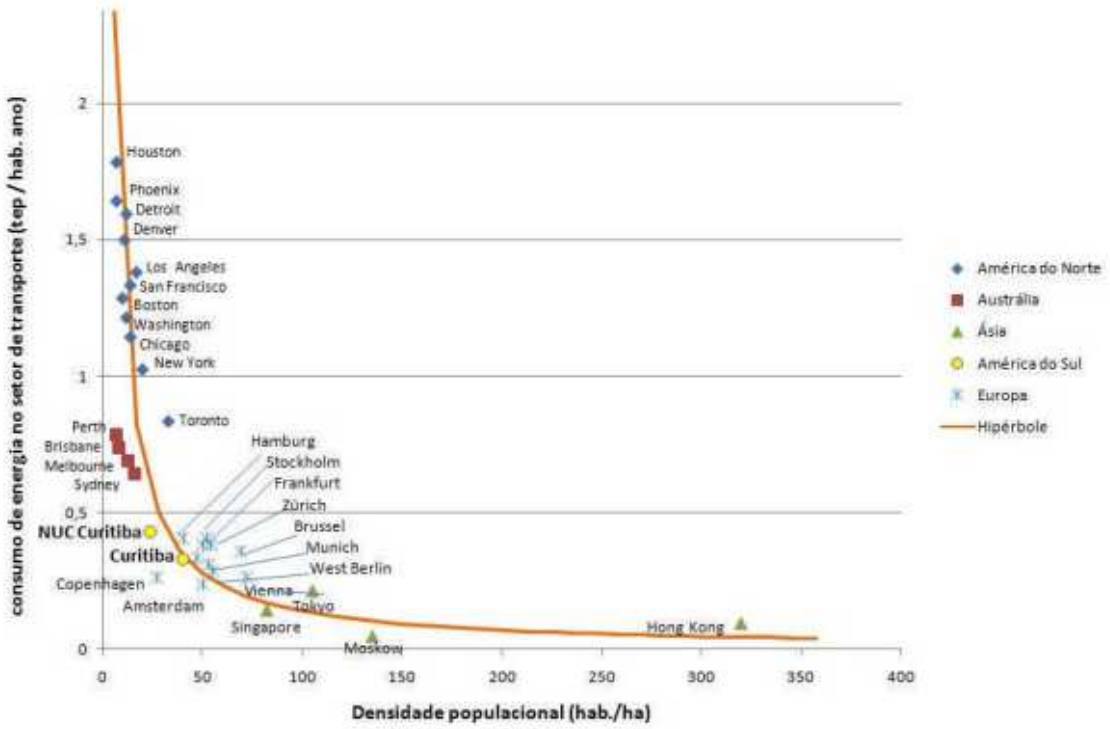
Buses in Operation	2,216
Total Quantity of Buses	2,580
Passengers transported/day	2,281,654
Lines	470
Interchange Stations	34
Tube Stations	350
Companies	28



Bus rapid transit system

Curitiba consume less 30% in transport compared to same size Brazilian cities

Figura 2 – Relação entre densidade populacional e consumo de energia no transporte, adaptado de Newman e Kenworthy (1989).



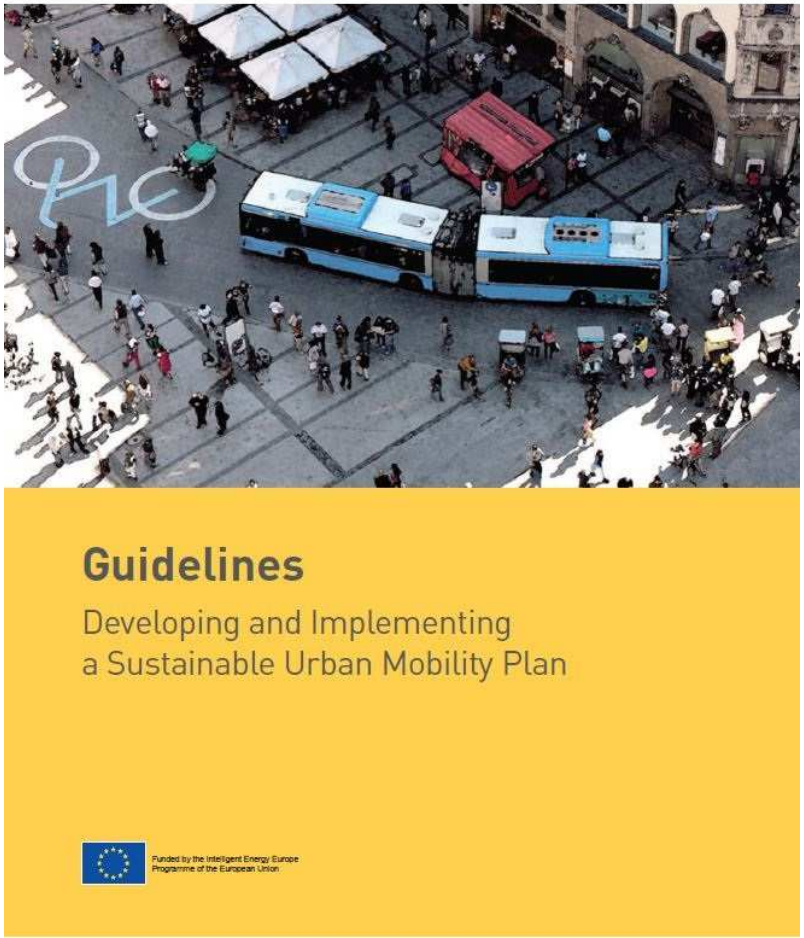
http://www.infohab.org.br/entac2014/2012/docs/0511.pdf

Global BRT data

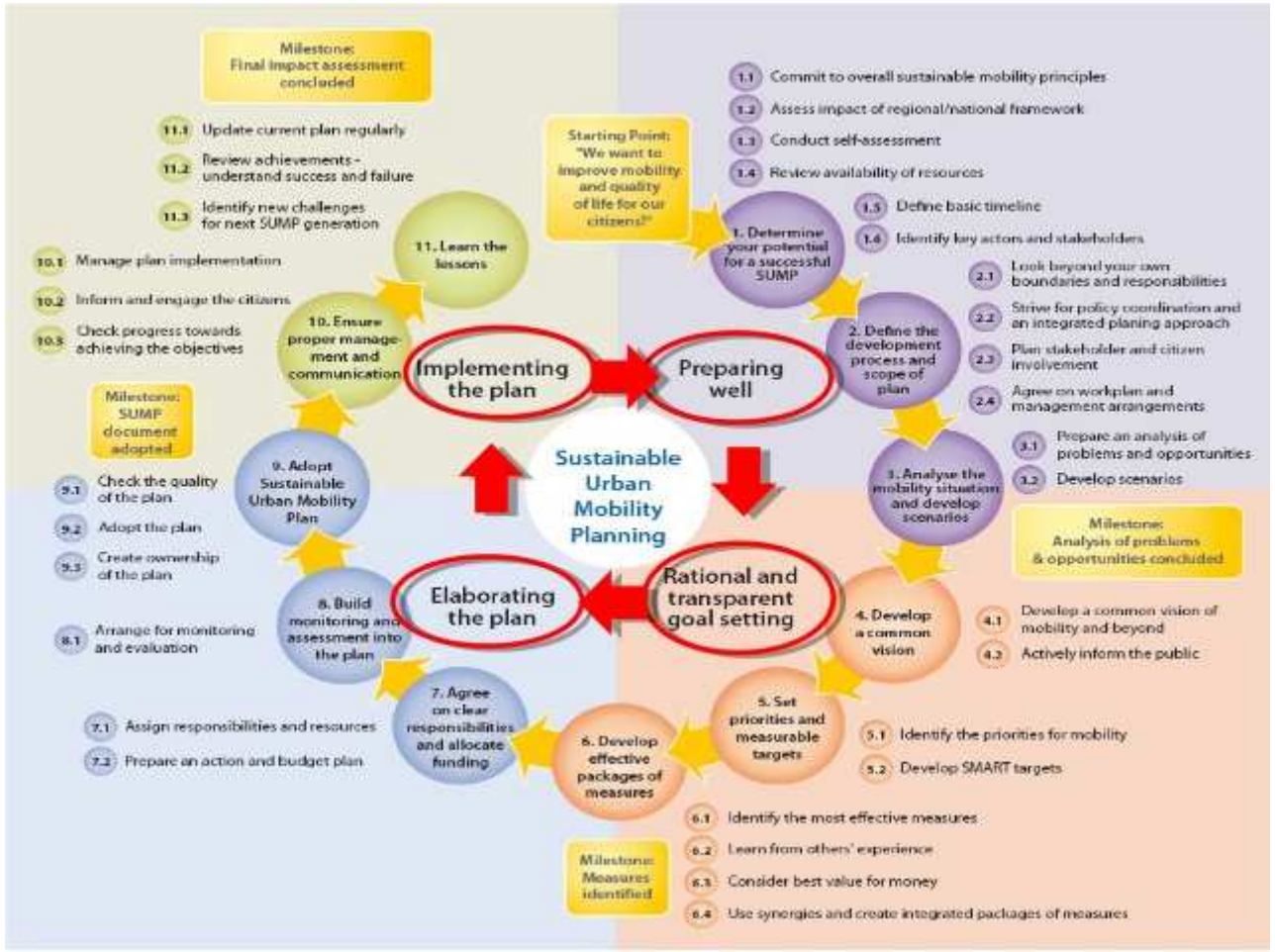
https://brtdata.org/

SUMP - Sustainable urban mobility plans

European Platform on Sustainable Urban Mobility Plans



SUMP - Sustainable mobility plans



Characterization of current status
SURVEYS

Vision for the future
Scenario building

Surveys

Surveys

CENSOS 2011

XV recenseamento geral da população
V recenseamento geral da habitação

RESULTADOS DEFINITIVOS

LISBOA

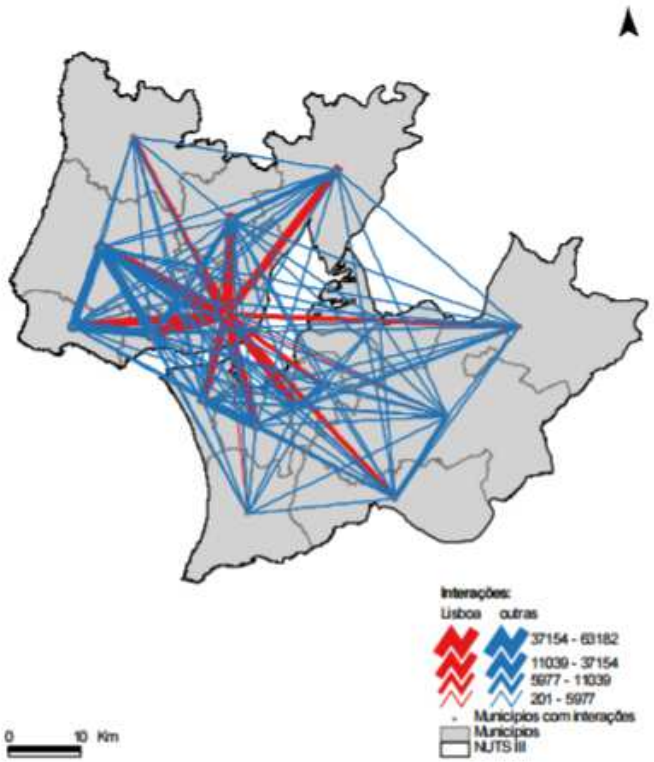
MOVIMENTOS PENDULARES .....

MEIO DE TRANSPORTE UTILIZADO NOS MOVIMENTOS PENDULARES .....

TEMPO MÉDIO POR DESLOCAÇÃO PENDULAR .....

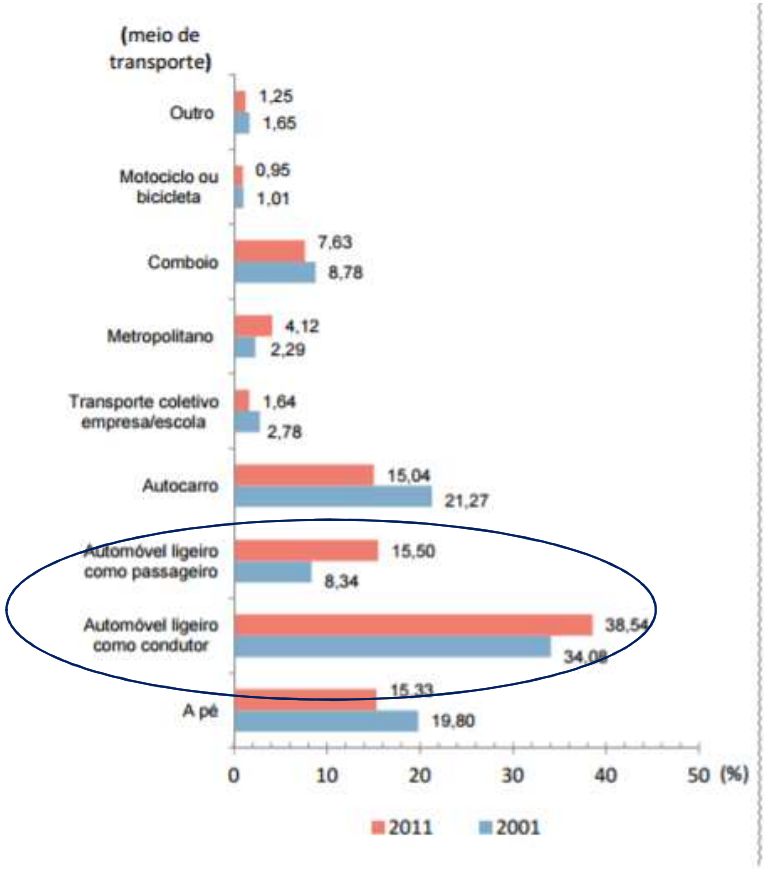
Surveys

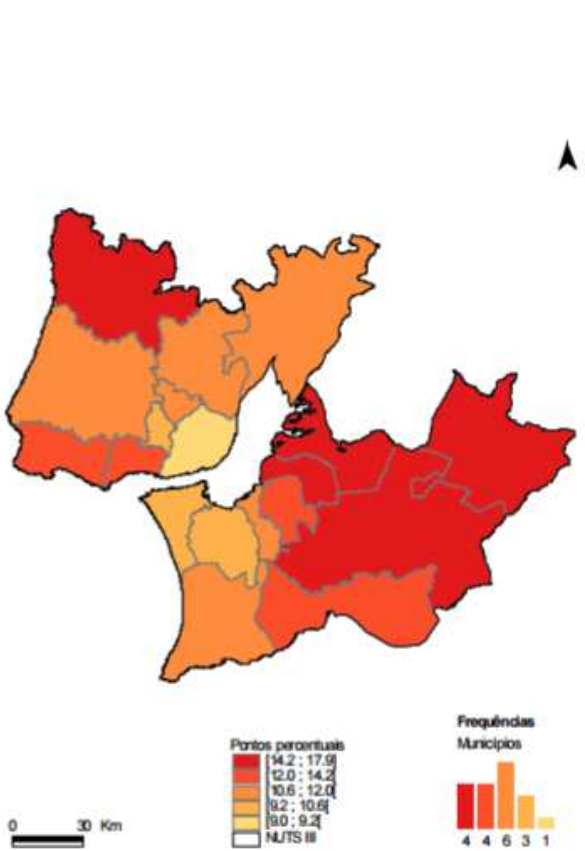
Commuting(regional interactions), 2011



Surveys

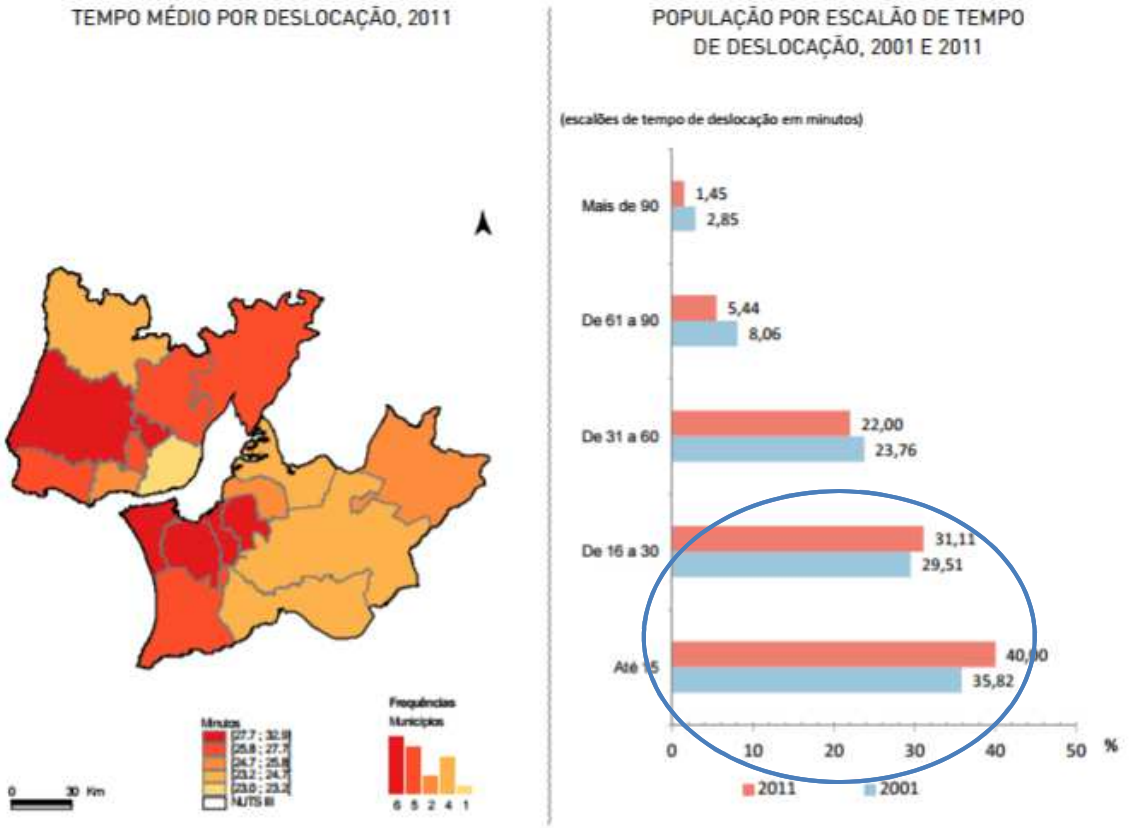
Means of transport in commuting



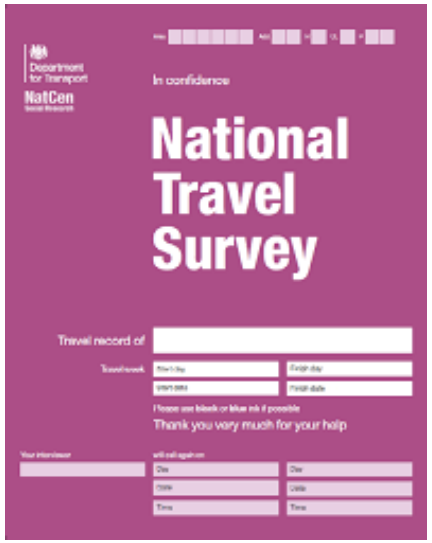


Surveys

Average time in commuting (average 30 min 2001; 26 min 2011)



How people travel?



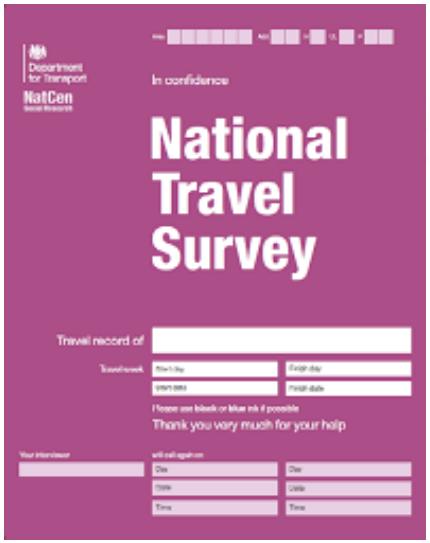
Why people travel?

How people travel?

When people travel?

Surveys

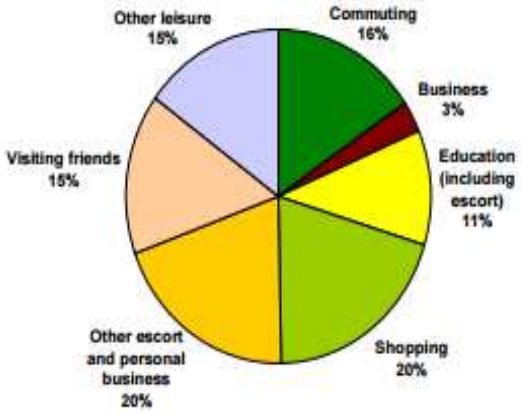
How people travel?



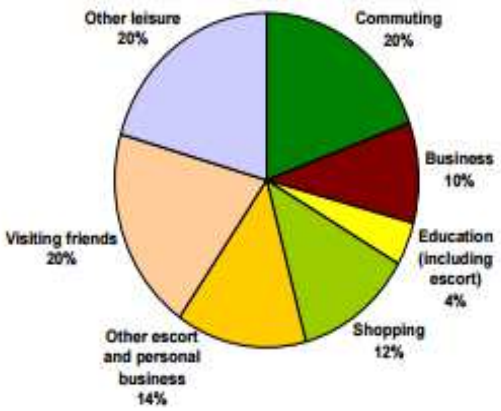
Why people travel?

Purpose share: Great Britain, 2010
(NTS web tables NTS0401 and NTS0402)

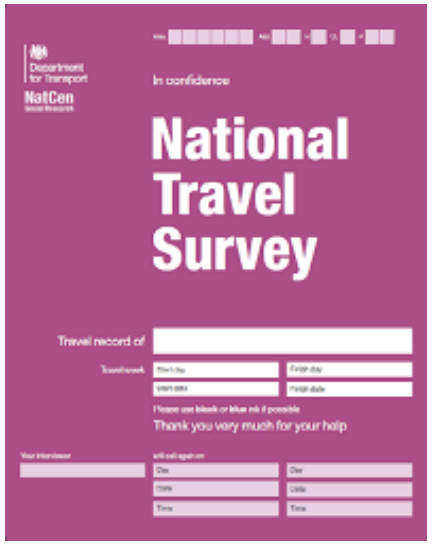
Average number of trips



Average distance travelled



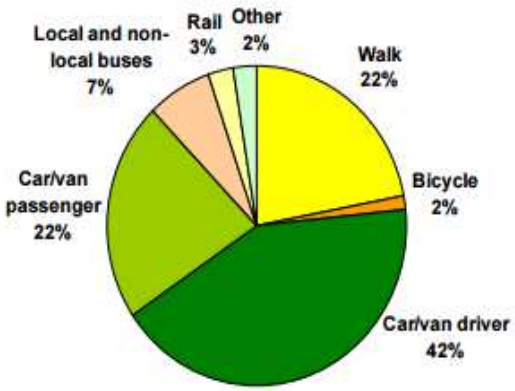
How people travel?



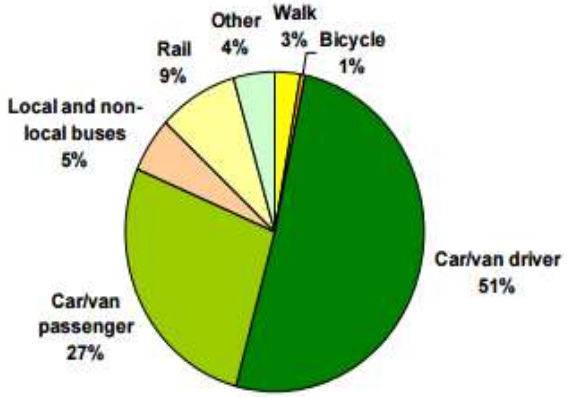
How people travel?

Mode share: Great Britain, 2010
(NTS web tables NTS0301 and NTS0302)

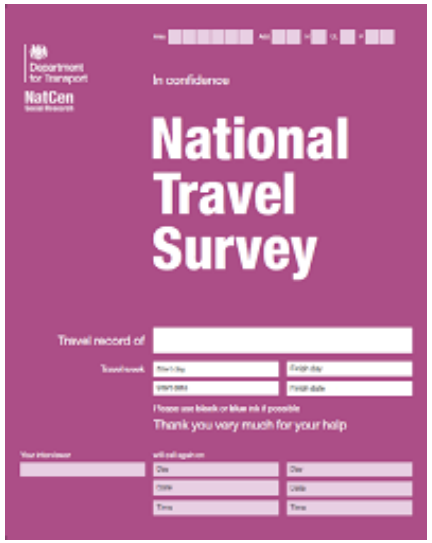
Average number of trips



Average distance travelled

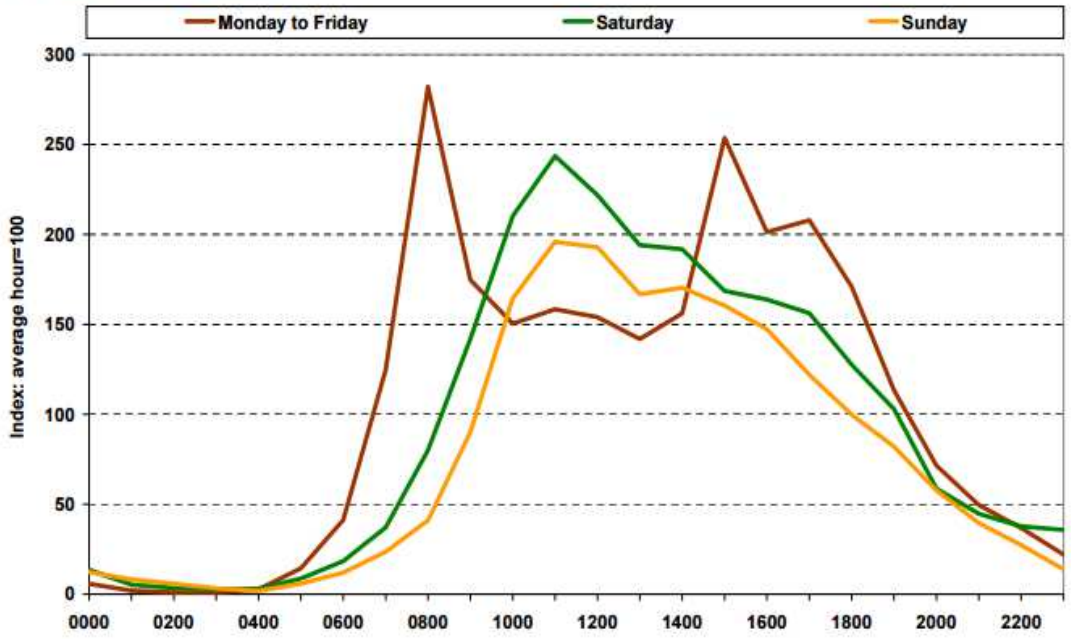


How people travel?

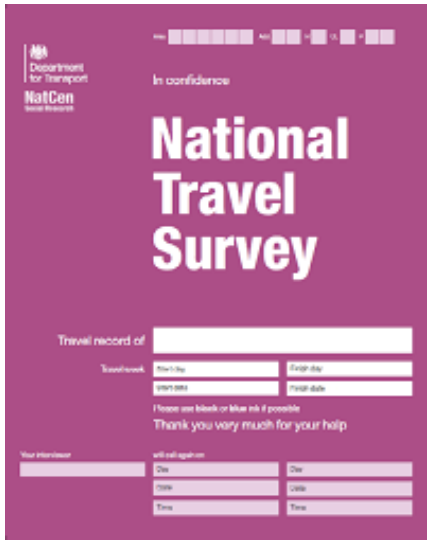


When people travel?

Trips in progress by time of day and day of week - index: Great Britain, 2010
(NTS web table NTS0501)



How people travel?

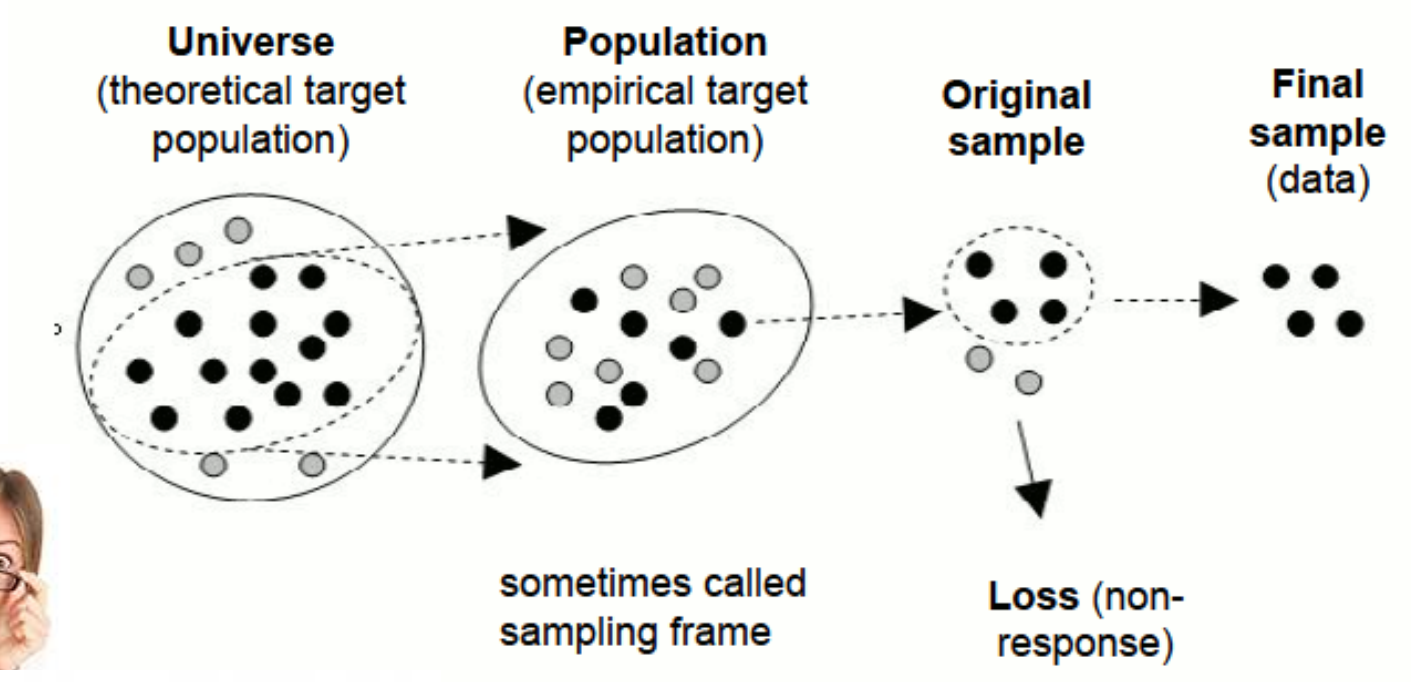


Why people travel?

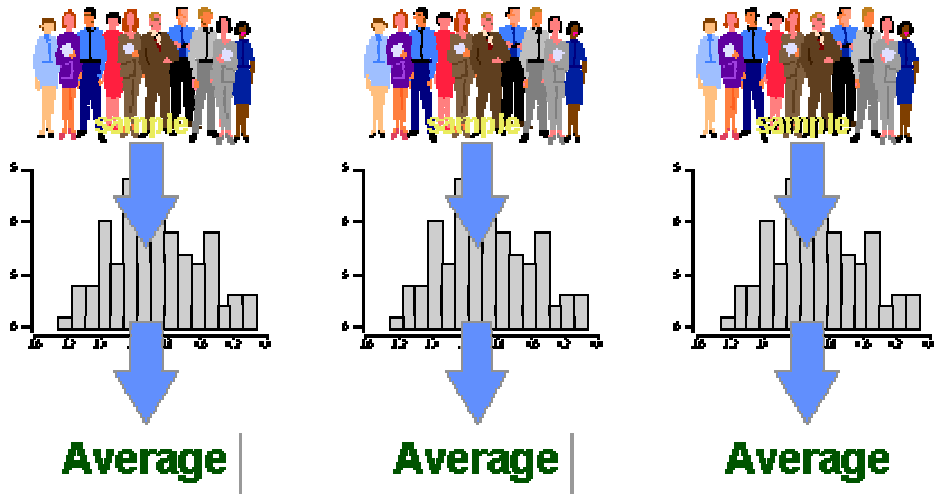
How people travel?

When people travel?

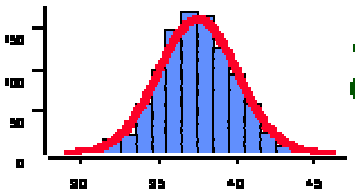
How people travel?



How people travel?

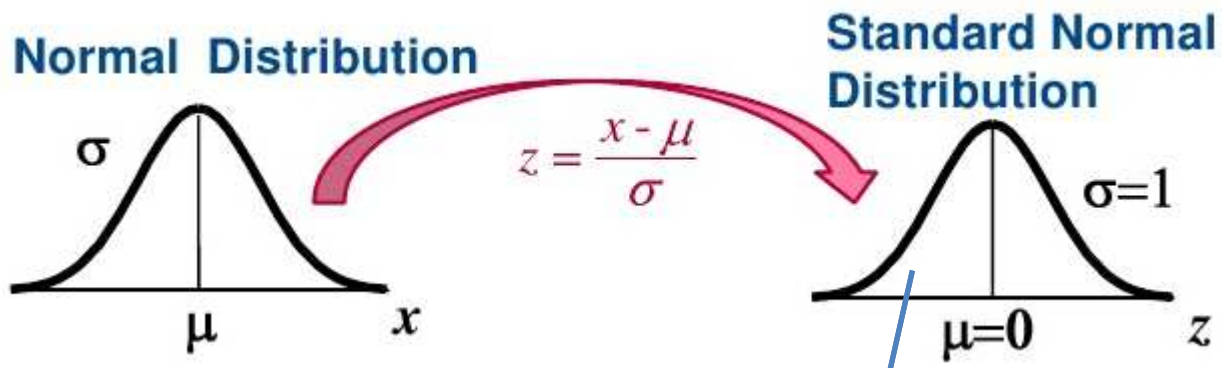


The Sampling Distribution...



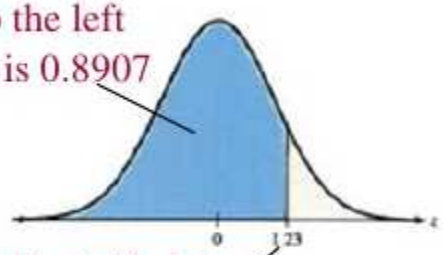
...is the distribution of a statistic across an infinite number of samples

Surveys



Area = 1

2. The area to the left of $z = 1.23$ is 0.8907



1. Use the table to find the area for the z-score

Surveys

How people travel? Origin –Destination

How many respondents?

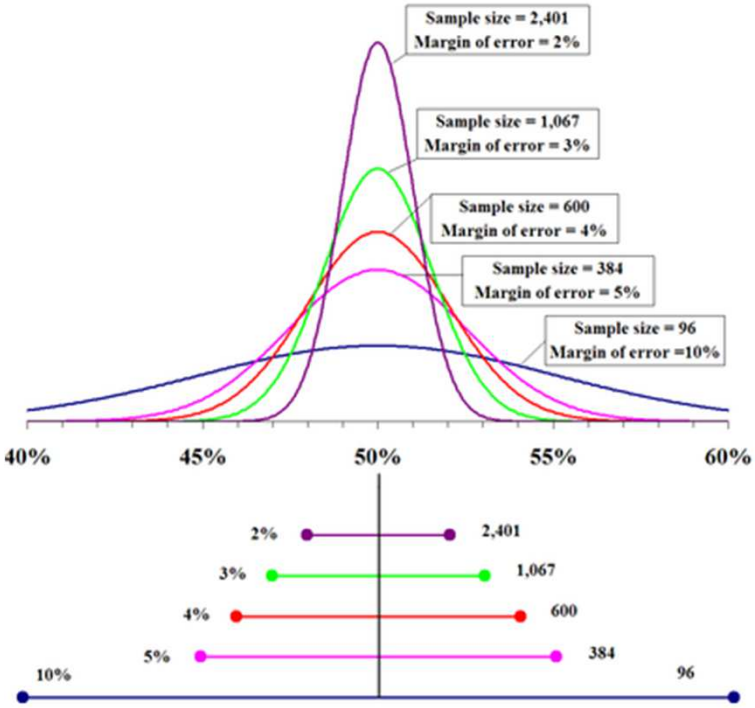
$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+(\frac{z^2 \times p(1-p)}{e^2 N})}$$

N= total population (small size)
Z = confidence level (90%, 99%, 95%)
e = margin of error (e.g. 5% input 0.05)
p= 50% (estimative of answer, 0.5)

N > 100.000 individuals $\Rightarrow$ Sample size $\frac{z^2 \times p(1-p)}{e^2}$

Surveys

How many respondents?



margin of error (or confidence intervals)

Suppose in your survey 40% of the respondents pick a certain answer and your margin of error is 2%. This would mean that if you interrogate the total population, you can be sure that between 38% and 42% would pick the same answer

Surveys

How many respondents?

Confidence level 90% -> Z=1.645

Confidence level 95% -> Z=1.96

Confidence level 99% -> Z=2.575

Confidence level

How often the actual percentage of the population that picks a certain answer, lies within the margin of error. In market research, margins of error are calculated generally for a confidence level of **95%**.

Surveys

How people travel? Origin –Destination

How many respondents?

Respondents Needed at Error of ±3%, ±5%, & ±10%			
Population	**±3%**	**±5%**	**±10%**
500	345	220	80
1,000	525	285	90
3,000	810	350	100
5,000	910	370	100
10,000	1,000	385	100
100,000	1,100	400	100
1,000,000	1,100	400	100
10,000,000	1,110	400	100

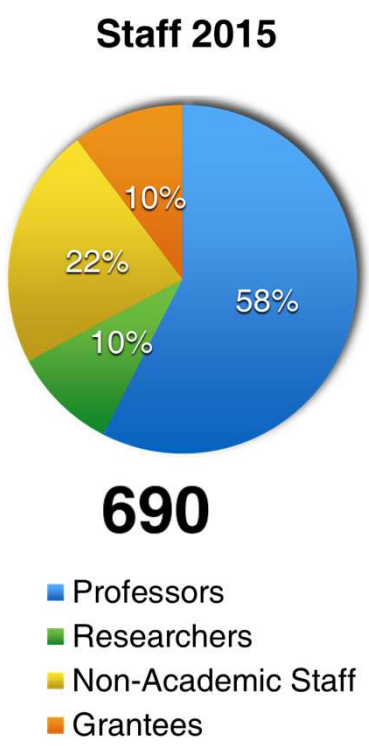
N > 100 000

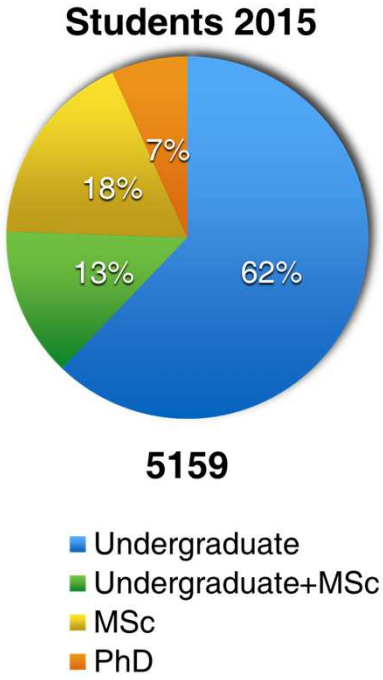
$$\frac{z^2 \times p(1-p)}{e^2}$$

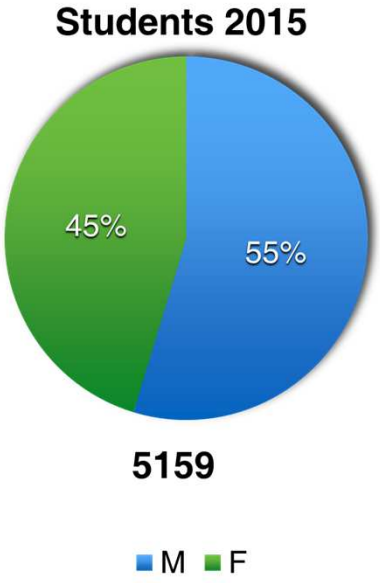
Exercice

P#8 Your survey results are meanfull for FCUL population?

FCUL population 5849







Exercice

P#9 Your survey results are meanfull for FCUL population, respondents 23?

FCUL population N=5849 < 100 000 $\Rightarrow$

$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+(\frac{z^2 \times p(1-p)}{e^2 N})}$$

Several questions for example: **Willing to use an Autonomous Vehicle?**

1. Margin or error, i.e, expect the population answer will be in 2% of the sample's **e=0.02**
2. We think the answer would be 50% chance of yes or no **p=0.5**
3. Level of confidence, i.e., 95% chance of population answers fall within the margin of error **Z=1.96**

Exercice

$$Sample\ Size = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1+(\frac{z^2 \times p(1-p)}{e^2 N})}$$

Z	1.96
p	0.5
e	0.02
N	5849
Sample size	1702.236

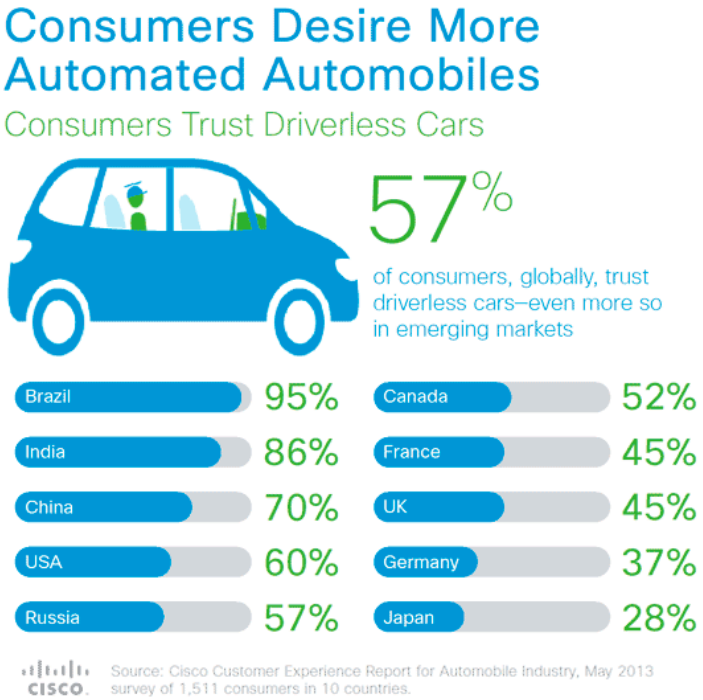
Z	1.96
p	0.5
e	0.1 ←
N	5849
Sample size	94.48

Z	1.645 ←
p	0.5
e	0.1 ←
N	5849
Sample size	66.87711

Not even at 10% margin error and 90% confidence!!

Surveys

P#10 the following survey results are meaningful?



1511 persons

10 countries (overall population > 2 000 million)

Surveys

N >> 100 000

$$\frac{z^2 \times p(1-p)}{e^2}$$

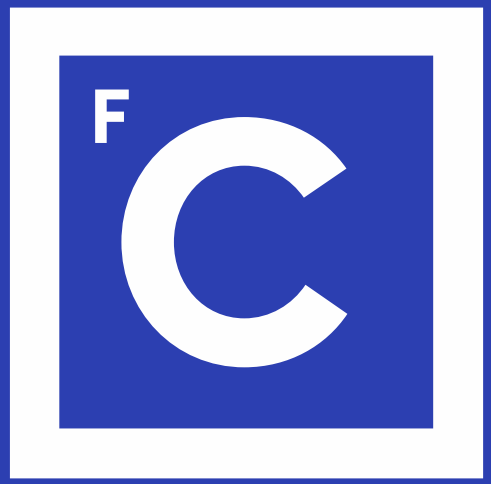
Z	1.96
p	0.5
e	0.02
N	2000000000
Sample size	2400.99712

N	Sample size
100000	2344.70367
500000	2389.5255
1000000	2395.24901
1000000000	2400.99424
2000000000	2400.99712

Margin of error increase

Z	1.96
p	0.5
e	0.03
N	2000000000
Sample size	1067.11054

Thanks



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