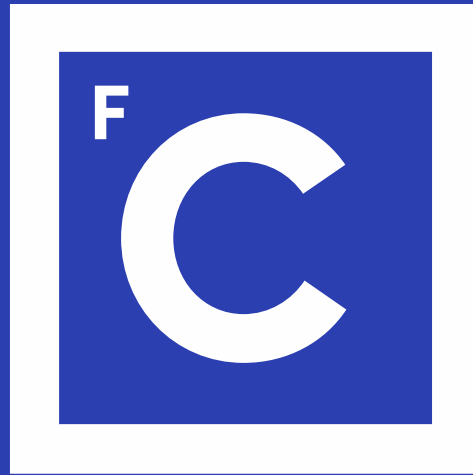




Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

Eng. Energy & Environment

move ► green



Sustainable Mobility

Program

Topics	#	Contents
Basic concepts and definitions	1	Transportation system; Transports classification; historical evolution;
	2	Introduction to “sustainability and metrics”
	3	Energy conversions, primary energy, final energy, useful energy; Minimum energy and emissions in mobility,
	4	Propulsion technologies, internal combustion engines, electric motors, fuel cells, efficiencies
Characterization of mobility patterns	5	Surveys; Statistics; transport sector share energy & emissions;
Sustainability – Environmental dimension	6	Development of “sustainability and Metrics”
Air quality	7	World Health Organization, Directives, standards for emissions, air quality index
	8	Air quality networks and pollutants covered - local and global emissions
Emission inventories	9	Emission inventory models, micro to macro, motor vehicle dynamics
	10	COPERT 5 fleet model

Program

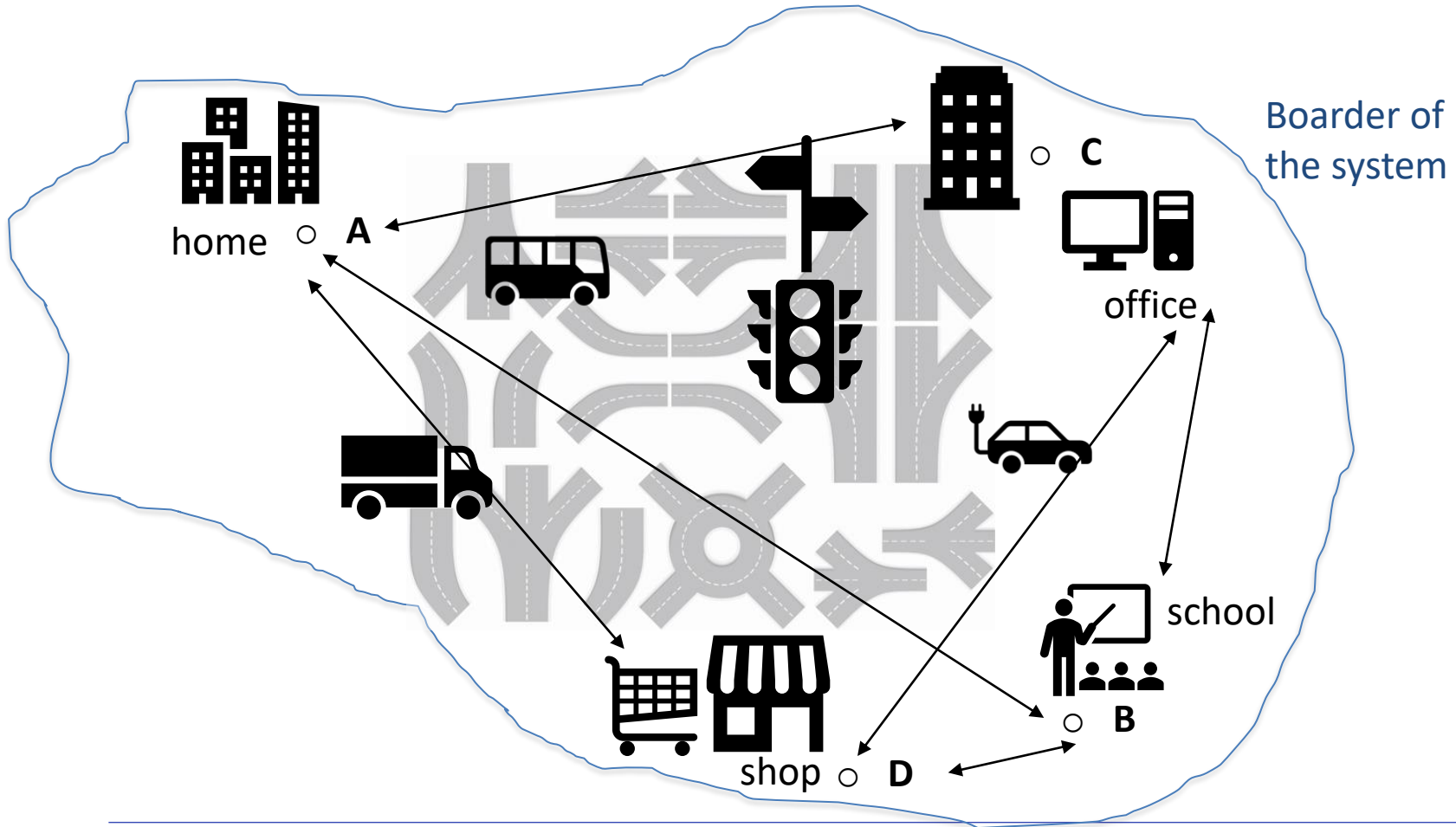
Topics	#	Contents
Application of metrics of Sustainable mobility	11	Comparing Lisbon and Oporto mobility Screening mobility patterns in University campus
Life cycle analysis in transportation systems	12	Life cycle analysis
	13	Water, land use, resources scarcity and carbon footprint
	14	Carbon footprint in transport
	15	Carbon footprint applied to electric versus diesel technology
Disruptions & consequences	16	COVID19 impact overview

TOPIC #1

- **When addressing “Sustainable Mobility” it is common to hear some terms like:**
 - ✓ Autonomous vehicles;
 - ✓ Transportation system;
 - ✓ Electric vehicles;
 - ✓ Logistics;
 - ✓ Biofuels;
 - ✓ ITS;
 - ✓ Energy consumption;
 - ✓ Commuting;
 - ✓ CO₂ emissions;
 - ✓ Intermodal;
 - ✓ NOx emissions;
 - ✓ Seamless;
 - ✓ PM emissions.

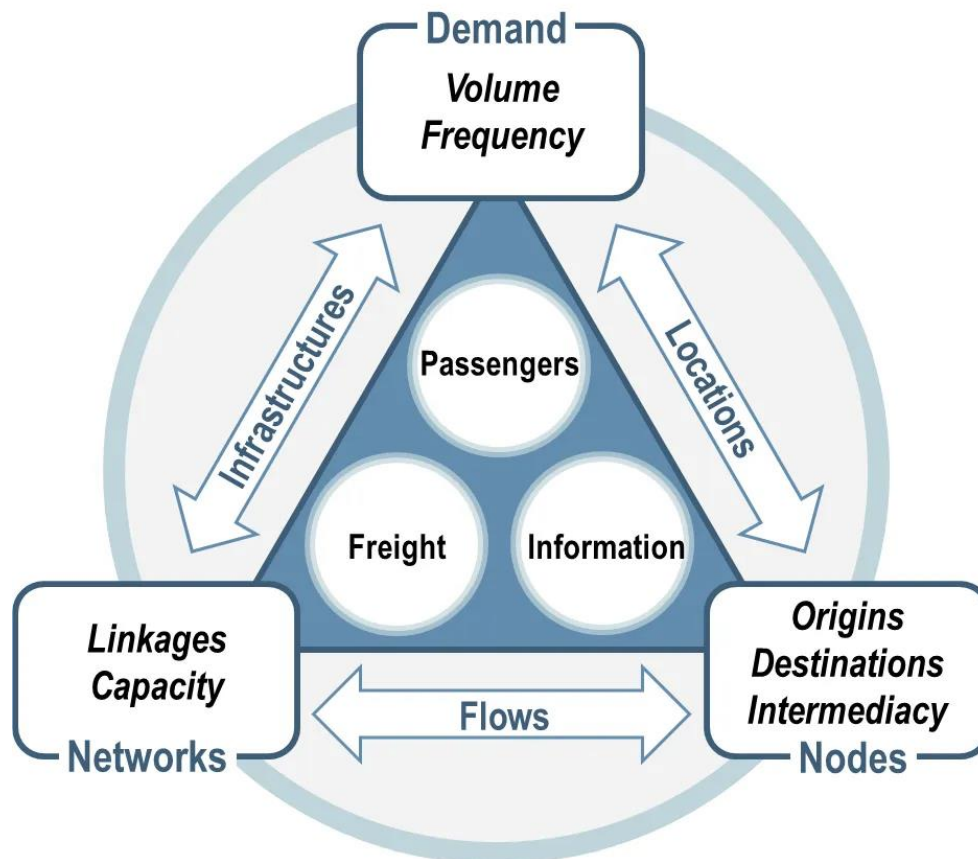
Transportation system

- A transportation system is an infrastructure that serves to move people and goods.



Transportation system

- A transportation system is an infrastructure that serves to move people and goods **efficiently**.

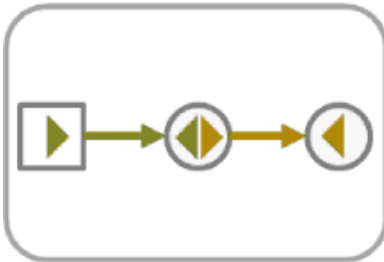


Transportation system composition



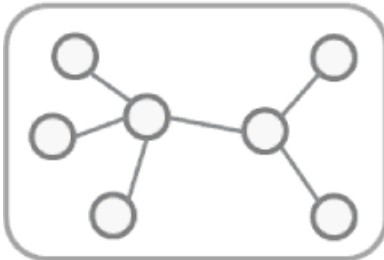
Modes (carriers)

Conveyances (vehicles) used to move passengers or freight.
Mobile elements of transportation.



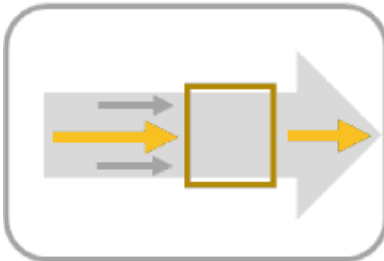
Infrastructures

Physical support of transport modes, such as routes and terminals.
Fixed elements of transportation.



Networks

System of linked locations (nodes).
Functional and spatial organization of transportation.



Flows

Movements of people, freight and information over their network.
Flows have origins, intermediary locations and destinations.

NODES Origin –Destination matrix

The Origin Destination matrix should have three things.

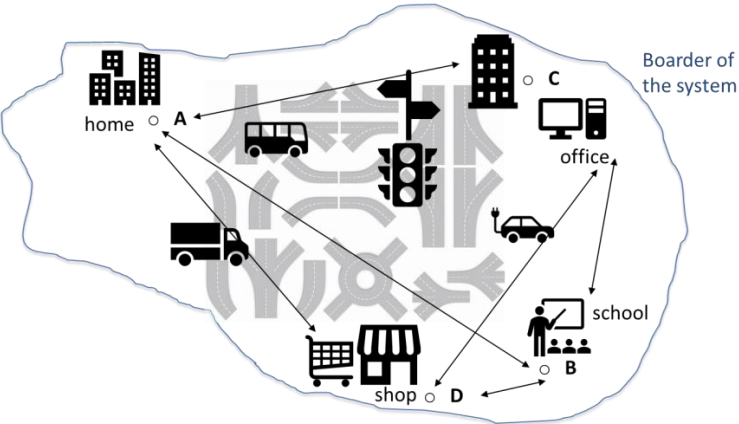
1. Name of Location.
2. Code of Each Location.
3. Compiled entries from Survey.

NAME	CODE	ward no 1	ward no 2	ward no 3	ward no 4	ward no 5	ward no 6	ward no 7	ward no 8	ward no 9	ward no 10	ward no 11	ward no 12	ward no 13	ward no 14	ward no 15	ward no 16	ward no 17	ward no 18	ward no 19	ward no 20	ward no 21	ward no 22	ward no 23	ward no 24	ward no 25
ward no 1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 13	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 14	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 16	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 18	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 19	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 21	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 22	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 23	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ward no 25	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Prepare the Origin Destination Matrix

Transportation system composition

NODES Origin –Destination matrix

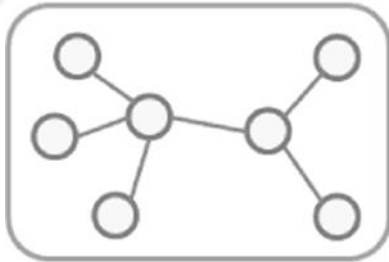


e.g Info n^{er} trips per day (flows and nodes)

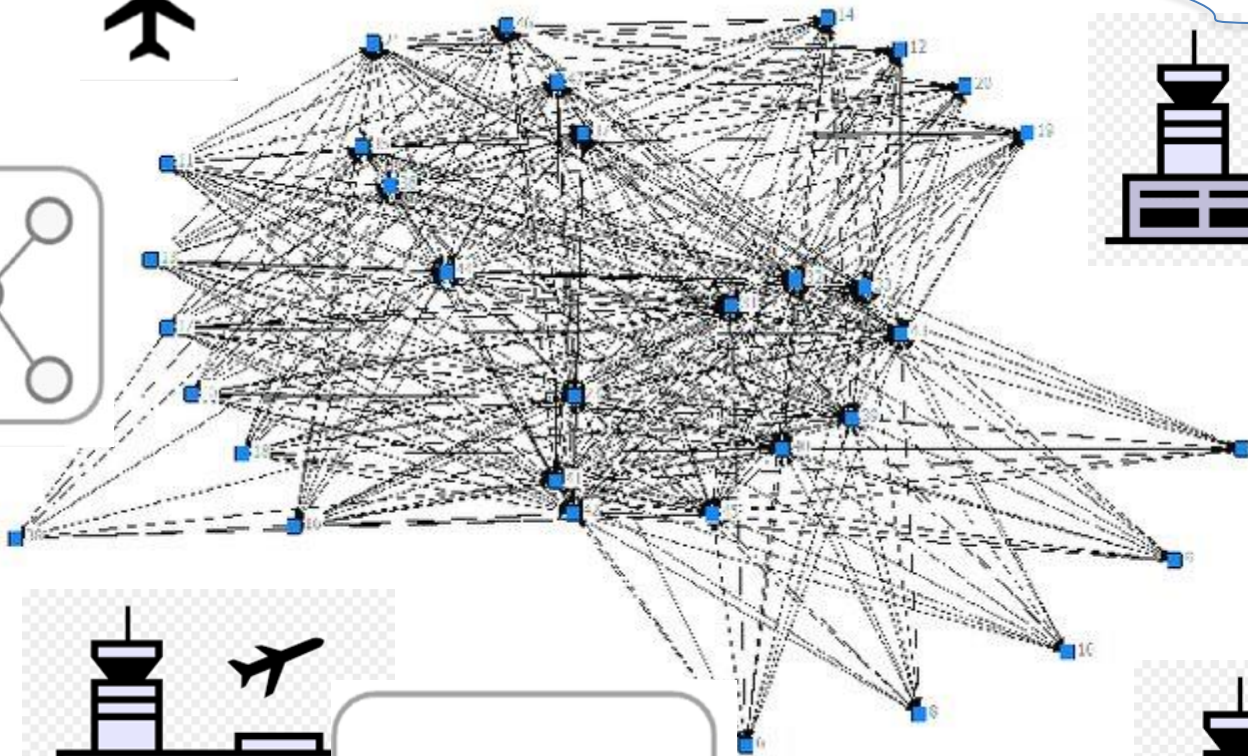
		DESTINATION				SUM
		A	B	C	D	
ORIGIN	A		65	28	28	121
	B	69		12	83	164
	C	100	60		217	377
	D	86	127	63		276
SUM		255	252	103	328	938

Transportation system example

Air transport mode



Network
Routes

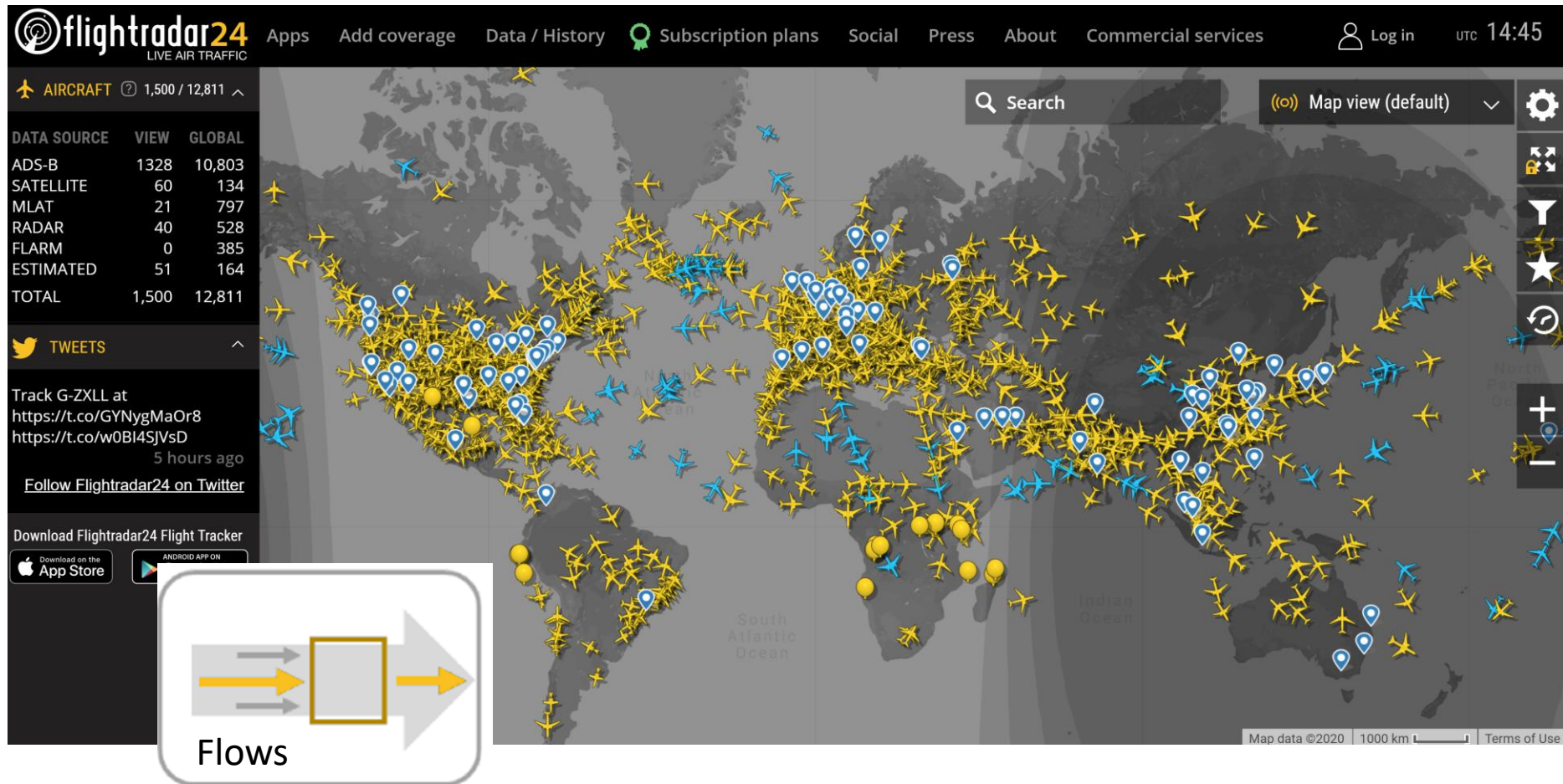


Infrastructure –
Airports/Terminals

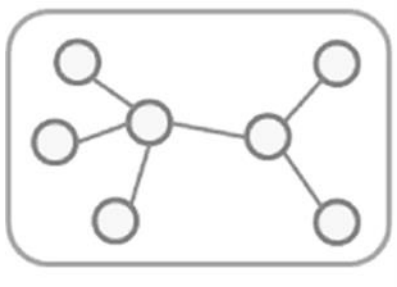


Transportation system example

<https://www.flightradar24.com/38.72,-9.13/2>



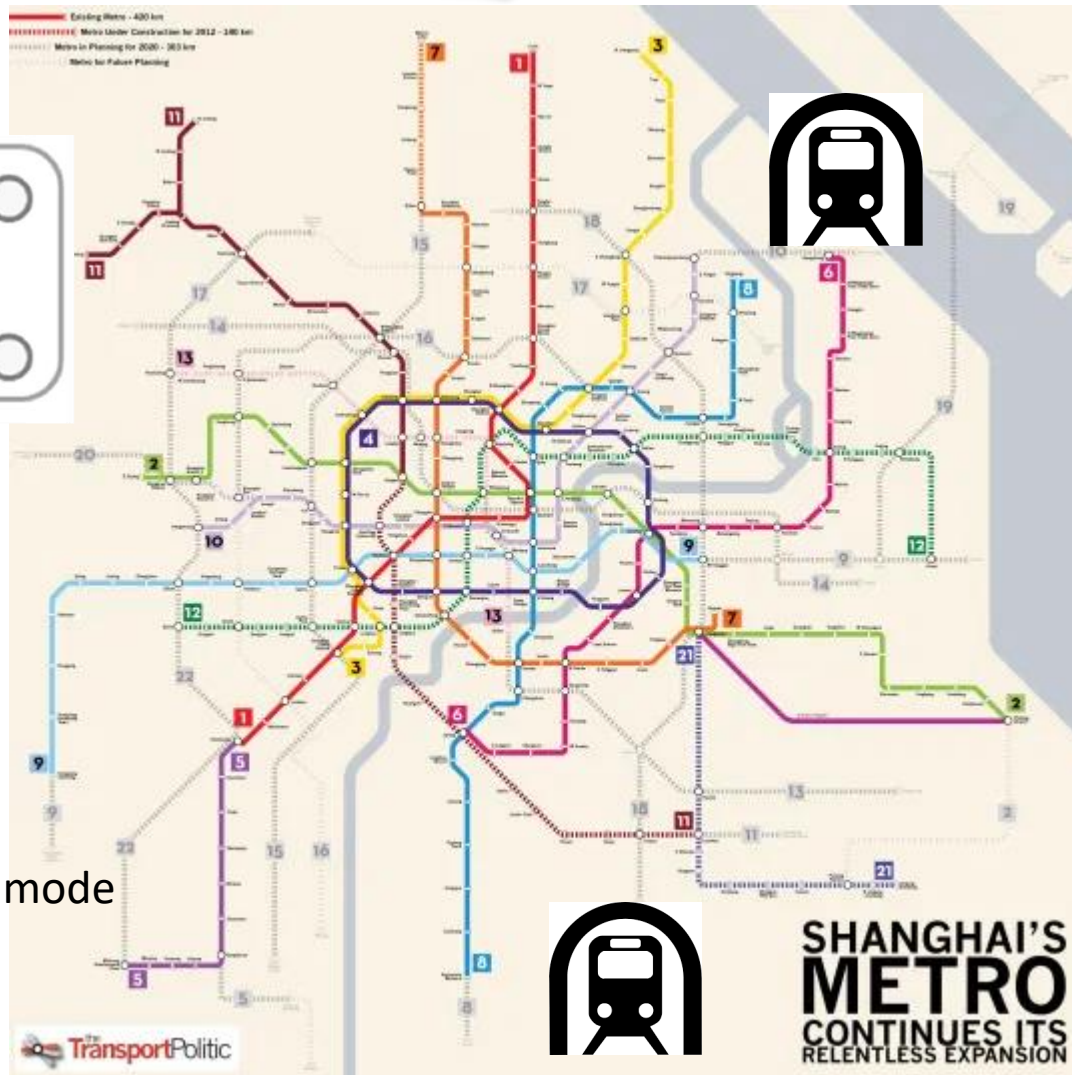
Transportation system example



Network
Routes



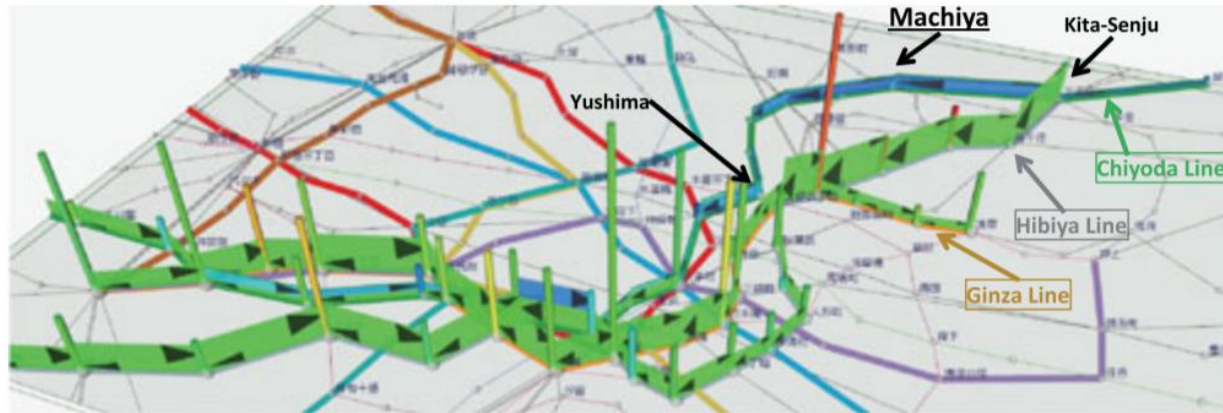
railway transport mode



Infrastructure –
Stations & railways



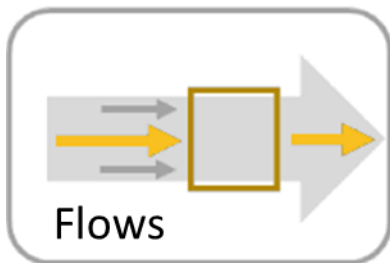
Transportation system example



(a) Estimated passenger flows without suspension information

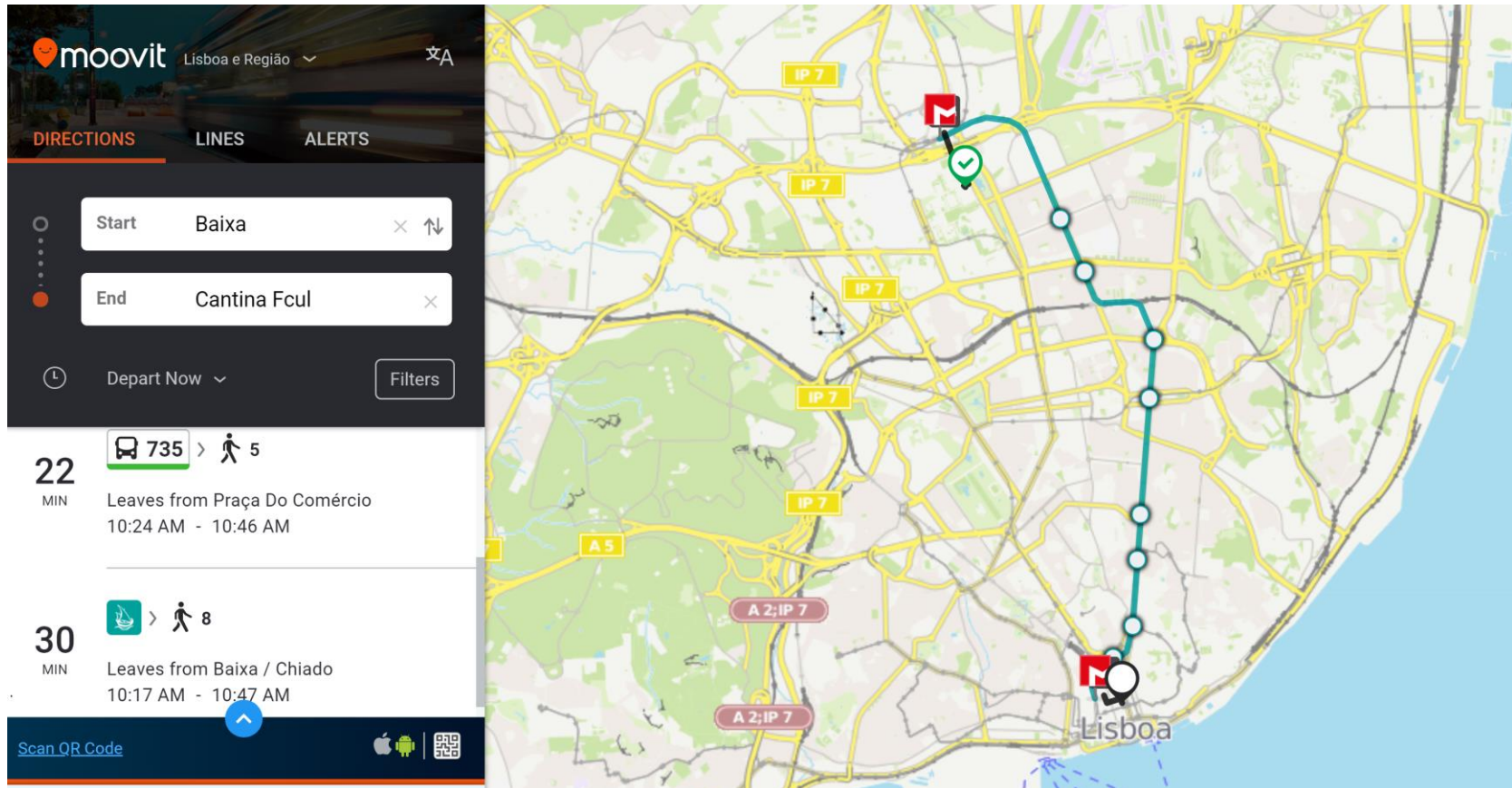


(b) Recomputed passenger flows with suspension information:
Sections from Kita-Senju to Yushima on the Chiyoda Line are suspended
from 9:59 to 10:37.



- Transportation...is moving people or goods from an origin to a destination;
- Logistics....is management of flows between origin and destination, i.e. optimization of modes, routes and schedules with a target objective. For example:

Fastness Cost Fuel consumption Comfort
Security



1 ROUTE

Starting point

or click [here](#) and then click on the map

Arrival point

or click [here](#) and then click on the map

2 TRANSPORT MODES

Transport Modes

- ☒ All
☒ Buses ☒ Subway
☒ Trains ☒ Ferries

or choose the operator

- All
 Carris
 Metro de Lisboa
 CP
☐ Operadores Preferenciais

3 OPTIONS

Date of...

Departure

Date

21/09/2020

Time

1h h 2h m

Choose the Route

- ☐ Faster
☐ Less Walking
☒ Less Transfers

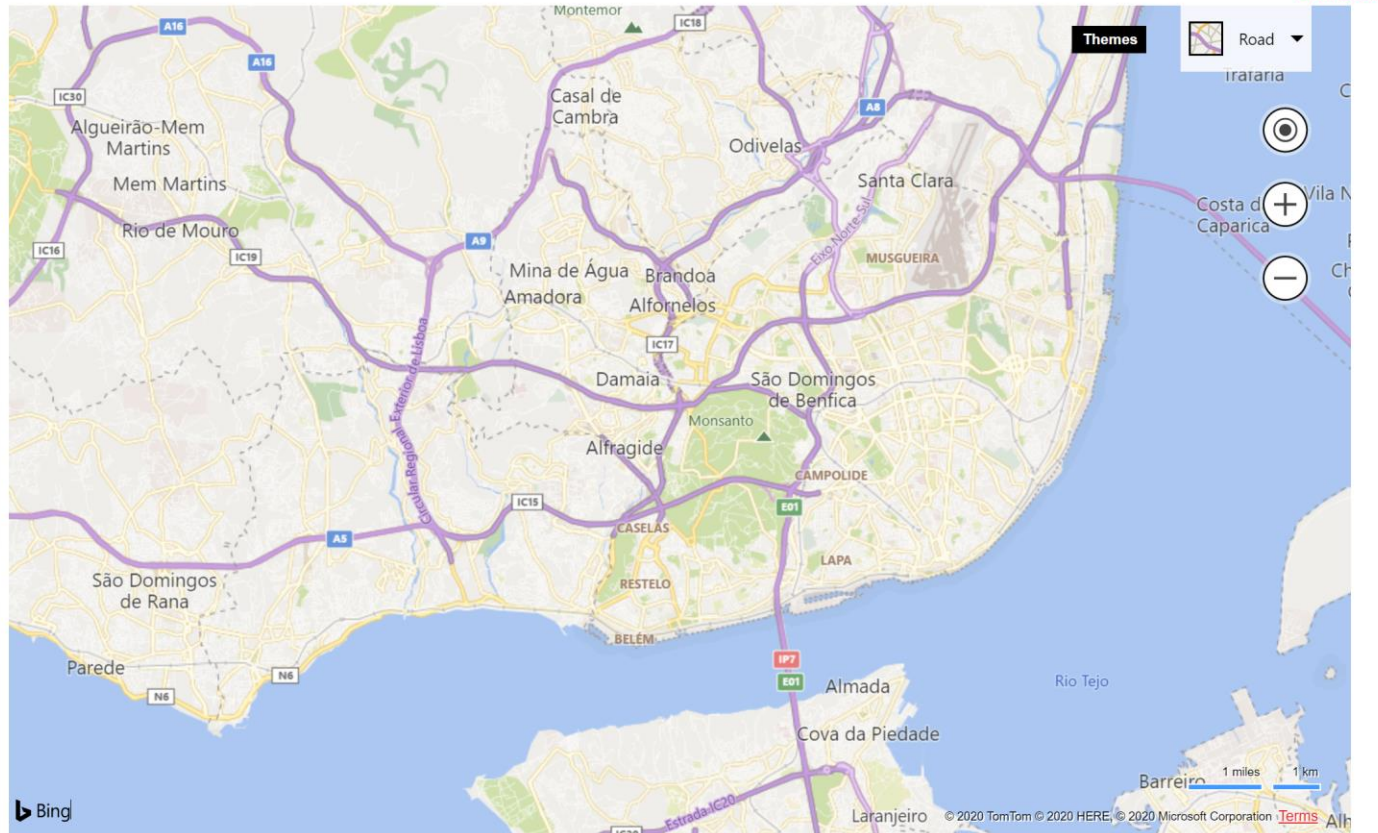
Alternativas

☐ 1 ☒ 3

Tempo Real

☒ Tempo Real

Calculate



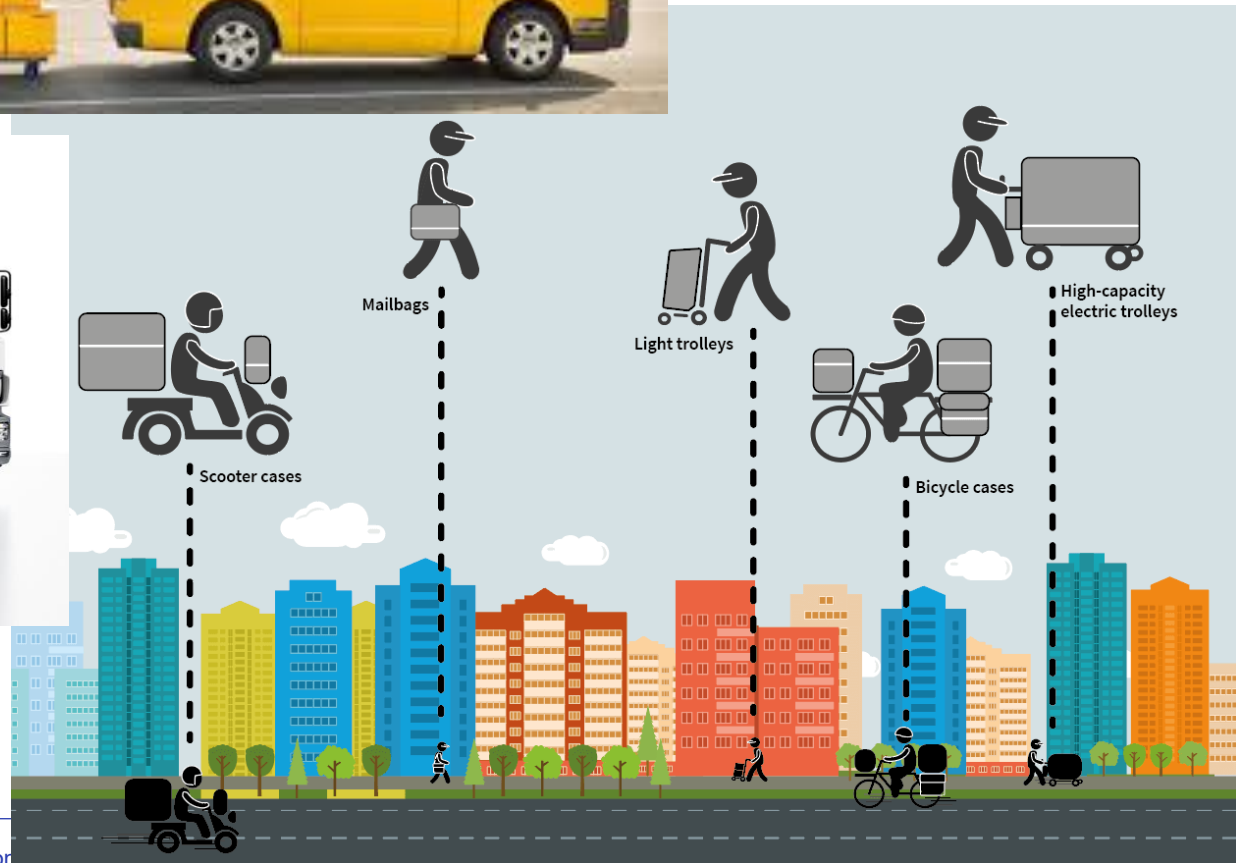




- Qingdao, China
- Seoul, South Korean
- Setar, Malaysia
- Dhaka, Bangladesh



Transportation system Logistics

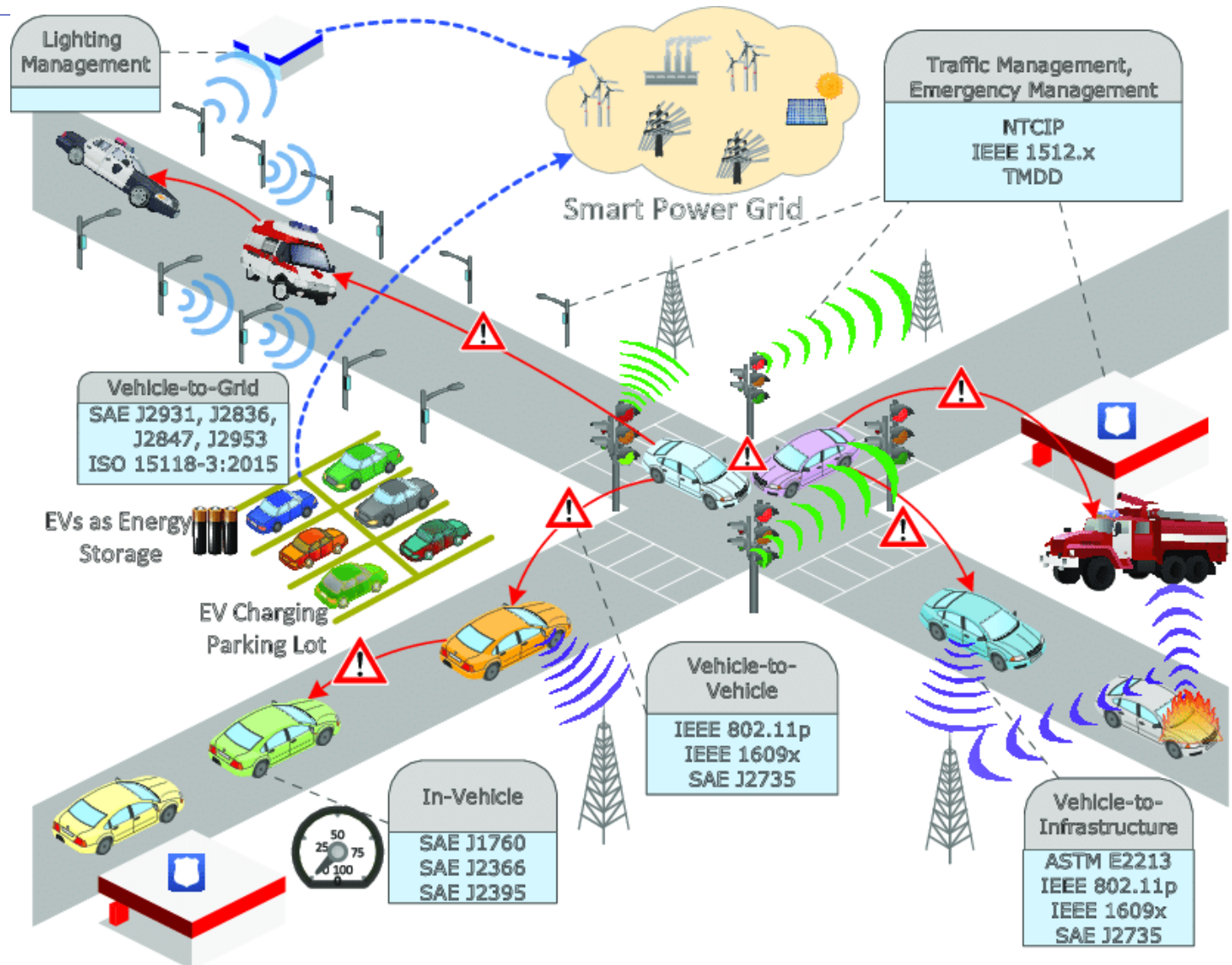


Intelligent Transportation System (ITS)

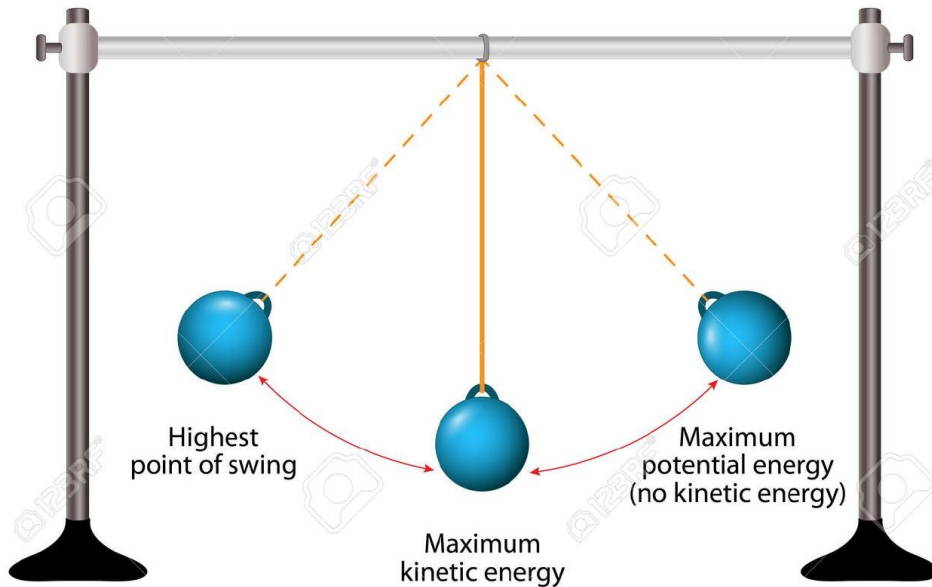
- ... exchange information.....



ITS – Intelligent Transportation System



- Repetitive movement between an origin A and destination B, on a daily basis (usually weekdays).



Origin

Destination



home



school

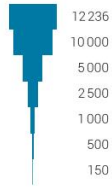
A



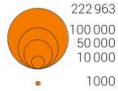
B

Wichtigste Pendlerströme zwischen den Gemeinden, 2014

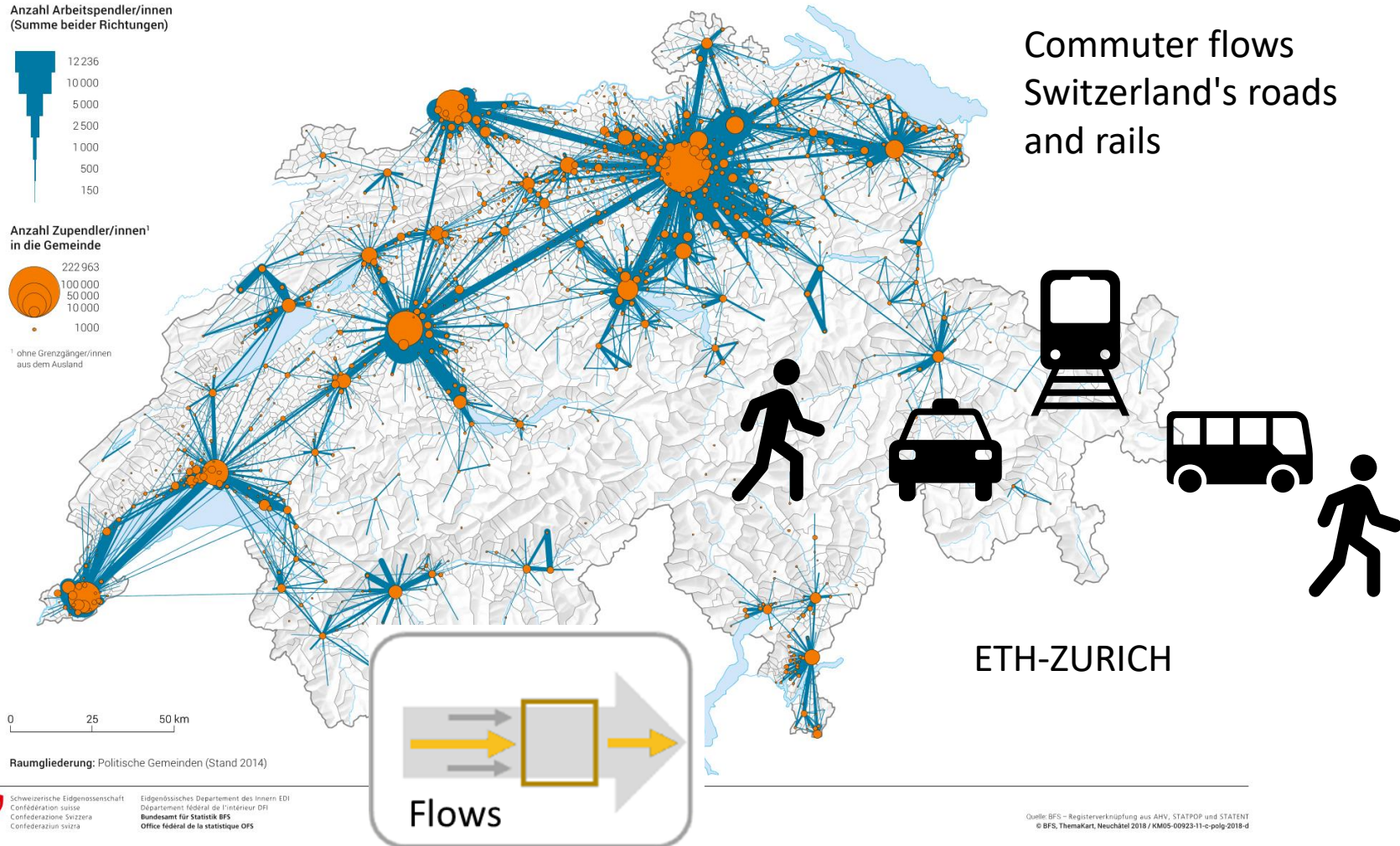
Anzahl Arbeitspendler/innen
(Summe beider Richtungen)



Anzahl Zupendler/innen¹
in die Gemeinde



¹ ohne Grenzgänger/innen
aus dem Ausland



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Département fédéral de l'intérieur DFI
Bundesamt für Statistik BFS
Office fédéral de la statistique OFS

Quelle: BFS – Registerverknüpfung aus AHV, STATPOP und STATENT
© BFS, ThemaKart, Neuchâtel 2018 / KM05-00923-11-e-poly-2018-d

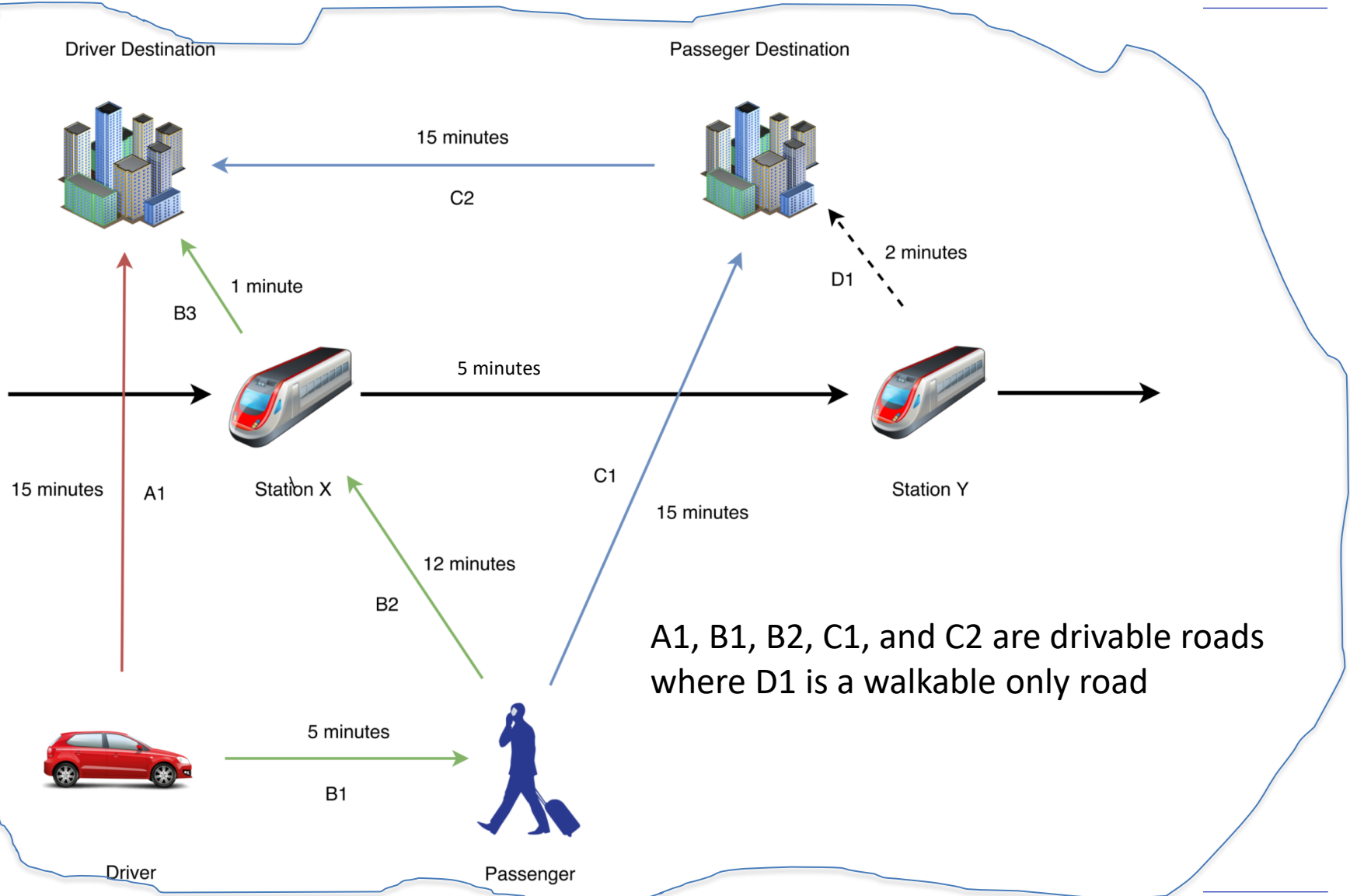
OBJECTIVE: MAXIMUM EFFICIENCY AND INTEGRATION

Mandatory:

- designed to minimize transfer time between modes;
- designed to minimize waiting times;
- tariff connection with a single ticket, even if operated by different carriers;
- a very good information technology connection

- Intelligent Transport systems addressing first and last mile connectivity;
- Transparency and Accountability across all the stakeholders;
- Transport Safety;
- Cost effective on-demand services with maximum asset utilization.

Seamless transportation system



- **Can be classified by:**

- ✓ Modes;
- ✓ Function;
- ✓ Geographical coverage;
- ✓ Ownership;
- ✓ Automation level;
- ✓ Technology;
- ✓ Fuel/energy source;
- ✓ Electric vehicles;
- ✓ Biofuels;
- ✓ Emission standard.

- **air, road, rail, maritime** /passenger or goods carriers



Soft modes (or active modes) /passenger or goods carriers



TRANSPORTATION BY FUNCTION/ SERVICE

- Passengers and freight (goods)



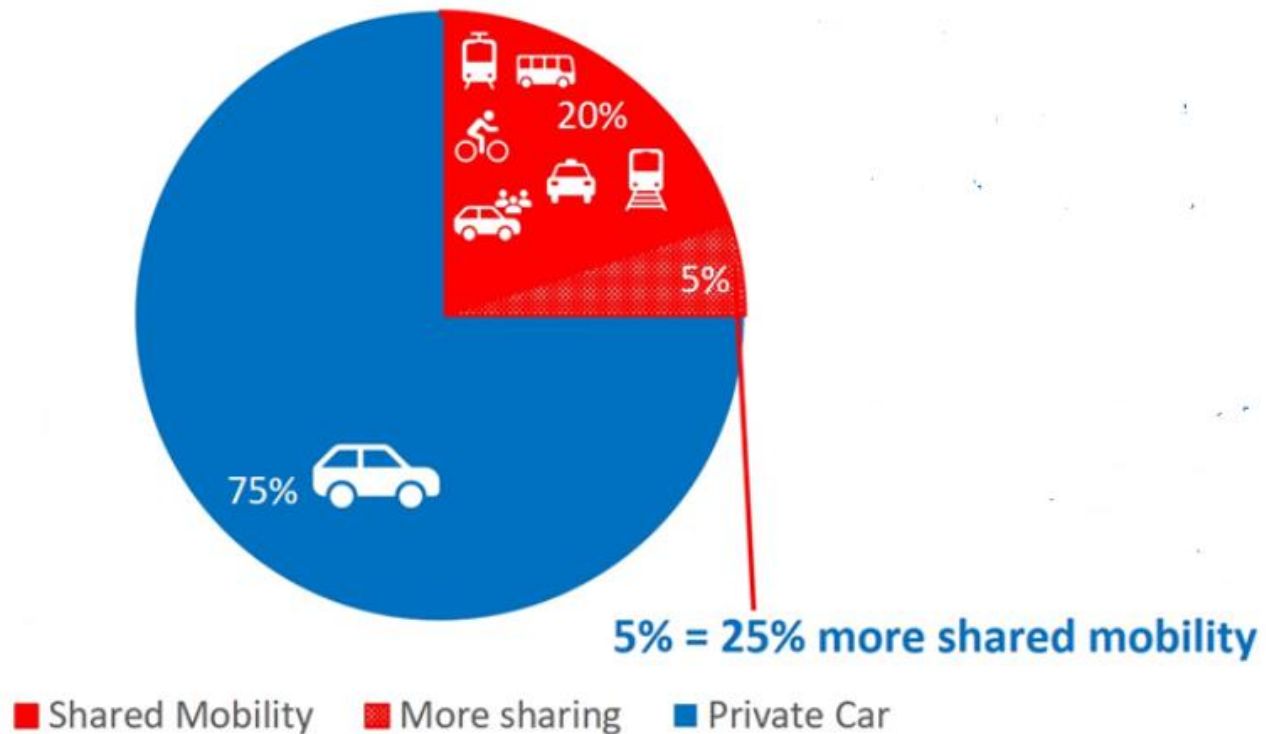
TRANSPORTATION BY geographical coverage

- National / International



TRANSPORTATION BY OWNERSHIP

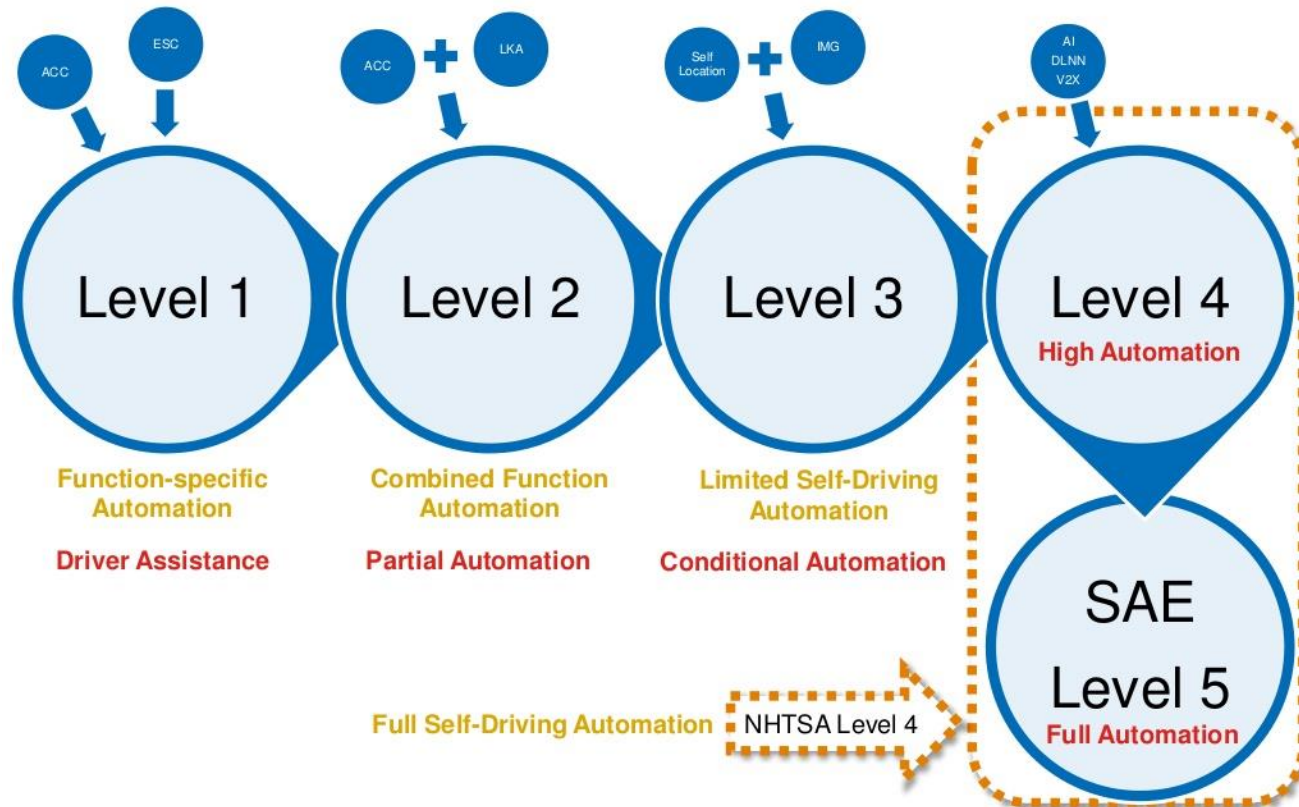
- Public or private
- Personal or shared



TRANSPORTATION BY AUTOMATION LEVEL

- Levels of automation**
- National Highway Traffic Safety administration (NHTSA);
 - Society of Automotive Engineers (SAE).

NHTSA and SAE Levels of Automation



TRANSPORTATION BY AUTOMATION LEVEL



SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	You <u>are</u> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <u>are not</u> driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features			These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met	This feature can drive the vehicle under all conditions	
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering OR • adaptive cruise control	• lane centering AND • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

forward collision avoidance - adaptive cruise control

<https://www.youtube.com/watch?v=GInSPWZRFRM>

SAE 1



SAE 2



TRANSPORTATION BY AUTOMATION LEVEL

Example full automation non-road

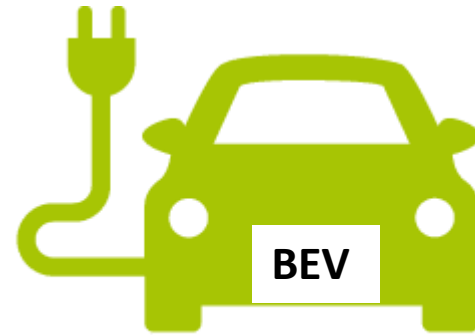


Heathrow Personal Rapid Transit system
2011

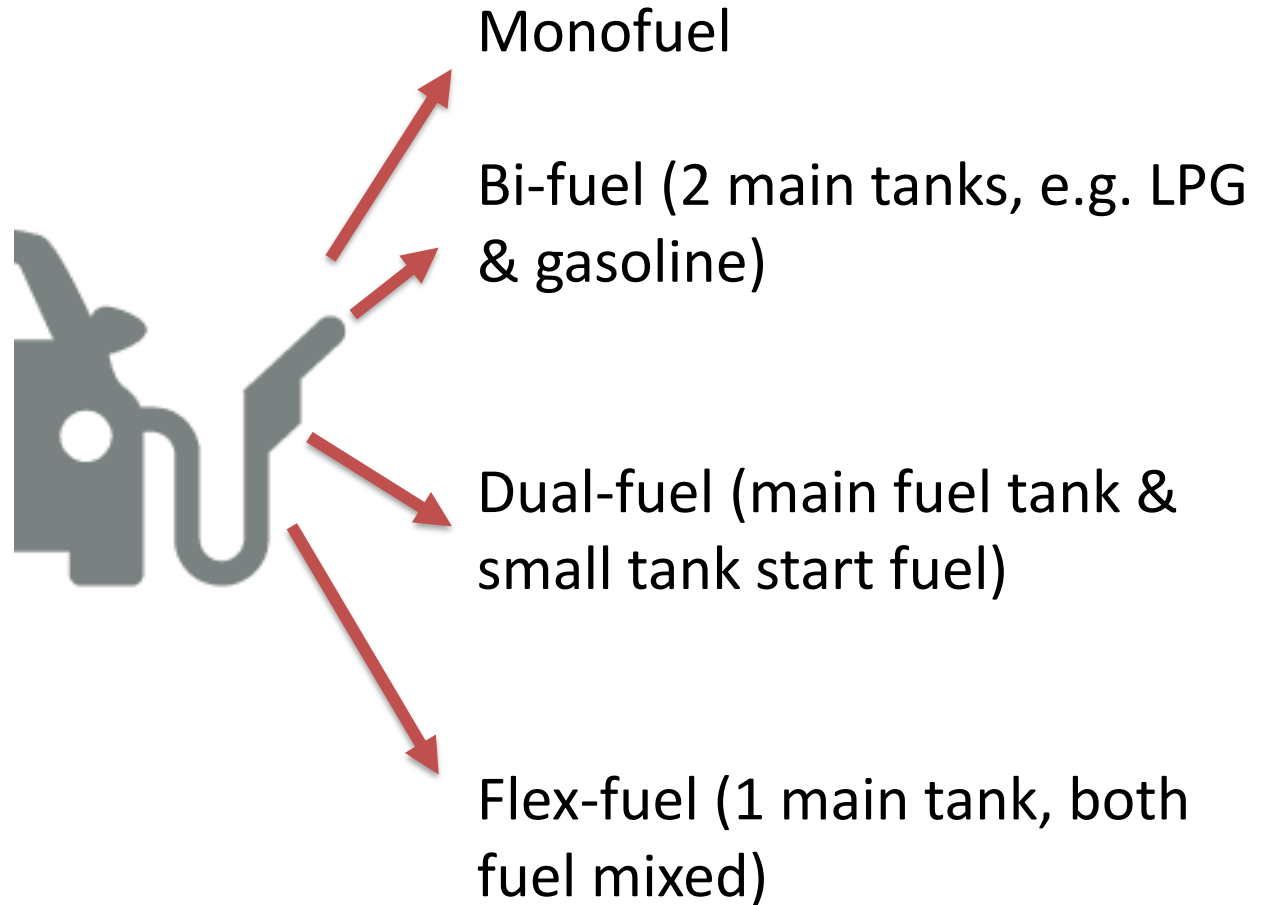
18 low-energy, driverless vehicles can each carry four passengers and their luggage.
(Ultra PRT | www.ultraprt.com.)



- Pure electric (battery EV)
- Plug-in Hybrid (PHEV)
- Hybrid (HEV)
- Conventional (ICEV)



- Diesel
- Gasoline
- biodiesel
- bioethanol
- GPL
- Natural gas



- Pre-Euro < 1992
- Euro I
- Euro II
- Euro III
- Euro IV
- Euro V
- Euro VI > 2014

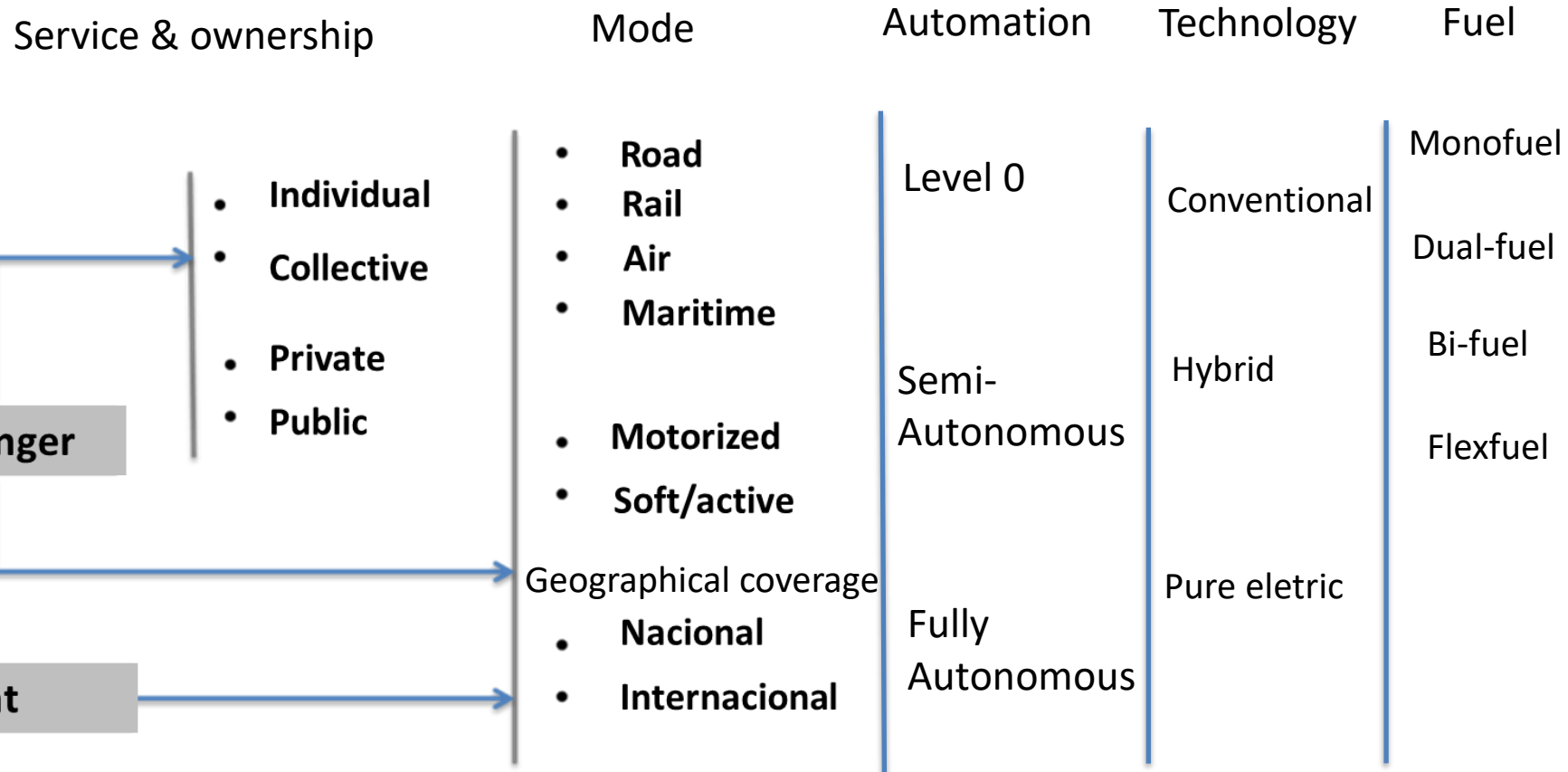


Less sulfur

Less NO_x

Less PM

CLASSIFICATION OF TRANSPORTS



Classification....examples



e.g. *bike-sharing* individual passenger transportation, public, road (motorized in case of electric bikes)



e.g. táxi individual motorized

Uber individual motorized



e.g. *car-sharing* individual, road motorized

Examples



e.g. bike-sharing
individual, road
motorized/non-
motorized



shutterstock.com • 1416827321

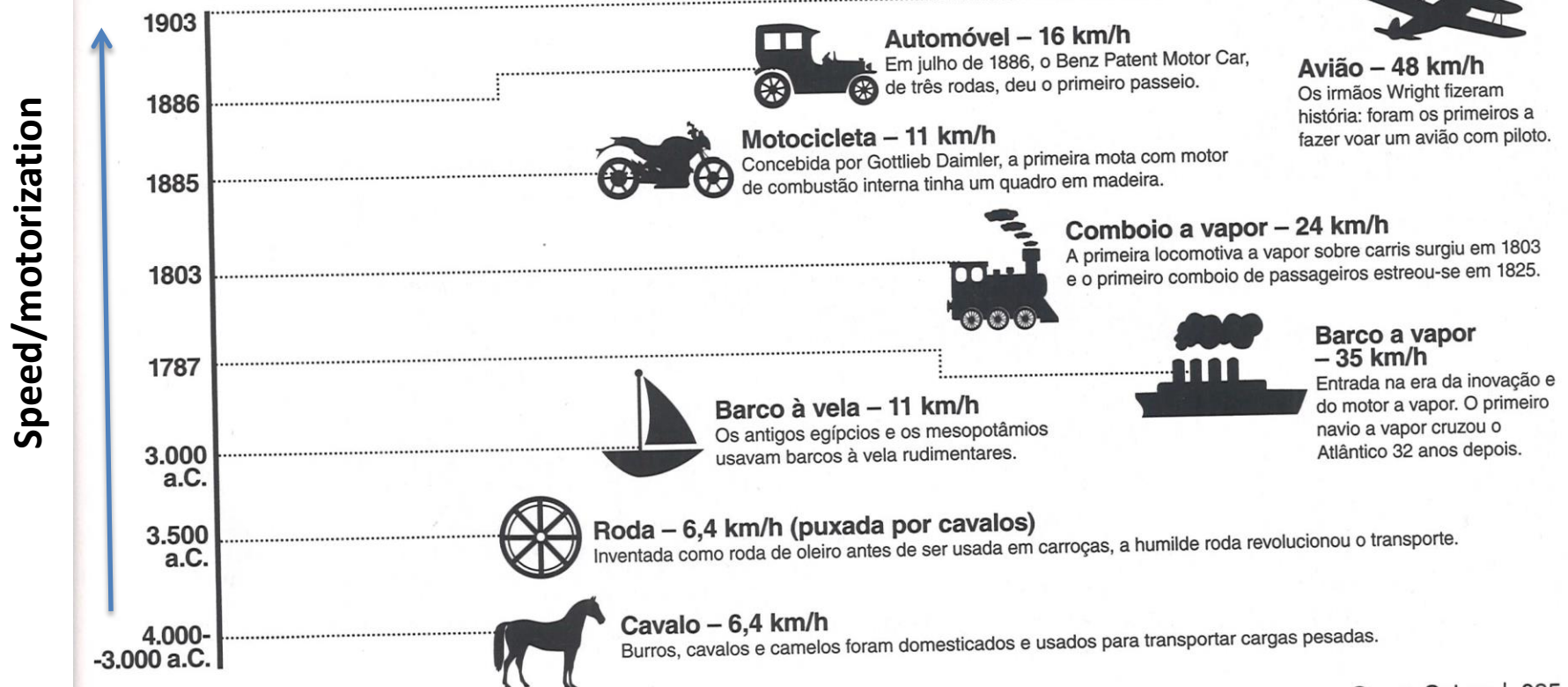
Classification....



e.g. bus colective, public, road, motorized

Viajar através do tempo

Da carroça ao automóvel, como nos deslocámos de A para B ao longo da história.



WWW.QUEROSABER.SAPO.PT

Quero Saber | 085



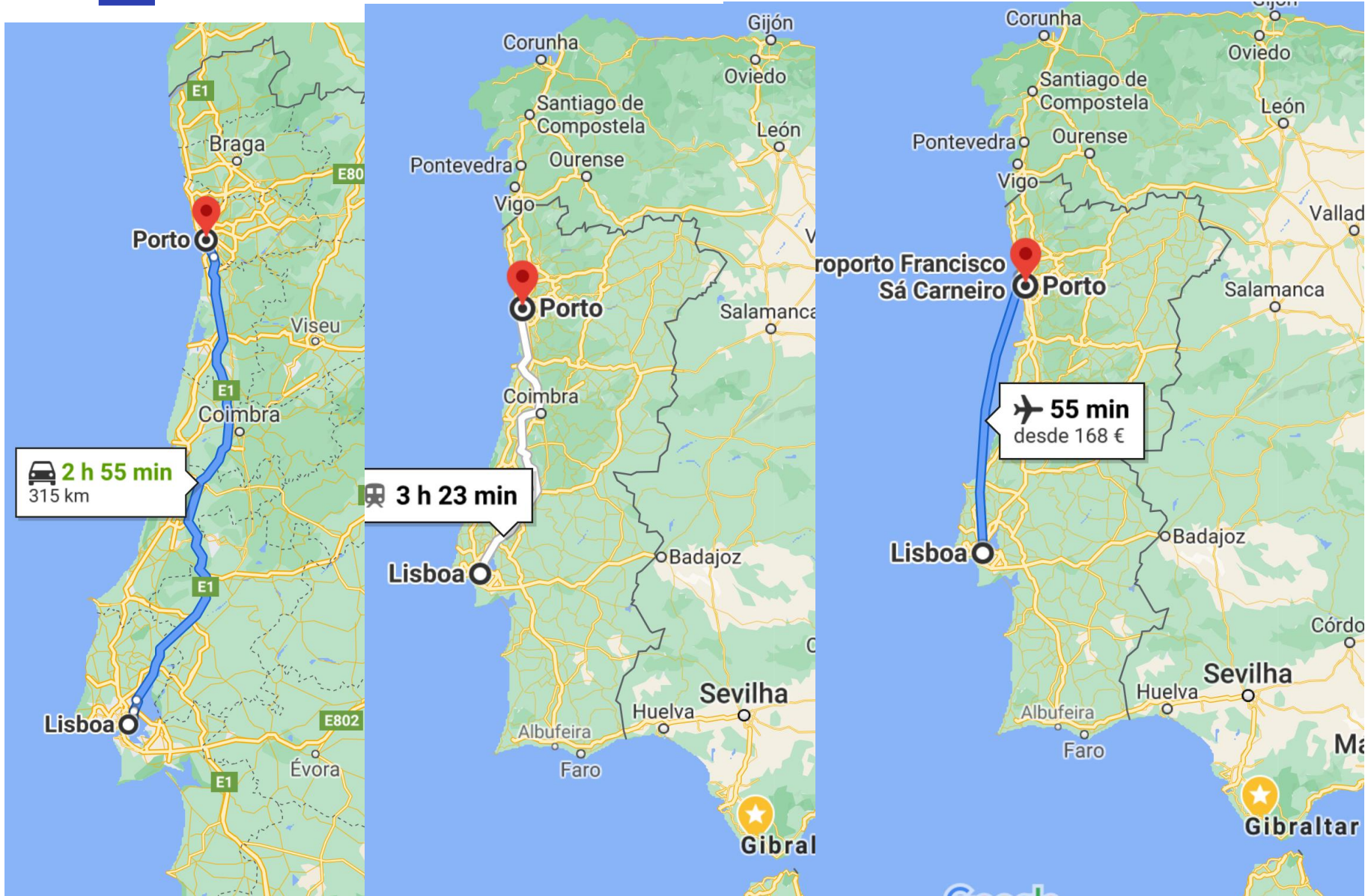
Lisbon - Porto

~ Year 1859	~ Year 1864	~ Year 2000	~ Year 2016
	1 st train 		
7 days	14h	2h35 Alfa Pendular	<1h Airplane

3h



History....and...future



New York on the 1800's



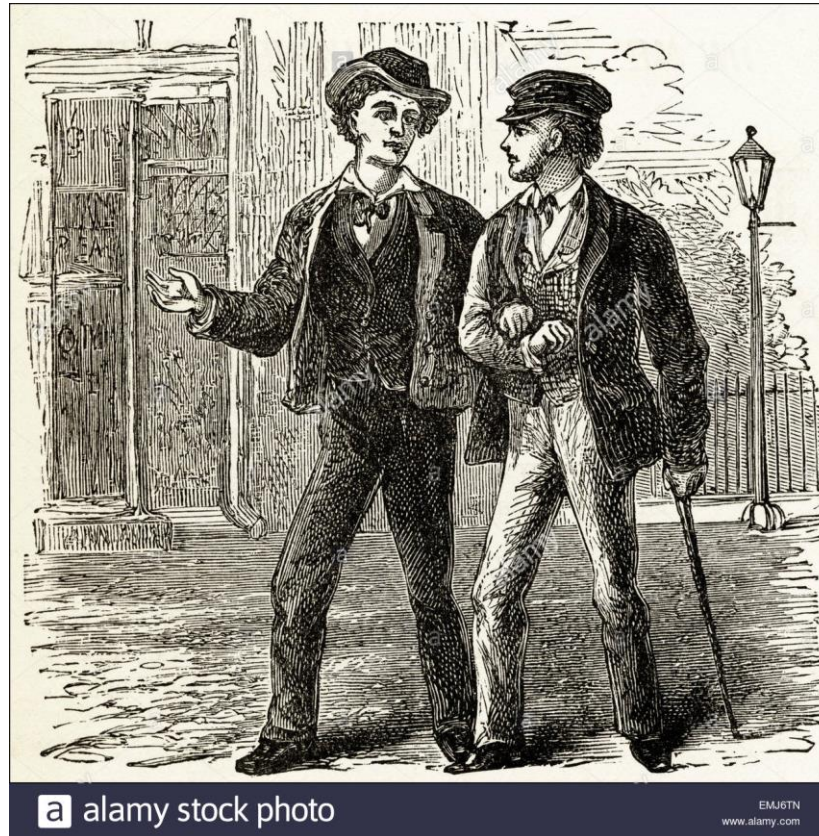
Lisbon on the 1800's, CARRIS carriage



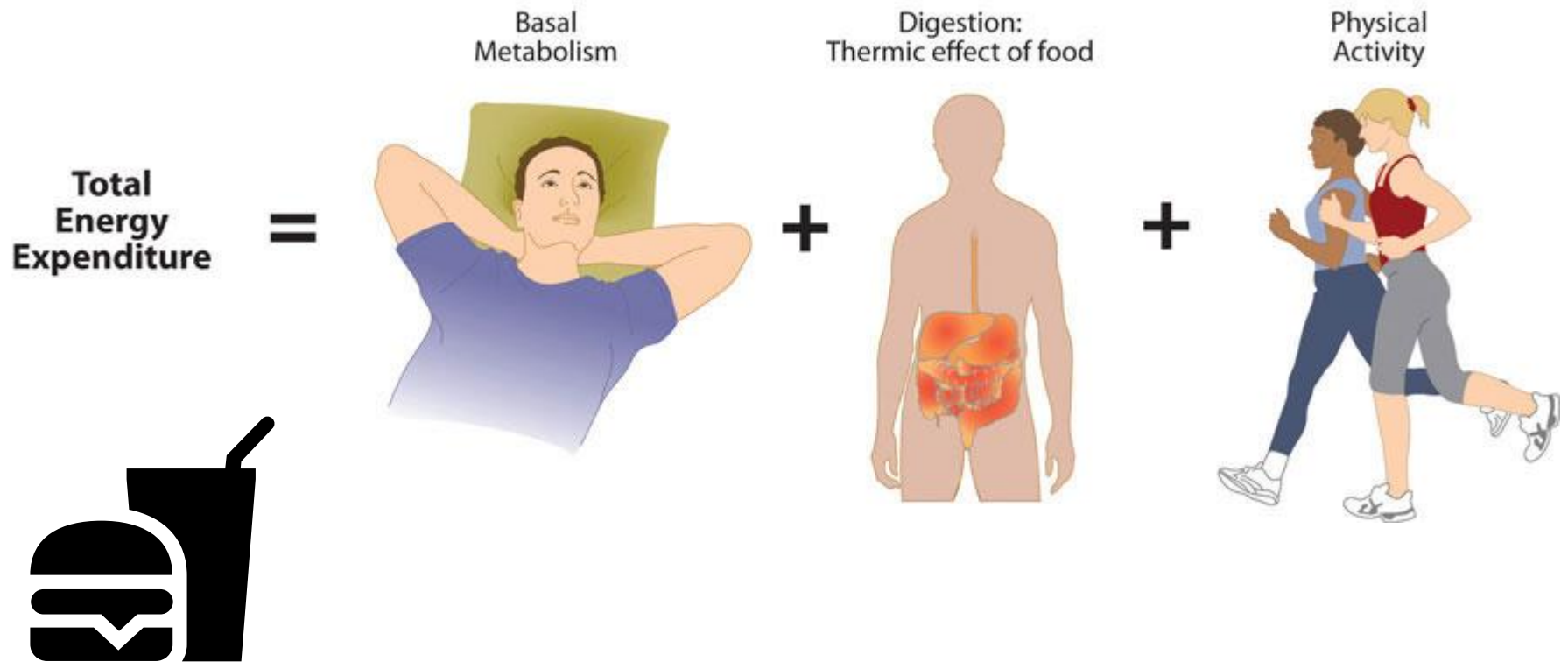
Lisbon Av. 24 Julho 1912, CARRIS electric tram

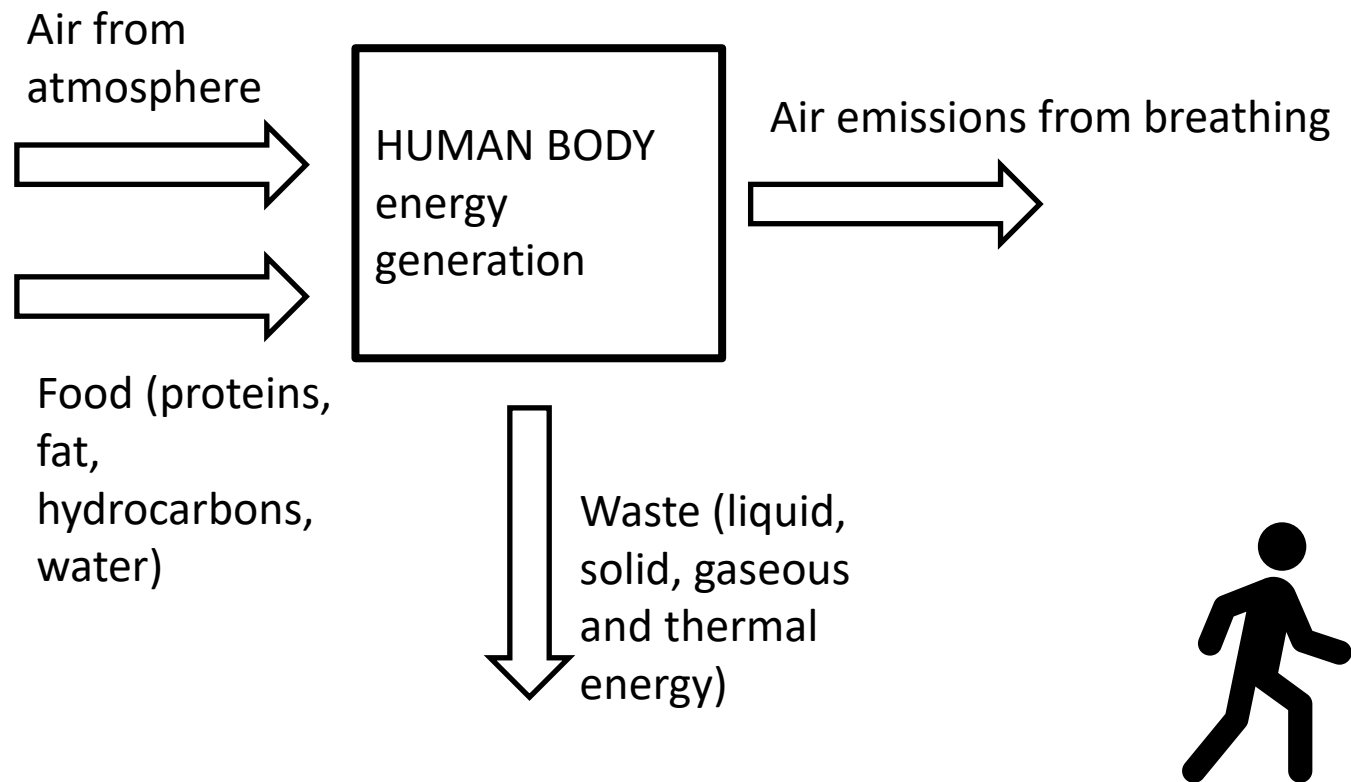


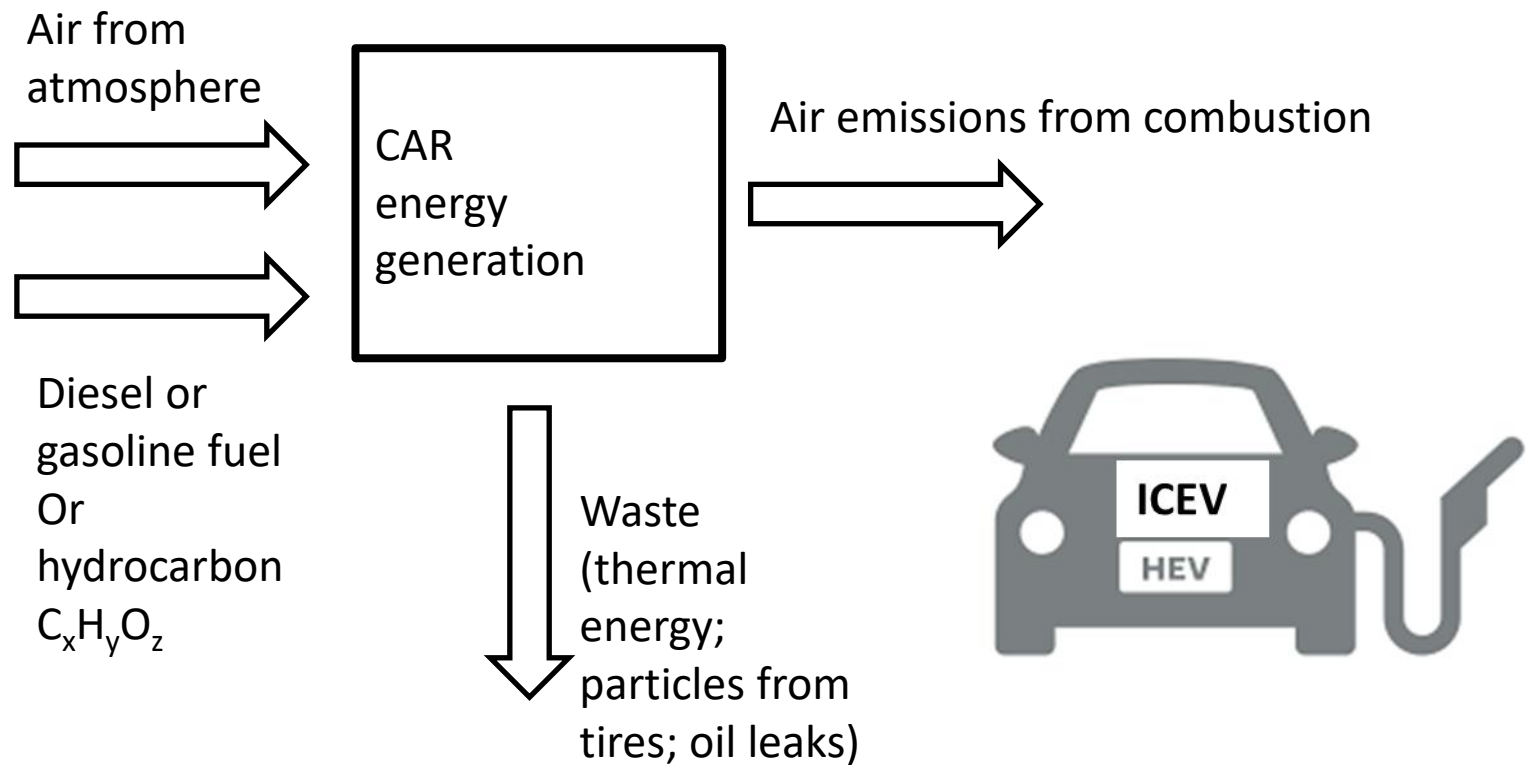
Walk....always....Energy????



Walk....always....Energy????

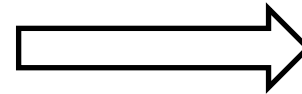








Air emissions from combustion



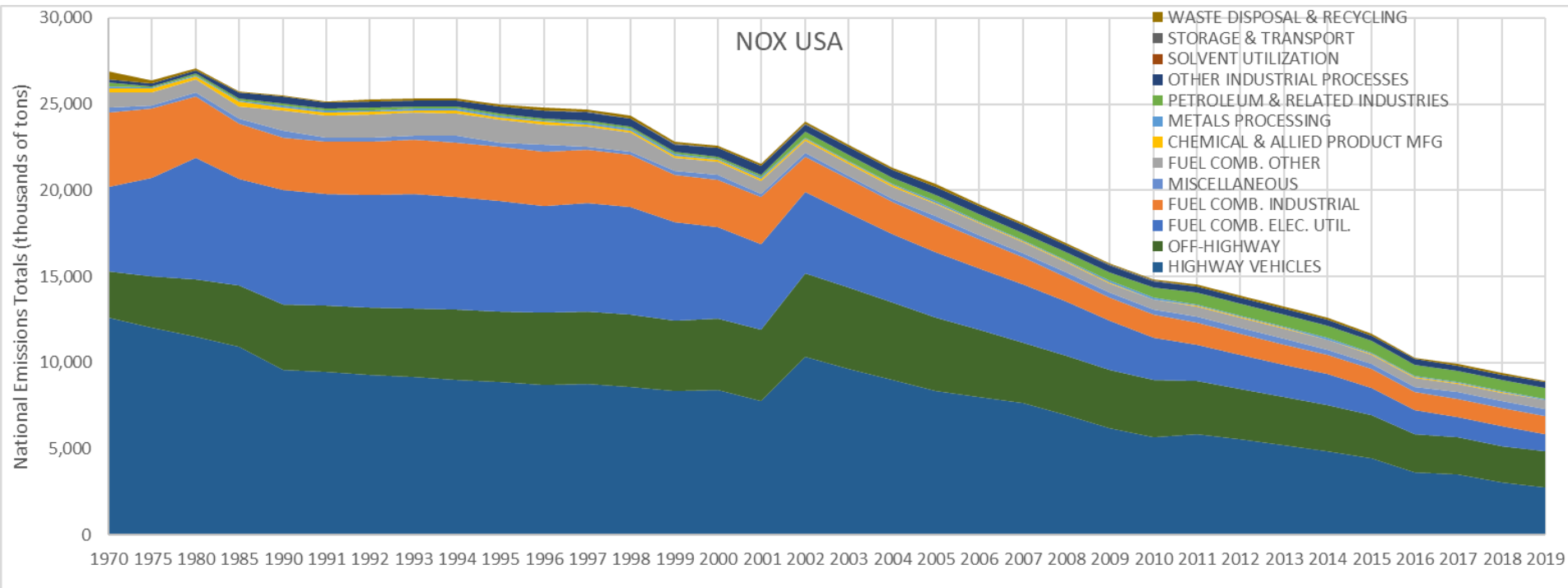
1970 |



2013 |



Stricker emission standards



Previously...e.g. 1800....1970????

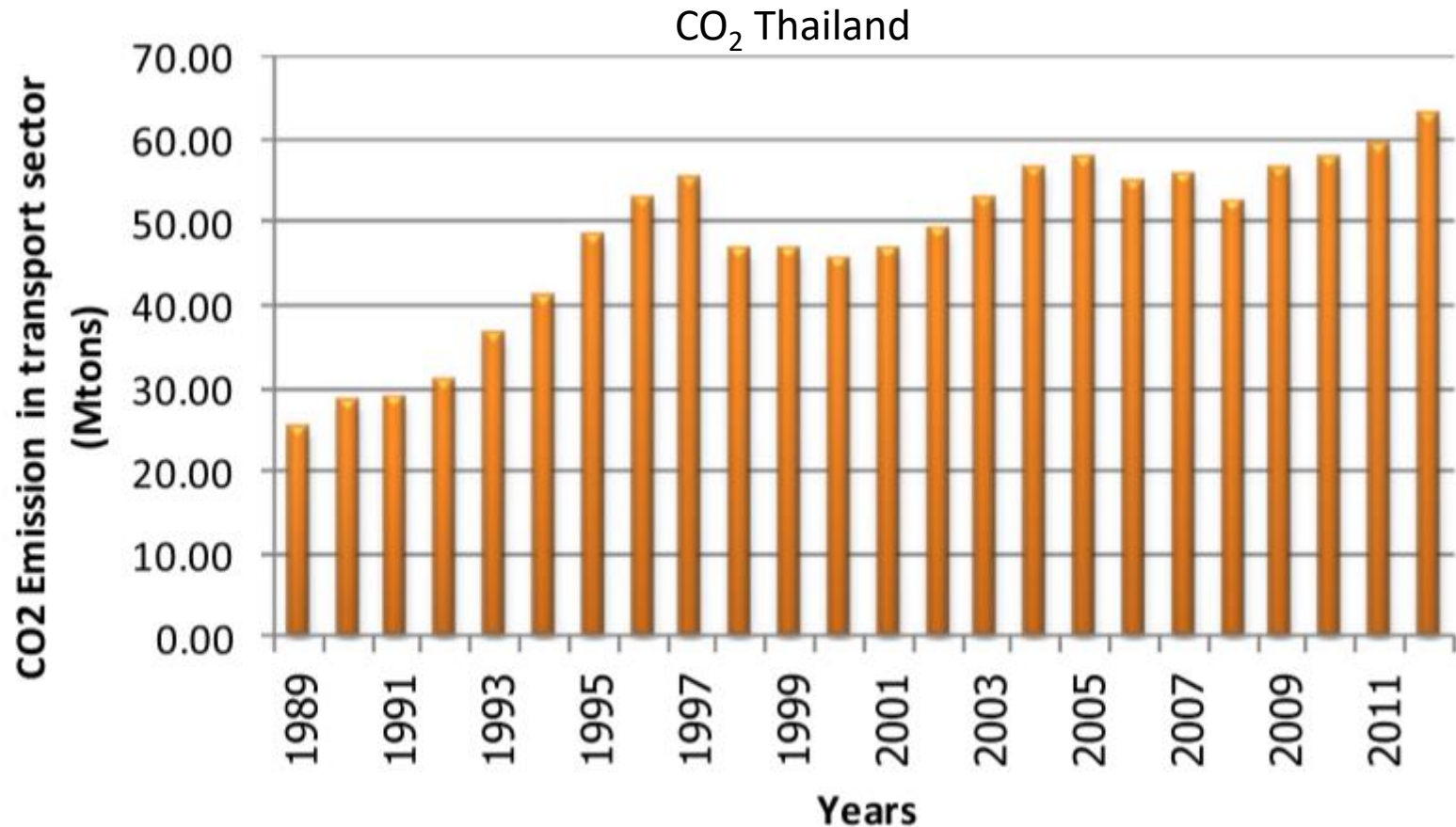
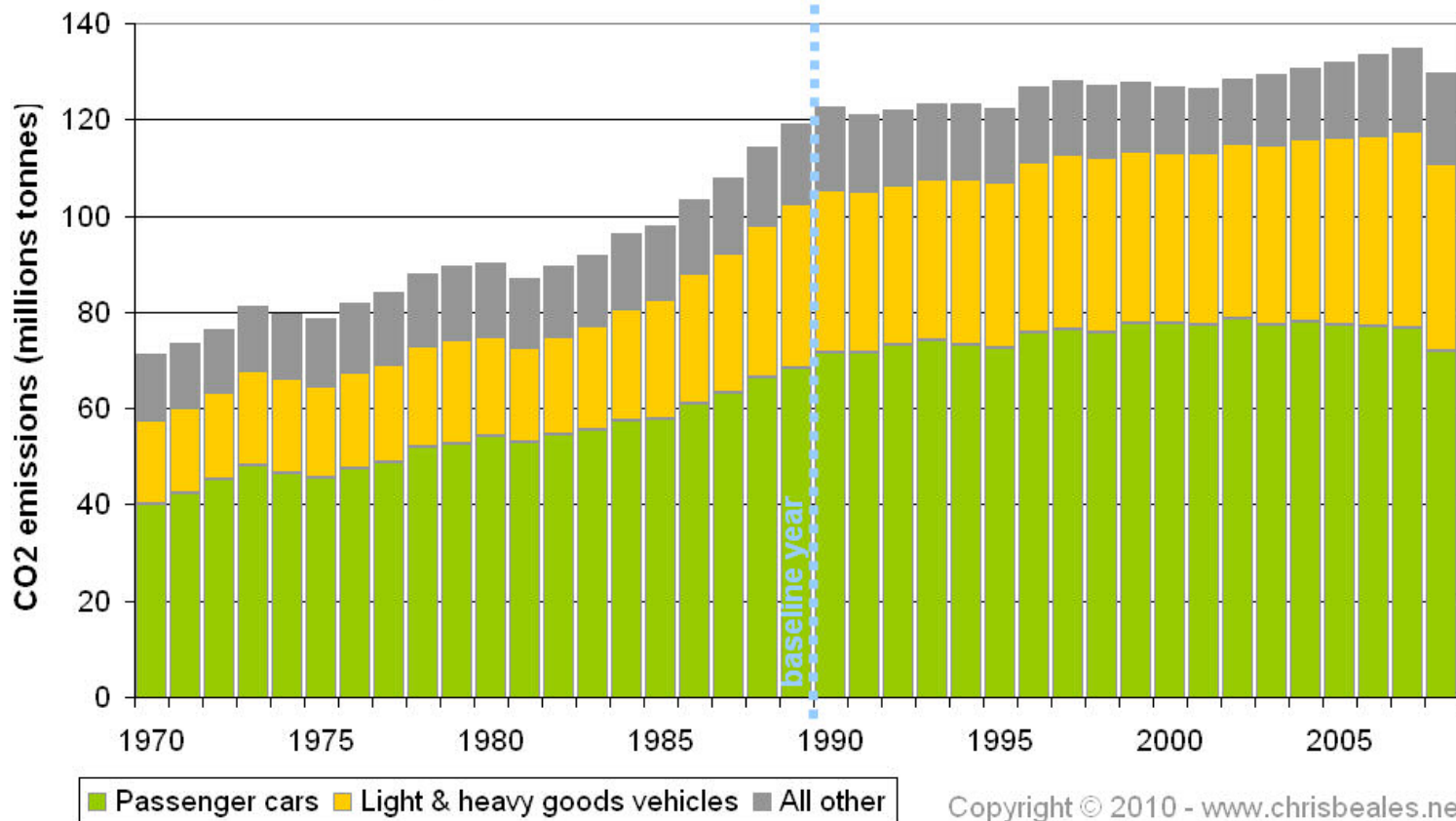


Fig. 2. The statistics of CO₂ concentrations in the transportation sector from 1989 to 2012.

Previously...e.g. 1800....1989????

CO₂ UK

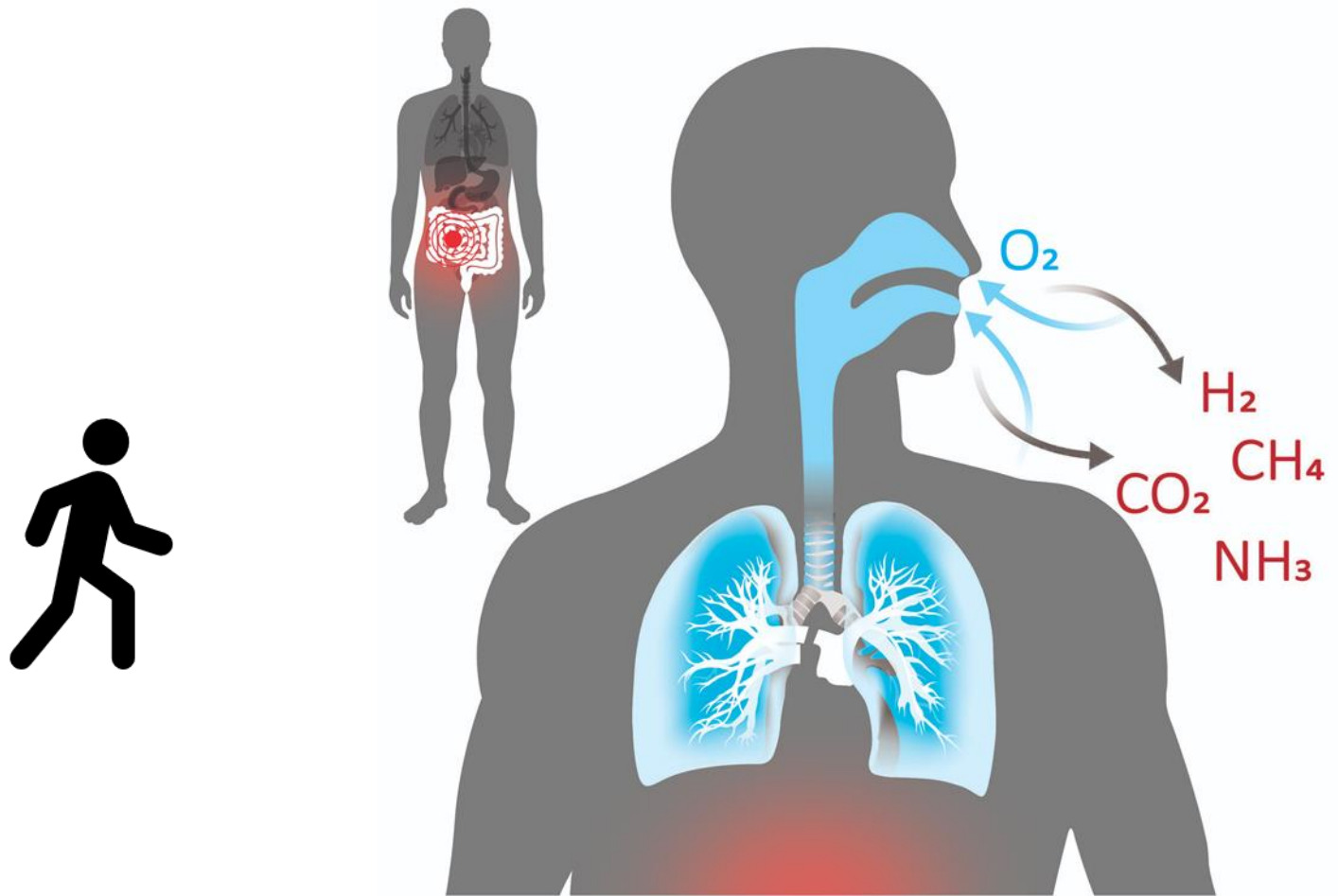
UK transport - carbon dioxide emissions from 1970

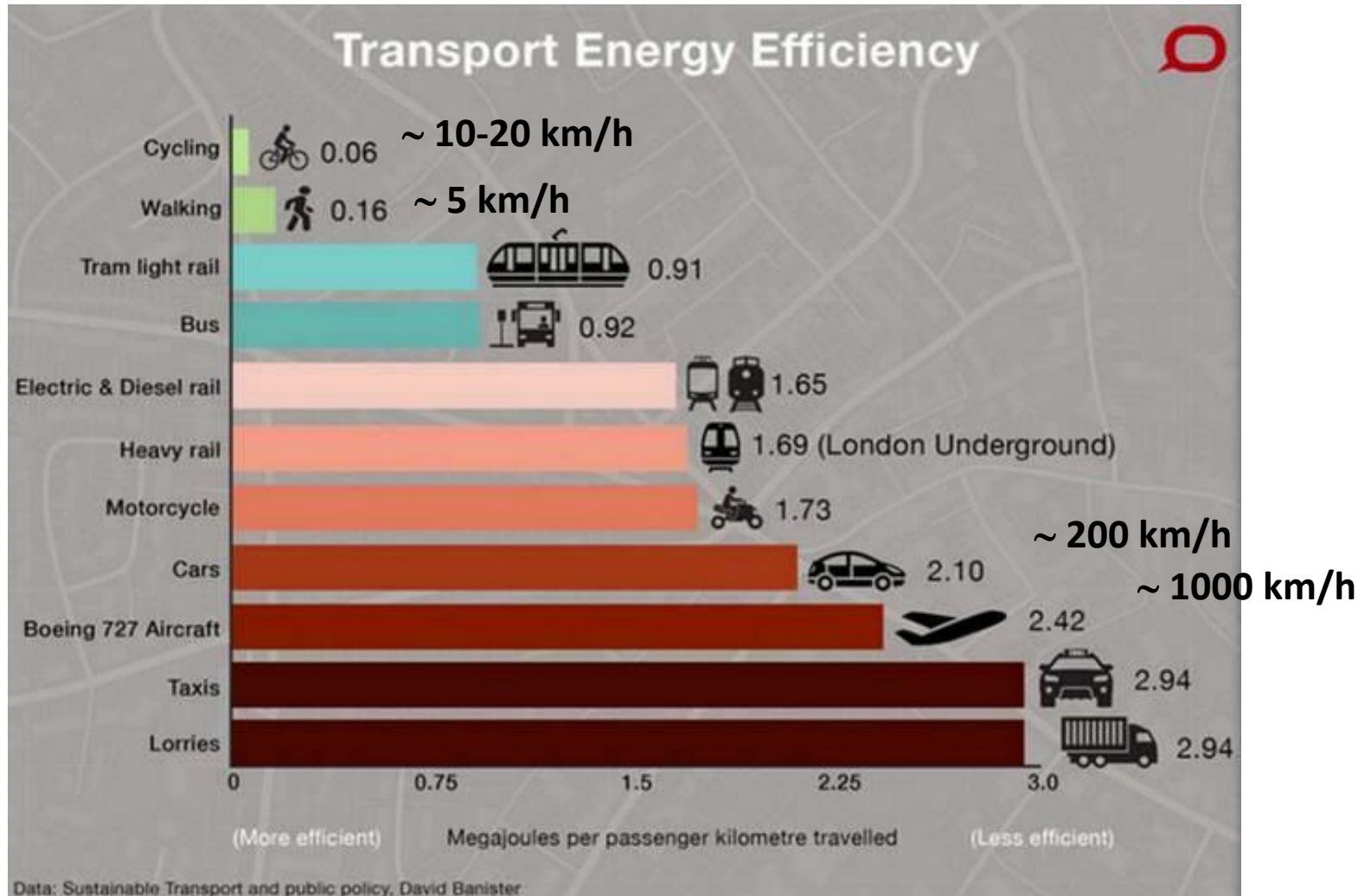


Previously...e.g. 1800....1970????

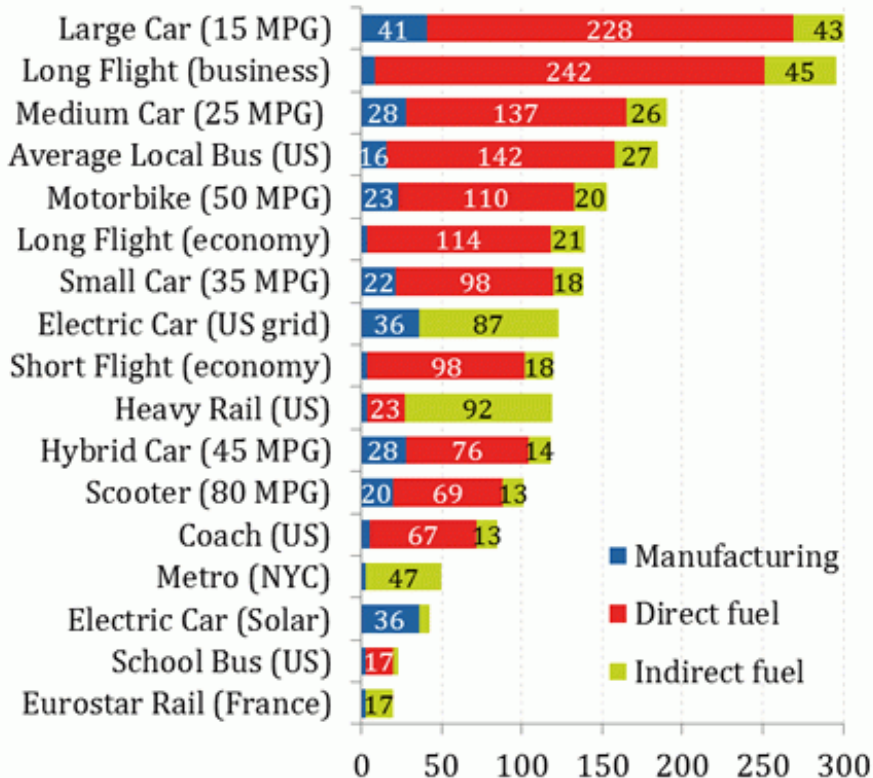
Substance	Inhaled air (%)	Exhaled air (%)	Explanation
Nitrogen (N ₂)	78	75	Not used
Oxygen (O ₂)	21	16	Used in respiration
Carbon dioxide (CO ₂)	0.04	4	Produced in respiration
Inert (e.g. argon)	0.9	0.9	Not used
Volatile organic compounds (VOC, H and C and O)	Variable, depend outside air quality	Variable depends on outside air quality	Not used
Water (variable)	variable	Typical 4	Produced in respiration







Carbon Intensity of Travel: g CO₂e/pkm

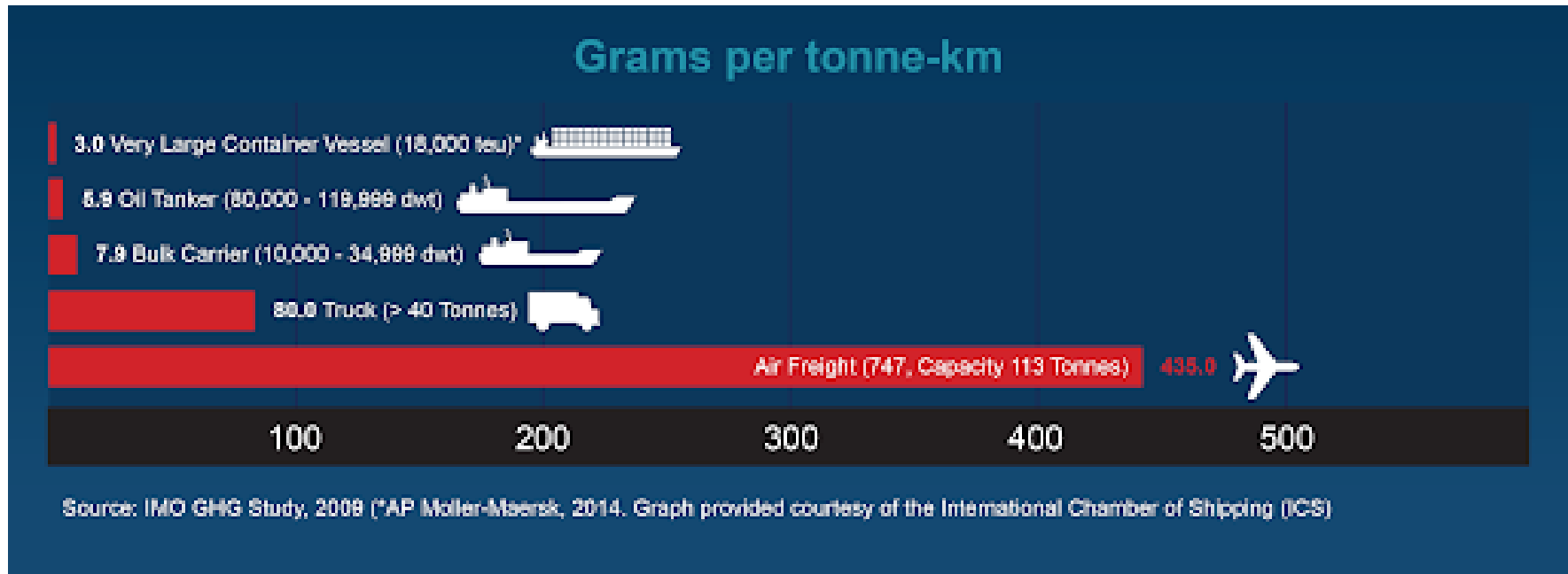


Slow
 Efficient (food-energy)
 Low CO₂ (~0.01 g/pkm)

Note: All figures are grams of carbon dioxide equivalents per passenger kilometre (g CO₂e/pkm). Figures include direct fuel emissions from combustion, indirect fuel emissions from production and vehicle manufacturing emissions. Average loading is assumed for each mode of travel, 1.6 for all cars and 1 for motorbikes. Miles per gallon (MPG) is on road efficiency in US gallons. No radiative forcing multiplier is used for air travel. The electric car is assumed to achieve 200 Wh/km.

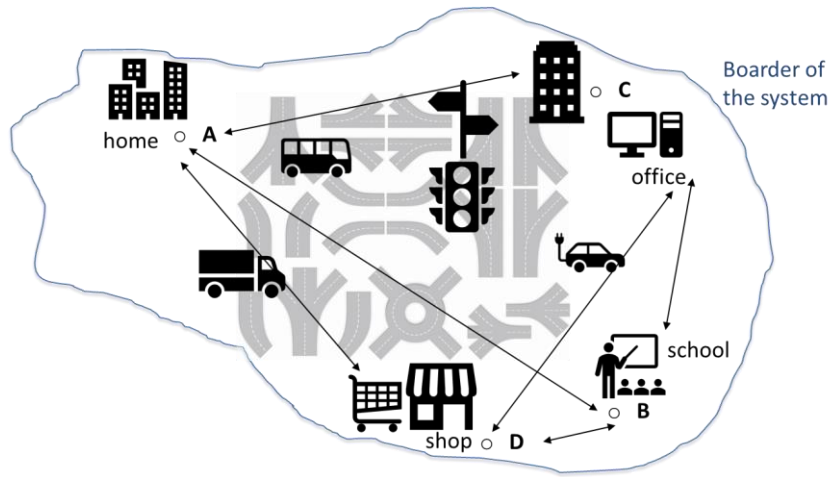
Sources: DEFRA, EIA, EPA, GREET 1.8, Chester & Horvath





Consider the transportation system in the figure next slide. With the OD matrices regarding n^{er} of trips and n^{er} trips per day (flows) and regarding road distances, estimate, for the System:

- Number of links, nodes and carriers;
- Number of total trips per week;
- **Energy** consumption; in **MJ/week**;
- **CO₂** emissions; in **g/week**.



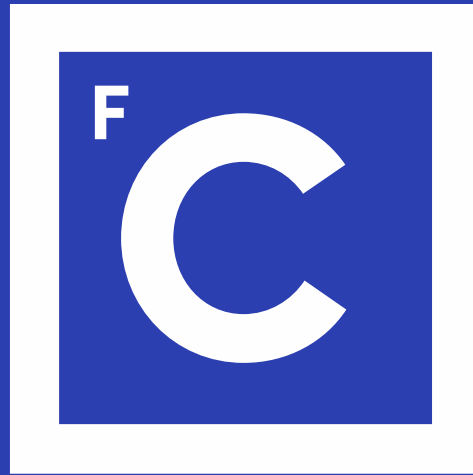
n^{er} km per link (distance between nodes)

		DESTINATION				SUM
		A	B	C	D	
ORIGIN	A		15	10	10	35
	B	15		5	2	22
	C	10	5		10	25
	D	10	2	10		22
SUM						

n^{er} trips per day (flows)

		DESTINATION				SUM
		A	B	C	D	
ORIGIN	A		65	28	28	121
	B	69		12	83	164
	C	100	60		217	377
	D	86	127	63		276
SUM		255	252	103	328	938

Thanks



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