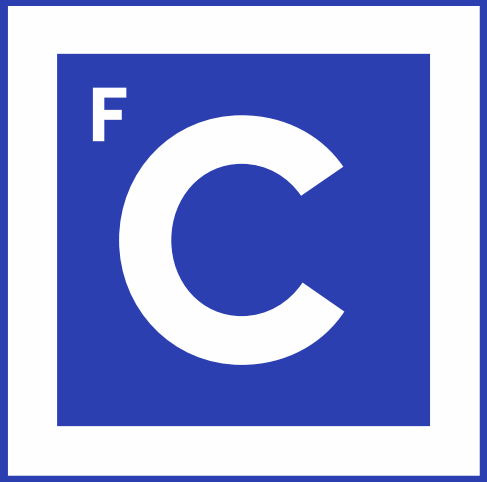


Ciências ULisboa

Faculdade
de Ciências
da Universidade
de Lisboa

Eng. Energy & Environment

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

BASIC CONCEPTS

TOPIC #II

SUSTAINABILITY & METRICS

- **What is "Sustainable Mobility" ???**

Environmentally friendly….

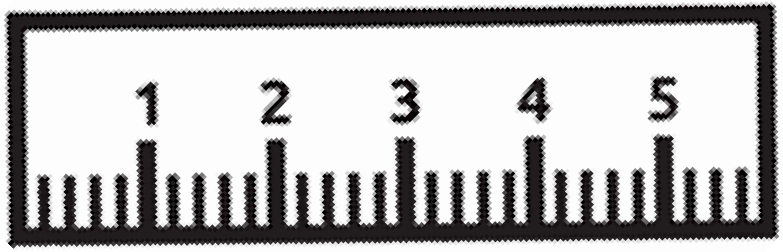
Don't harm future generations….

Electric cars….

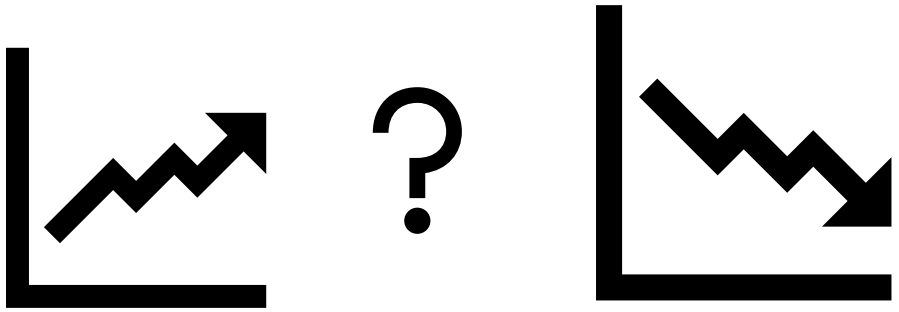
Don't waste resources….

SUSTAINABILITY & METRICS

- **How could be measured???**



MONITOR



SUSTAINABILITY & METRICS

COMPARE

?

VS

SUSTAINABILITY & METRICS

- **Concept of sustainabiliy appear in the 80's**

Dixon et al 1989 doi.org/10.1080/0894192890938067 5

SUSTAINABILITY & METRICS

Avoid physical stock (resource) depleation

Avoid physical stock (resource) depleation in a ecosystem

Sustained increase in the level of societal and individual welfare; social-physical-economic sustainability.

1987 UNITED NATIONS -World Commission on Environment and Development - Brandtland Report “Our common future”

https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

“ Development that meets our needs without compromising future generation needs” – page 43

Human welfare drives sustainability

Question:

How to achieve sustainability and how to measure progress toward it????

SUSTAINABILITY & METRICS

United Nations on 1 January 2016 – an ambitious set of goals to banish a whole host of social ills by 2030.

"They are a to-do list for people and planet, and a blueprint for success," he added of the **17 goals** and **169 targets** to wipe out poverty, fight inequality and tackle climate change over the next 15 years.

SUSTAINABILITY & METRICS

SUSTAINABILITY & METRICS

- **Concept of sustainabiliy apply to the transportation system appear in the 90's**

William R. Black

Indiana University

"transport that meets the current transport and mobility needs without compromising the ability of future generations to meet these needs"

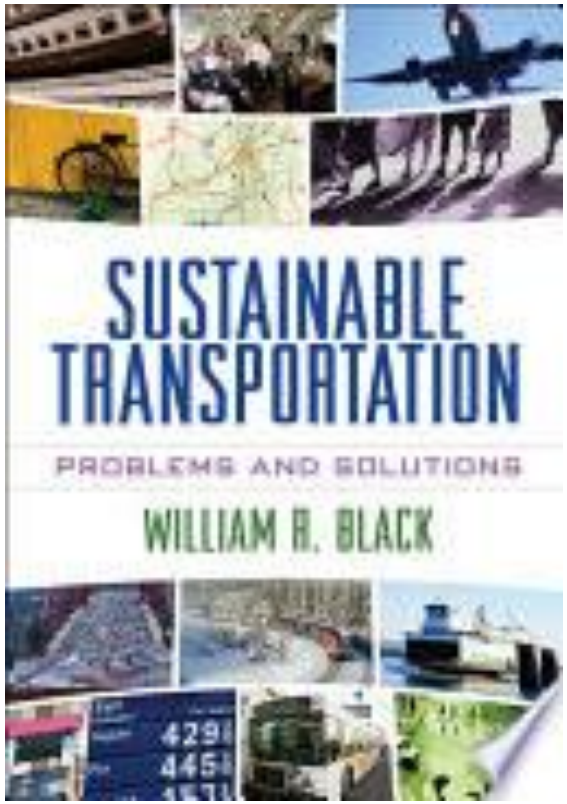
Black, 1996

"a more sustainable transportation system" as "one which provides affordable access to freight and passenger service and does so in an environmentally sound and equitable manner"

Black, 2010, from "Department transportation Canada, 2003"

SUSTAINABILITY & METRICS

- **Concept of sustainabiliy apply to the transportation system**



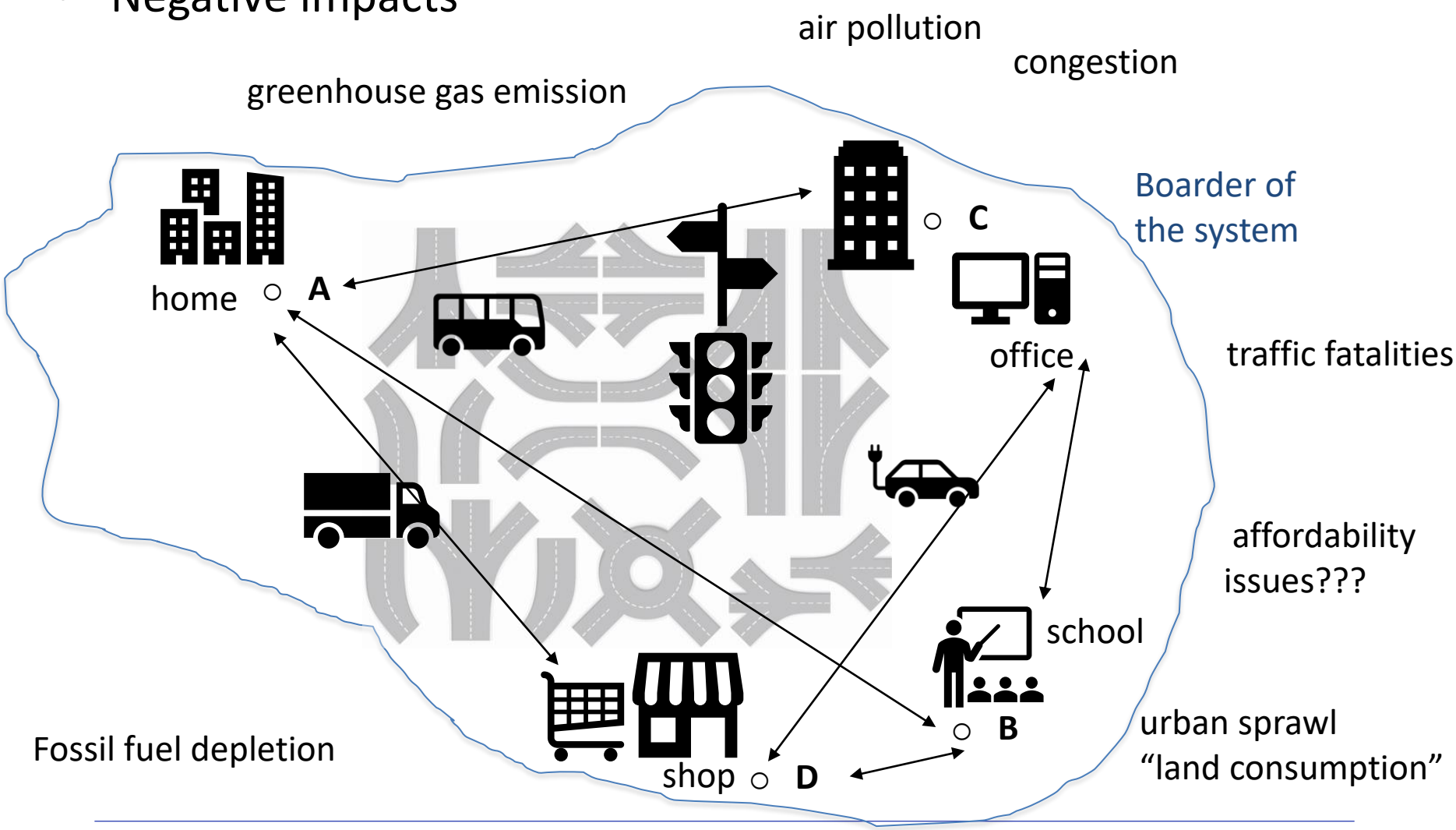
No definition standard:

e.g. Centre for Sustainable Transportation and the Government of Canada (Environment Canada and Transport Canada), 2003:

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy;
- Limits emissions and waste within the planet ability to absorb them, minimizes consumption of nonrenewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise.

Sustainable transportation system

- Negative impacts



SUSTAINABILITY & METRICS

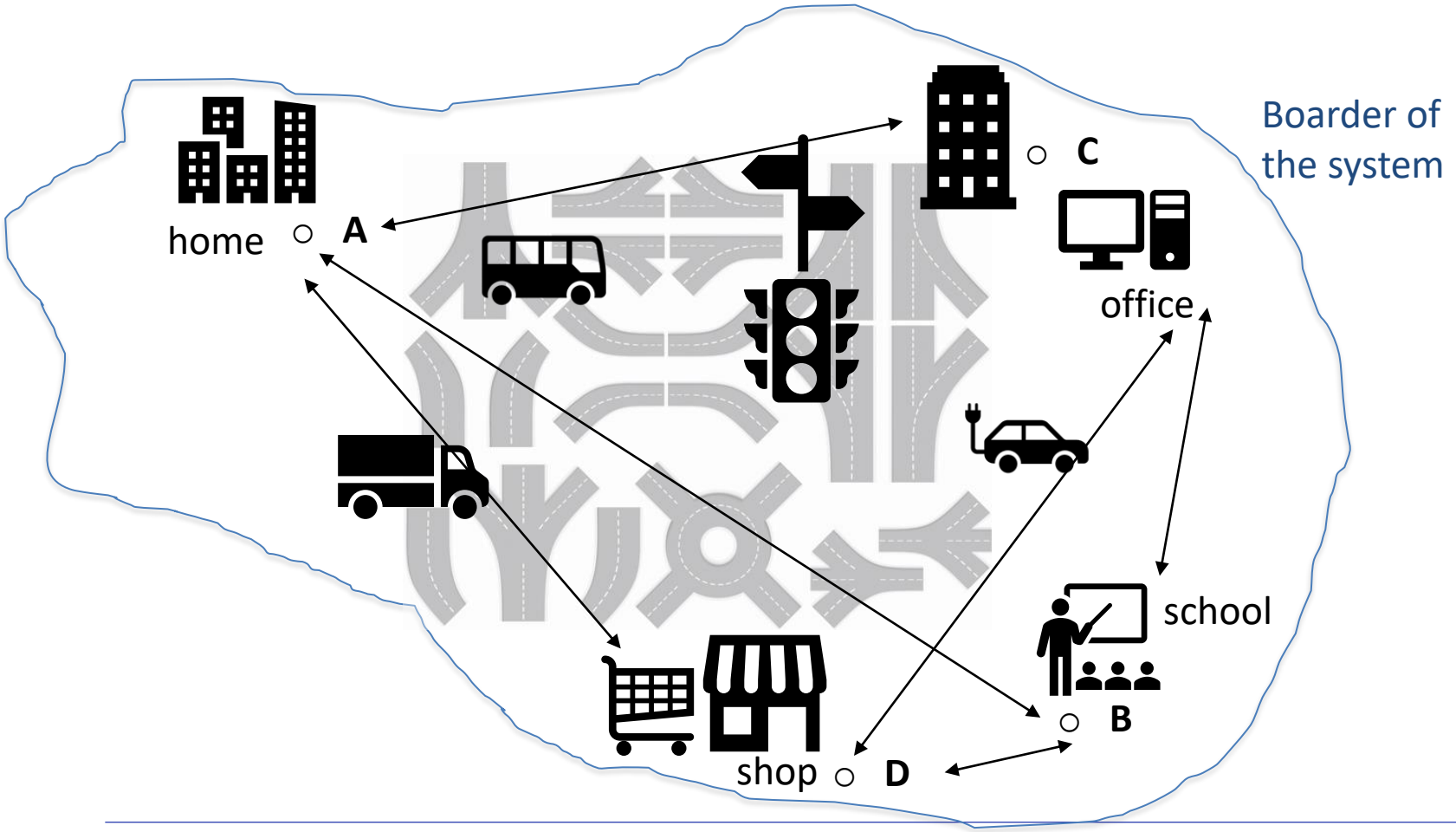
Question:

How to achieve sustainability and how to measure progress toward it????

Improved decision making & planning

Sustainable transportation system

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



Sustainable transportation system

- **Efficiently….**

"transport that meets the current transport and mobility needs without compromising the ability of future generations to meet these needs"

Black, 1996

Satisfy the needs of access/mobility

Compatible with the health of human being and ecosystems

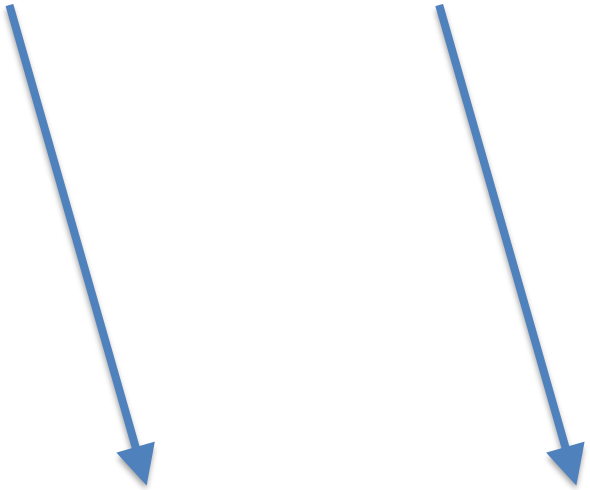
Reduce fossil fuel usage, reuse and recycle its materials, produce low noise and has low land use

Affordable, efficient, endorse model choice and supports a dynamic economy and local development

Seamless and intelligent

Sustainable transportation system

- **Indicators and Metrics**



Qualitative (property of the system)

Quantitative (calculations numbers with units of measurement addressing each property)

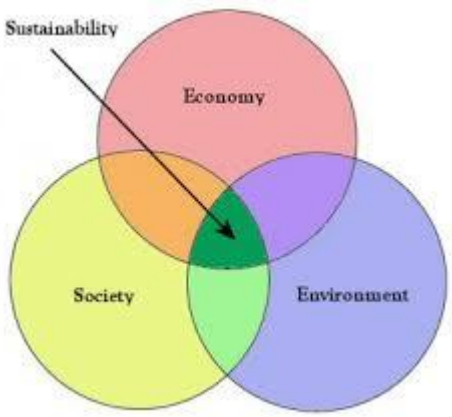
Sustainable transportation system

- **Metrics and indicators**

  - 1st each institute define its sustainability concept;
  - 2nd develop categories/dimensions;
  - 3rd develop indicators and metrics .

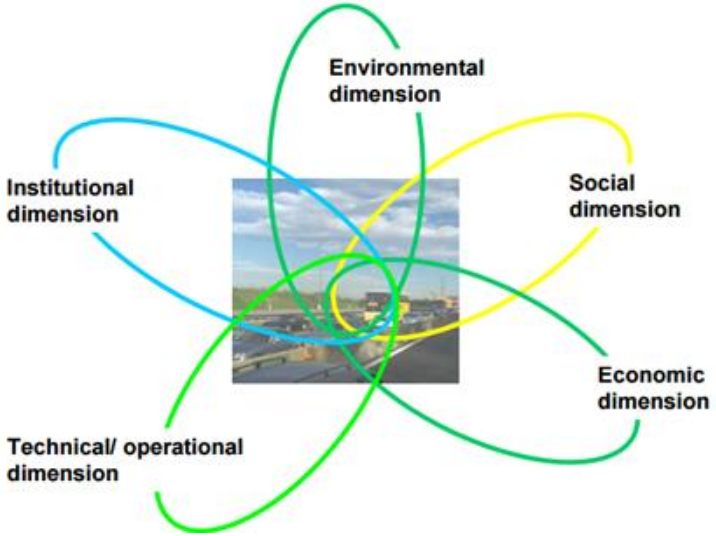
Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. DOI: 10.1061/(ASCE)1076-0342(2005)11:1(31)

SUSTAINABILITY & METRICS



7 INDICATORS

A – Transportes Públicos
B – Mobilidade Pedonal e Acessibilidade
C – Mobilidade Ciclável
D – Planos e Projetos
E – Acalmia de Tráfego
F – Sensibilização



55 Indicators– Joint Research Centre

JRC
EUROPEAN COMMISSION

Instituto da Mobilidade e dos Transportes Terrestres, I.P.

APA, 14 de Fevereiro de 2012

Sustainable transportation system

- **Metrics and indicators**

7 INDICATORS

A – Transportes Públicos
B – Mobilidade Pedonal e Acessibilidade
C – Mobilidade Ciclável
D – Planos e Projetos
E – Acalmia de Tráfego
F – Sensibilização

APA, 14 de Fevereiro de 2012

Instituto da Mobilidade
e dos Transportes Terrestres, I.P.

- Conjunto de processos e ações orientadas para a deslocação de pessoas e bens, com um custo económico razoável e simultaneamente minimizando os efeitos negativos sobre o ambiente e sobre a qualidade de vida das pessoas, tendo em vista o princípio de satisfação das necessidades atuais sem comprometer as gerações futuras

(IMTT(2011); Glossário do Pacote da Mobilidade)

2012

Set of processes and actions towards people and goods transportation with reasonable cost and simultaneously minimizing negative impacts on the environment and people welfare, satisfying todays and future generation needs.

Sustainable transportation system

- **Metrics and indicators**

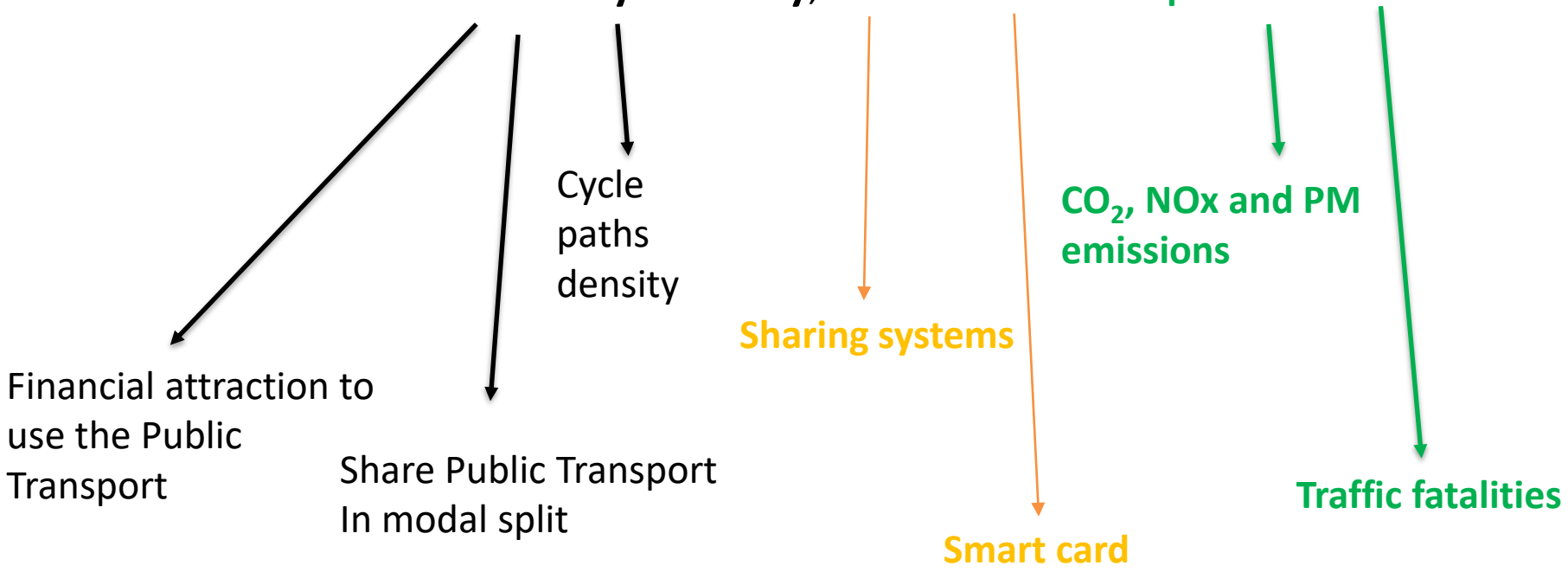
International private Institute

2010…2018

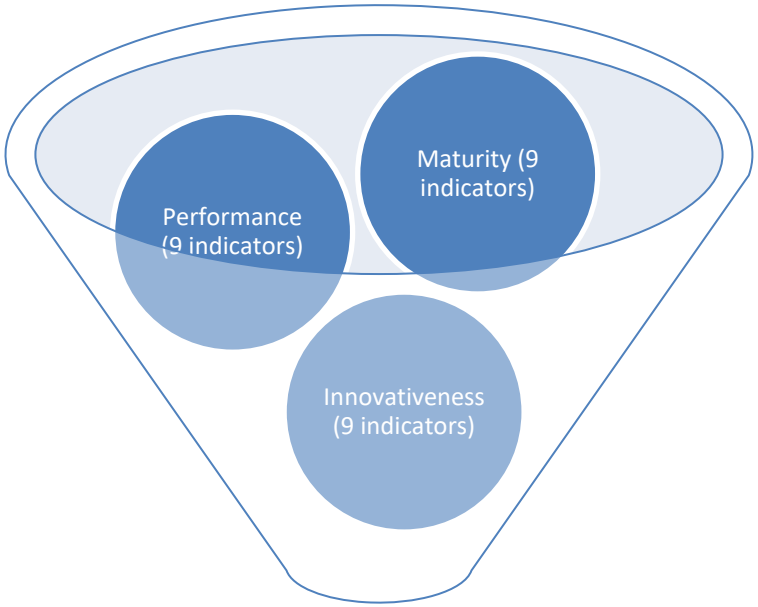
Sustainable transportation system

- **Sustainability**

No definition but considers **mobility maturity**, **innovativeness** and **performance**

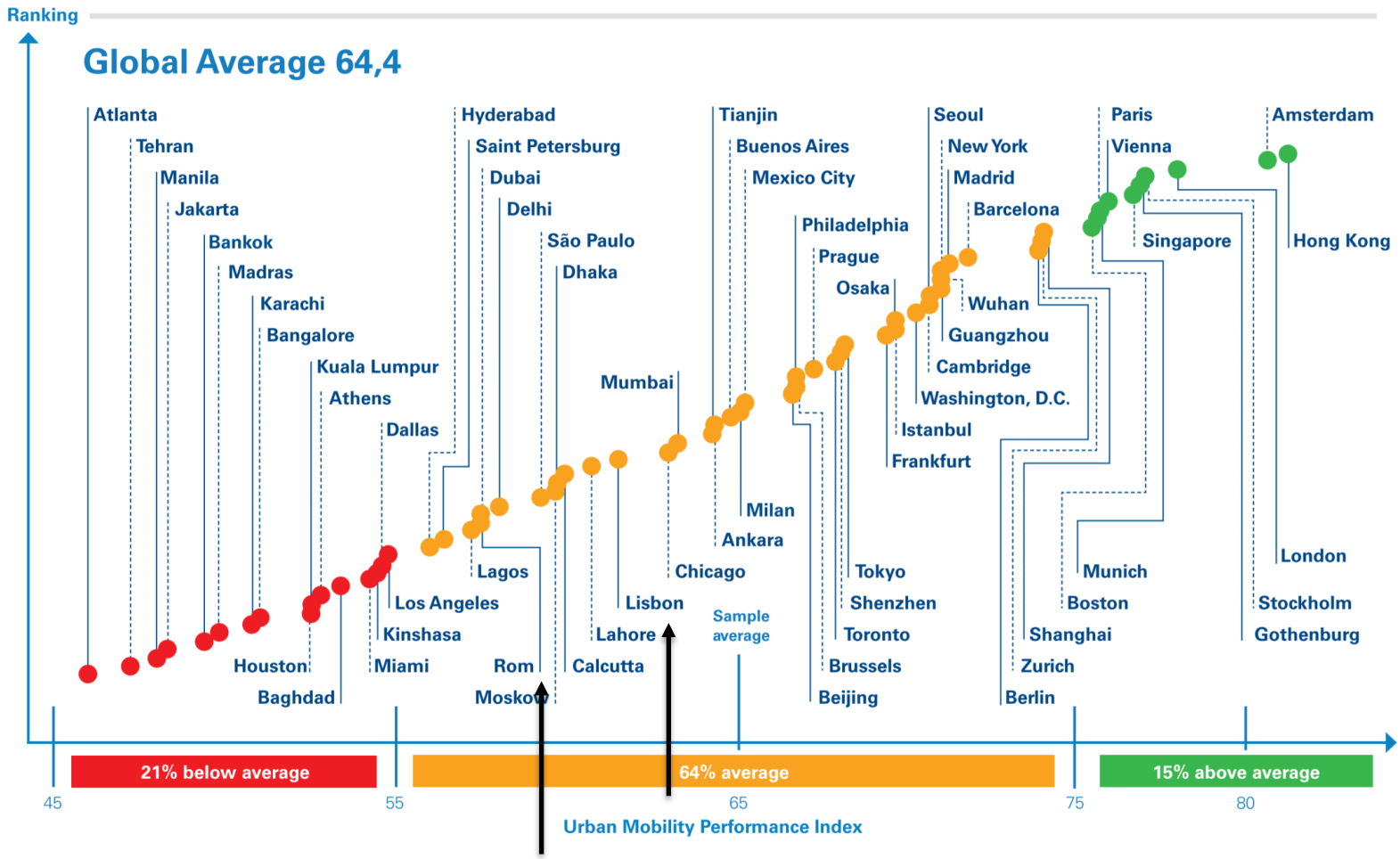


Sustainable transportation system



0 - 100 best

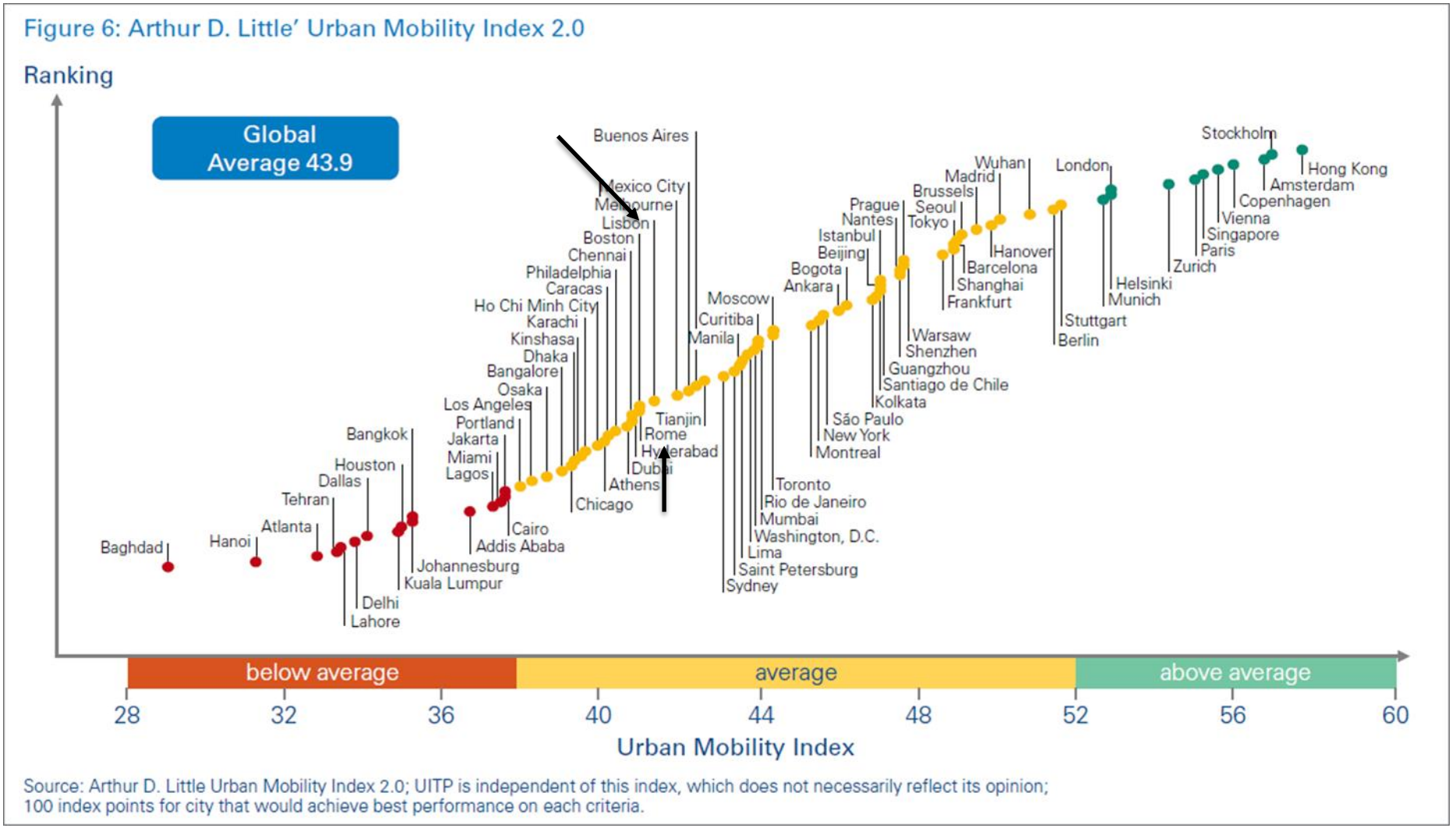
Sustainable transportation system



Source: Arthur D. Little Mobility Index; xx% : share of cities in this performance cluster; 100 index points for city that would achieve best performance which is achieved today on each performance criteria

2010

Sustainable transportation system



2014

Sustainable transportation system

19 indicators

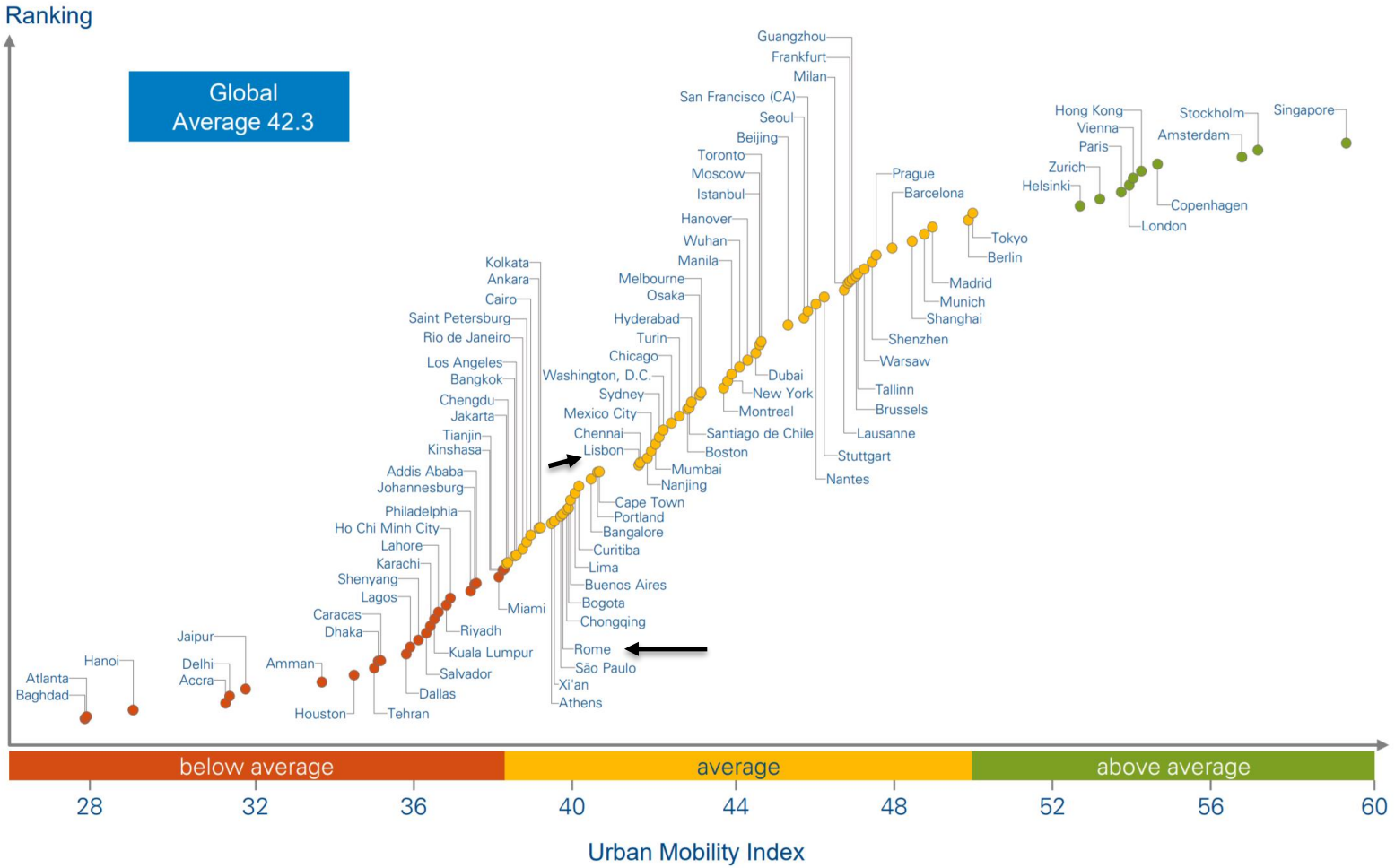
Figure 8: Top 11 cities with above average mobility score

		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

Sustainable transportation system

Figure 12: Arthur D. Little Urban Mobility Index 3.0 – City ranking



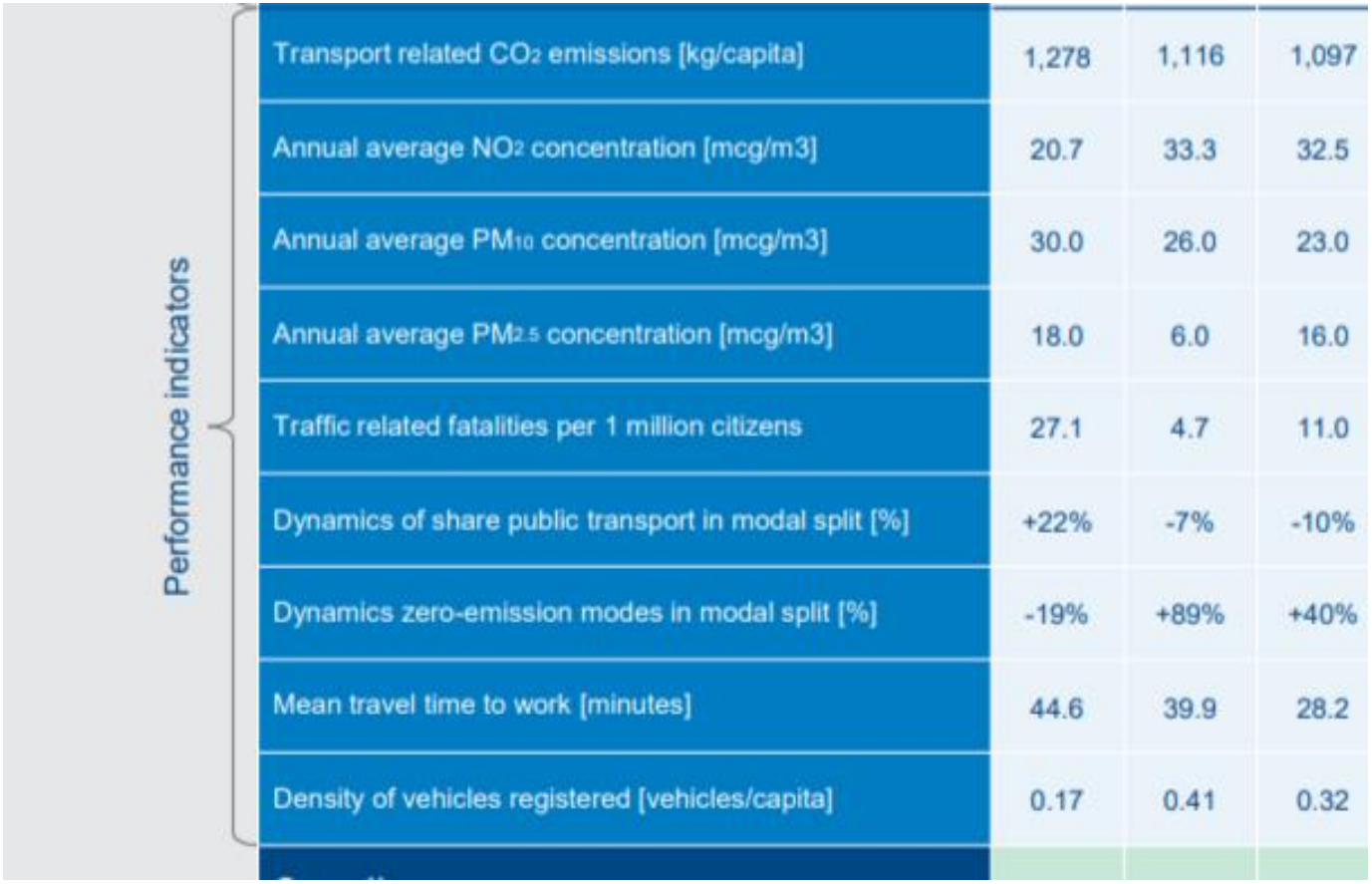
2018

Sustainable transportation system

		1 Singapore	2 Stockholm	3 Amsterdam	4 Copenhagen	5 Hong Kong	6 Vienna	7 London	8 Paris	9 Zurich	10 Helsinki
Maturity indicators	Fin. attract. of PT (cost of 5 km PT/ cost of 5 km car)	2.3	6.7	6.2	6.7	1.2	6.0	6.2	4.4	8.4	5.7
	Share of public transport in modal split [%]	53%	33%	18%	28%	52%	39%	37%	21%	41%	34%
	Share of zero-emission modes in modal split [%]	19%	34%	59%	43%	36%	34%	26%	40%	34%	43%
	Roads density (deviation from optimum) [km/km^2]	2.6	0.5	1.7	2.7	5.5	0.6	1.4	3.1	0.7	2.1
	Cycle path network density [km/ths km^2]	579	4,041	3,502	5,267	198	3,324	596	3,520	5,985	5,614
	Urban agglomeration density [citizens/km^2]	7.8	3.9	3.2	2.1	6.6	3.9	2.9	3.8	1.1	1.8
	Frequency of the busiest public transport line [times/ day]	237	212	155	238	349	294	468	267	145	168
	Urban mobility initiatives of public sector (0 to 10 scale)	10	10	10	10	10	10	10	10	10	10
	Urban logistics initiatives of public sector (0 to 4 scale)	4	4	4	4	4	4	4	4	4	4
Innovativeness indicators	Smart card penetration [cards/capita]	3.3	0.6	0.7	0.8	4.4	0.1	2.9	0.6	0.4	0.8
	Number of mobility platforms available	10	8	10	5	6	9	9	11	9	8
	Bike sharing performance [shared bikes/ million citizens]	5,161	2,243	1.559	1,803	273	856	1,111	2,204	401	1,271
	Car sharing performance [shared cars/million citizens]	85	458	1,250	556	0	619	271	218	954	85
	Number of peer-2-peer car sharing services available	1	3	3	2	2	2	8	11	3	2
	Number of e-hail services and taxi platforms available	7	7	2	3	4	4	8	5	5	3
	Number of ride sharing services available	6	4	2	2	3	1	5	7	3	1
	Number of initiatives related to autonomous vehicles	8	4	3	3	1	1	10	4	1	1
	Number of other smart mobility related initiatives	10	7	10	8	6	10	7	6	8	9
Performance indicators	Transport related CO_2 emissions [kg/capita]	1,278	1,116	1,097	769	1,026	1,149	935	1,354	894	1,120
	Annual average NO_2 concentration [mcg/m3]	20.7	33.3	32.5	36.5	47.0	30.8	56.1	37.0	39.5	19.2
	Annual average PM_{10} concentration [mcg/m3]	30.0	26.0	23.0	27.0	30.5	24.0	21.0	24.0	14.0	19.0
	Annual average $PM_{2.5}$ concentration [mcg/m3]	18.0	6.0	16.0	11.0	25.0	14.0	15.0	16.0	14.0	9.0
	Traffic related fatalities per 1 million citizens	27.1	4.7	11.0	7.1	16.7	6.6	17.7	17.3	14.4	10.2
	Dynamics of share public transport in modal split [%]	+22%	-7%	-10%	+27%	+14%	+12%	0%	+3%	+5%	+6%
	Dynamics zero-emission modes in modal split [%]	-19%	+89%	+40%	+13%	-4%	+2%	+13%	+15%	+10%	+10%

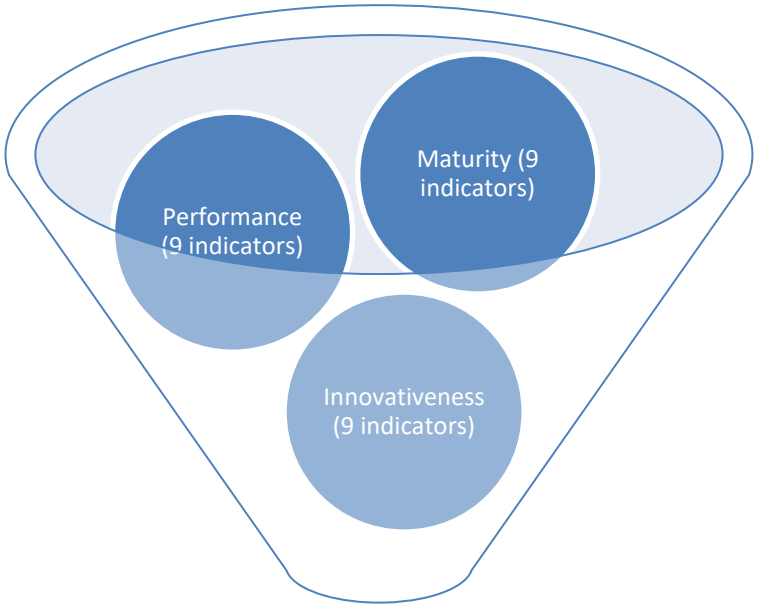
27 indicators

Sustainable transportation system



Performance indicators				
	Transport related CO_2 emissions [kg/capita]	1,278	1,116	1,097
	Annual average NO_2 concentration [mcg/m3]	20.7	33.3	32.5
	Annual average PM_{10} concentration [mcg/m3]	30.0	26.0	23.0
	Annual average $PM_{2.5}$ concentration [mcg/m3]	18.0	6.0	16.0
	Traffic related fatalities per 1 million citizens	27.1	4.7	11.0
	Dynamics of share public transport in modal split [%]	+22%	-7%	-10%
	Dynamics zero-emission modes in modal split [%]	-19%	+89%	+40%
	Mean travel time to work [minutes]	44.6	39.9	28.2
	Density of vehicles registered [vehicles/capita]	0.17	0.41	0.32

Sustainable transportation system



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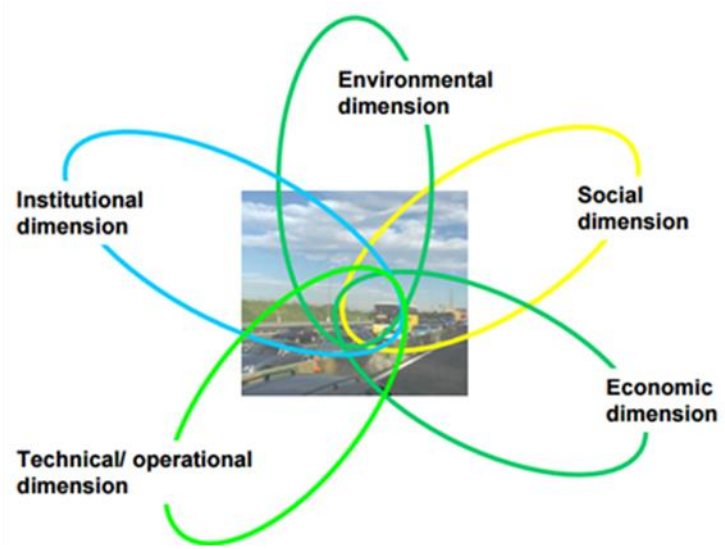
Sustainable transportation system

- **Metrics and indicators**



55 metrics– Joint Research Centre

JRC
EUROPEAN COMMISSION

2012

Sustainable transportation system

- **Definition of sustainability in transports**

"On the basis of the definition of sustainable transport system established in the European Union's Sustainable Development Strategy (EC, 2003) and characterization of sustainable transportation system according to so-called Vancouver principles "Towards Sustainable Transportation" (OECD, 1996) the scope for measurement of transport performance using indicators is identified. "

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC41602/indicators%20report_green%20template.pdf

Indicators of sustainable Mobility

55 Indicators– Joint Research Centre

Table 1. Indicator Framework for the Evaluation of Transport Sustainability Performance

DIMENSION	THEME	RELATED INDICATORS
ECONOMIC	*Transport Demand and Intensity*	1.Volume of transport relative to GDP (tonne-km; passenger-km)
		2. Road transport (passenger and freight; tonne-km and passenger -km)
		3. Railway transport (passenger and freight; tonne-km and passenger-km)
		4. Maritime transport for goods and passengers (tonne-km and passenger-km)
		5. Inland waterway transport (passenger and freight; tonne-km and passenger-km)
		6. Air transport (passenger and freight; tonne-km and passenger-km)
		7. Intermodal transport (tonne-km and passenger-km)
	Transport Costs and Prices	8. Total per capita transport expenditures (vehicle parking, roads and transit services)
		9. Motor vehicle fuel prices and taxes (for gasoline and gas/ diesel)
		10. Direct user cost by mode (passenger transport)
		11. External costs of transport activities (congestion, emission costs, safety costs) by transport mode (freight and passenger)
		12. Internalization of costs (implementation of economic policy tools with a direct link with the marginal external costs of the use of different transport modes)
		13. Subsidies to transport
		14. Taxation of vehicles and vehicle use
		15. % of GDP contributed by transport
		16. Investment in transport infrastructure (per capita by mode/ as share of GDP)
	Infrastructure	17. Road quality - paved roads, fair/ good condition
		18. Total length of roads in km by mode

http://publications.jrc.ec.europa.eu/repository/bitstream/JRC54971/sust_transp_ind_report_final.pdf

Indicators of sustainable Mobility

		19. Density of infrastructure (km-km^2)
SOCIAL	***Accessibility and Mobility***	20. Average passenger journey time
		21. Average passenger journey length per mode
		22. Quality of transport for disadvantaged people (disabled, low incomes, children)
		23. Personal mobility (daily or annual person-km and trips by income group)
		24. Volume of passengers
	Risk and Safety	25. Persons killed in traffic accidents (number of fatalities - 1000 vehicle km; per million inhabitants)
		26. Traffic accidents involving personal injury (number of injuries – 1000 vehicle km; per million inhabitants)
	Health Impacts	27. Population exposed to and annoyed by traffic noise, by noise category and by mode associated with health and other effects
		28. Cases of chronic respiratory diseases, cancer, headaches. Respiratory restricted activity days and premature deaths due to motor vehicle pollution
	Affordability	29. Private car ownership
		30. Affordability (portion of households income devoted to transport)
	Employment	31. Contribution of transport sector (by mode) to employment growth

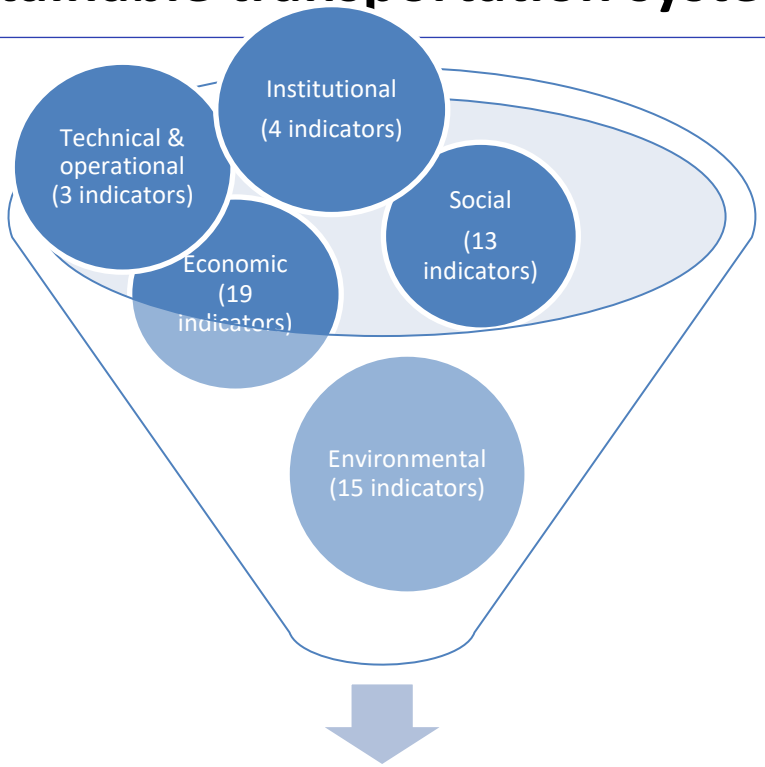
Indicators of sustainable Mobility

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
TECHNICAL and OPERATIONAL	***Occupancy of Transportation***	47. Occupancy rate of passenger vehicles
		48. Load factors for freight transport (LDV, HDV)
	Technology Status	49. Average age of vehicle fleet
		50. Size of vehicle fleet (vehicle/ 1 mln. inhabitants)
		51. Proportion of vehicle fleet meeting certain air emission standards (Euro IV, Euro V etc.)
INSTITUTIONAL	***Measures to Improve Transport Sustainability***	52. R&D expenditure on "eco vehicles" and clean transport fuels
		53. Total expenditure on pollution prevention and clean-up
		54. Measures taken to improve public transport
	Institutional Development	55. Uptake of strategic environmental assessment in the transport sector

Indicators of sustainable Mobility

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

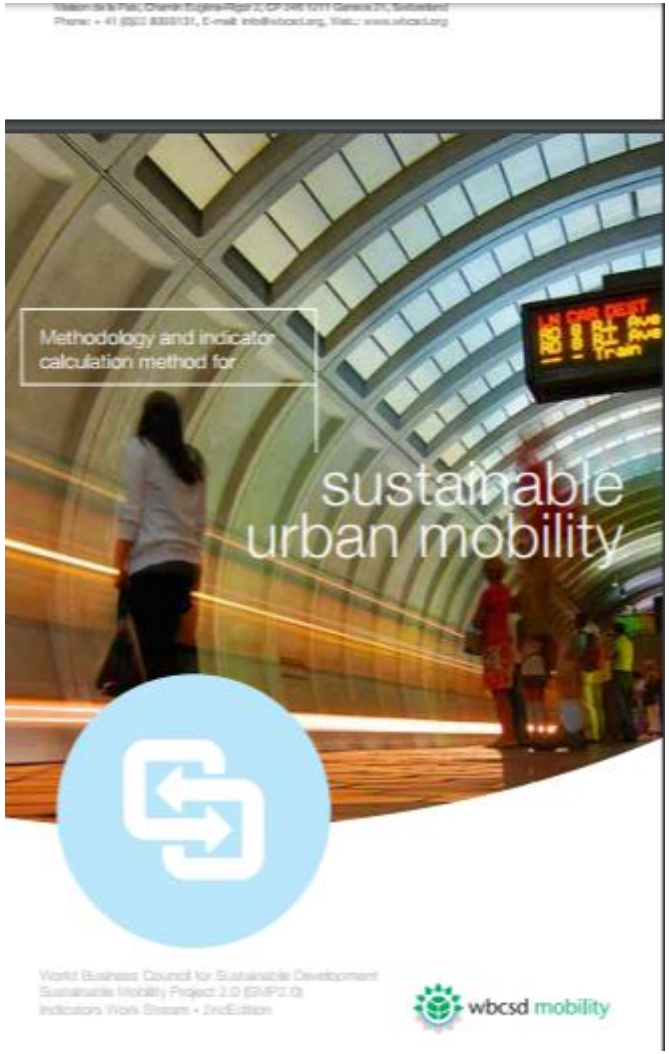
Sustainable transportation system



Several items

JRC
EUROPEAN COMMISSION

Sustainable transportation system



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

Published: 17 Dec 2015

Sustainable transportation system

World Business Council for Sustainable Development

"Sustainable mobility is the ability to meet society's need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future."

(Source WBCSD, Mobility 2030: Meeting the challenges to sustainability, 2004)

Sustainable transportation system

DIMENSIONS vs ***INDICATORS***

	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

Sustainable transportation system

19 Indicators

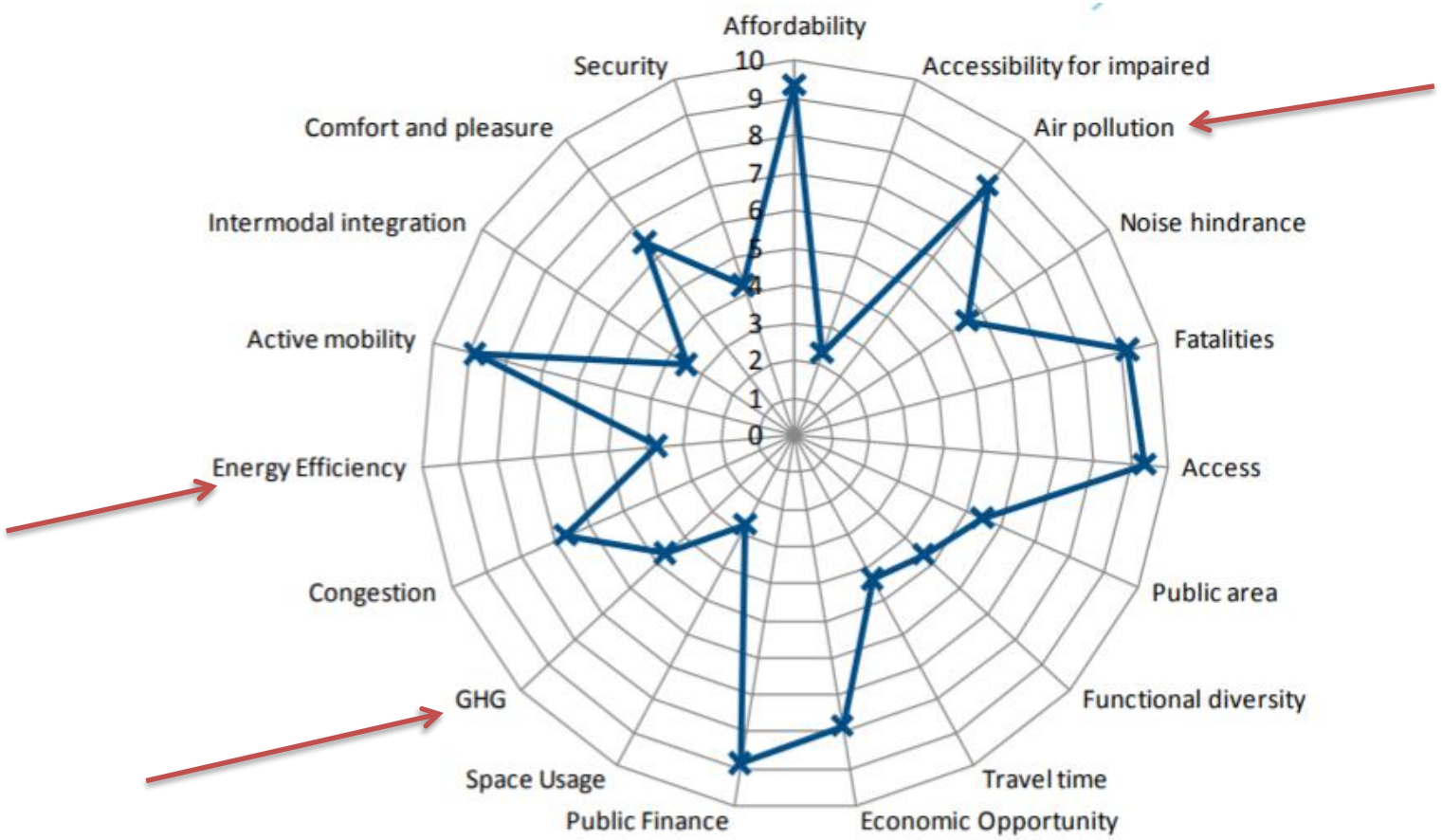
Metrics – equations & calculations

best

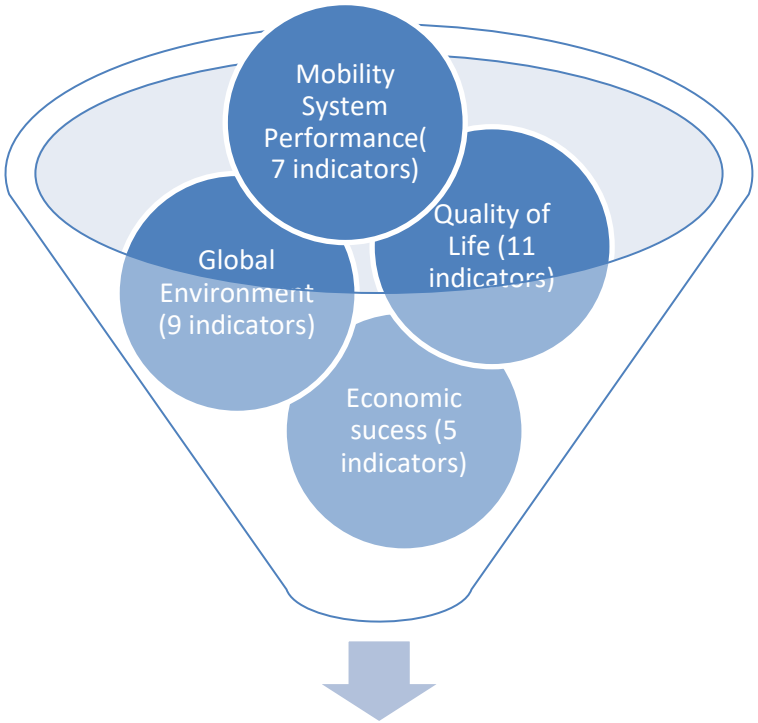
Each transformed with a 0-10 scale

Sustainable transportation system

19 INDICATORS



Sustainable transportation system



Radar graph

wbcsd mobility

- Other metrics; 4 dimensions 17 indicators

Table 1: Indicators for assessing urban public transport sustainability

ID	Indicator	Units	Desirability
A	**ENVIRONMENTAL**		
A1	Quantity of energy consumed	MJ/pkm	Less is desirable
A2	Mass of total pollutants emitted (e.g. NO_x, VOC, CO_2)	kg/ha	Less is desirable
A3	Land area consumed by public transport facilities	% of urban area	Less is desirable
B	**SOCIAL**		
B1	System accessibility	pkm/capita	More is desirable
B2	Average user trip distance	km	Less is desirable
B3	Affordability	10^{-4} per capita GDP/trip	Less is desirable
B4	Public transport related deaths	fatalities/billion-pkm	Less is desirable
C	**ECONOMIC**		
C1	Annual operating cost	$US/pkm	Less is desirable
C2	Cost recovery (proportion of costs recovered)	% of total costs	More is desirable
C3	Passenger km travelled per unit GDP	pkm/$US	More is desirable
C4	Average time per trip	mins	Less is desirable
D	**SYSTEM EFFECTIVENESS**		
D1	Average occupancy rate of passenger vehicles	% of seated capacity	More is desirable
D2	Annual public transport trips per capita	trips/capita	More is desirable
D3	Public transport mode split	% of all trips	More is desirable
D4	Public transport fleet size	vehicles/million people	More is desirable

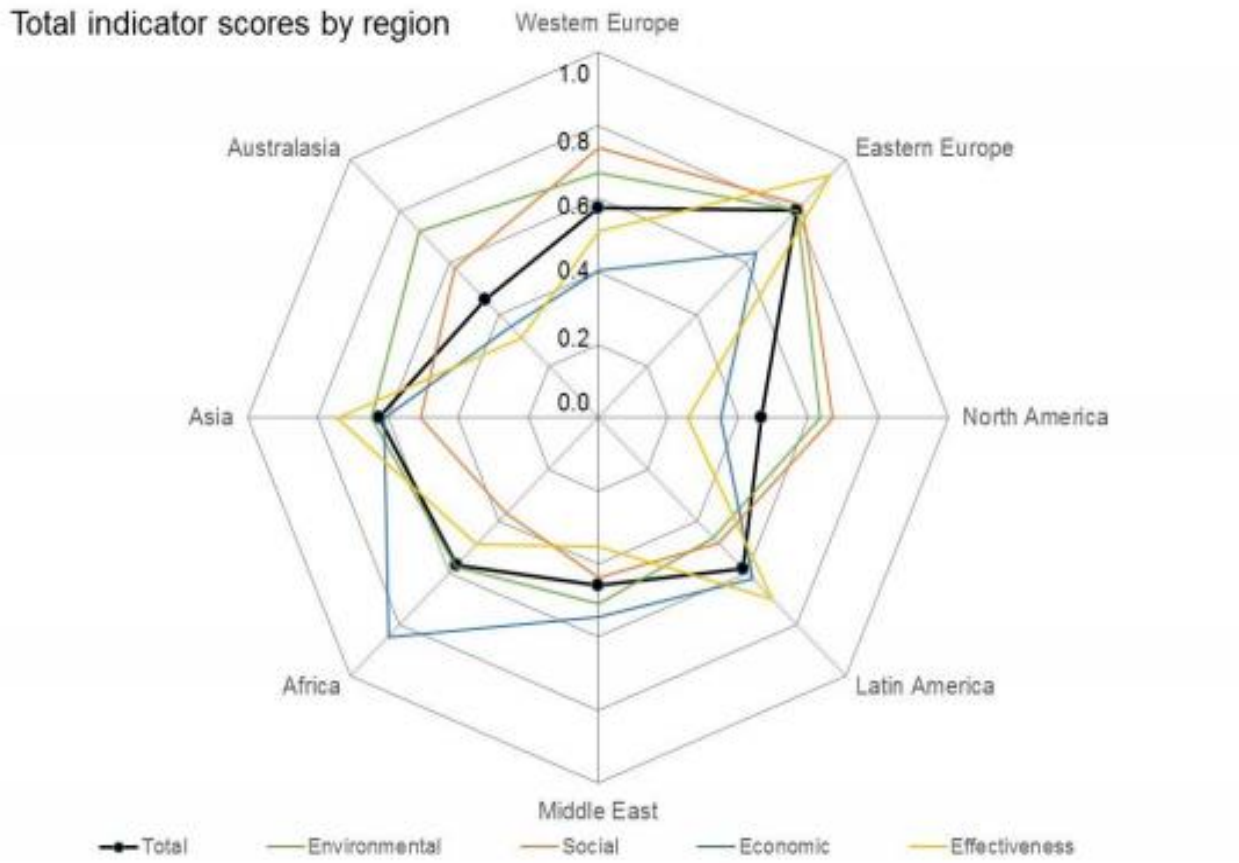
Source: De Gruyter et al. (2017)

Monash University

Australia

Chris De Gruyter , Graham Currie ,and Geoff Rose. Sustainability Measures of Urban Public Transport in Cities: A World Review and Focus on the Asia/Middle East Region. Sustainability 2017, 9, 43; doi:10.3390/su9010043

Figure 1: Aggregate Normalised Total and Category Public Transport Sustainability Indicators by World Region



Indicators of sustainable Mobility

4 categories
19 INDICATORS

Table 34 **Key Sustainable Transport Goals, Objectives and Indicators**

Sustainability Goals	Objectives	Performance Indicators
I. Economic		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	• Per capita GDP and income. • Portion of budgets devoted to transport. • Per capita congestion delay. • Efficient pricing (road, parking, insurance, fuel, etc). • Efficient prioritization of facilities (roads and parking).
Economic development	Economic and business development	• Access to education and employment opportunities. • Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	• Per capita transport energy consumption • Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	• Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). • Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.
II. Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	• Transport system diversity. • Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	• Per capita traffic casualty (injury and death) rates. • Traveler crime and assault rates. • Human exposure to harmful pollutants. • Portion of travel by walking and cycling.
Community development	Help create inclusive and attractive communities. Support community cohesion.	• Land use mix. • Walkability and bikability • Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	• Preservation of cultural resources and tradtions. • Responsiveness to traditional communities.
III. Environmental		
Climate protectin	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of global air pollutants (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce exposure to harmful pollutants.	• Per capita emissions of local air pollutants (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Prevent noise pollution	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality and minimize hydrological damages	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage more compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
IV. Good Governance and Planning		
Integrated, comprehensive and inclusive planning	Planning process efficiency. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning (the most overall beneficial policies and projects are implemented).	• Clearly defined goals, objectives and indicators. • Availability of planning information and documents. • Portion of population engaged in planning decisions. • Range of objectives, impacts and options considered. • Transport funds can be spent on alternative modes and demand management if most beneficial overall.

This table summarizes sustainability goals, objectives and performance indicators.

Concluding….

- ✓ **There is no unique metric system for measuring sustainable mobility;**
- ✓ **Stick to one set of metrics and conclude on that basis!**

SUSTAINABILITY & METRICS

TIP:

We must not place so many requirements on the Sustainability concept or we will fail in achieving such sustainable transportation system

Sustainable transportation system is KEY!!!

Sustainable transportation system is KEY!!!

OPEN QUESTION

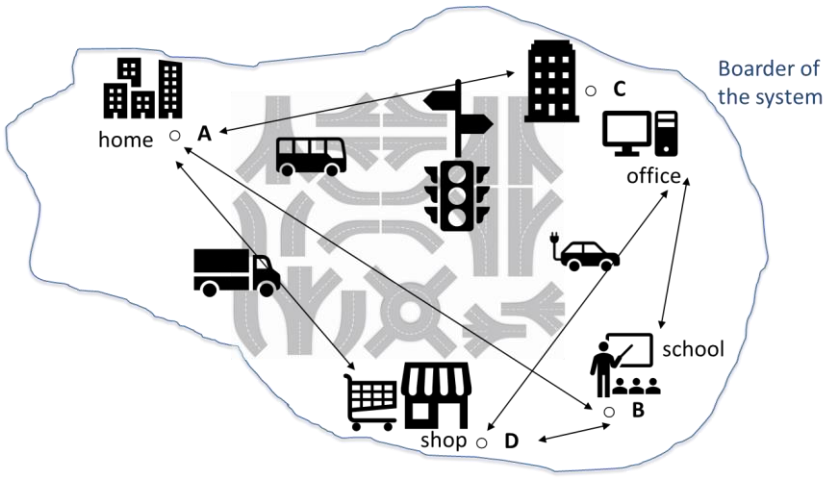
What information is missing to be able to compute, in the system indicated in the next slide,

- **NOX and PM** emissions; in **g/week?**

And,

- **Energy consumption, CO_2** and **NOX&PM emissions are enough to monitor the sustainability of the system???**

OPEN QUESTION



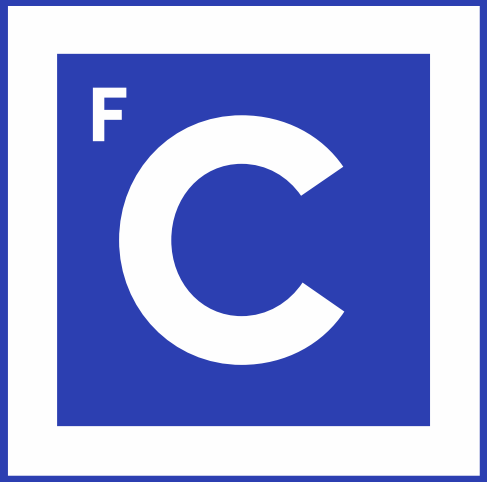
n^{er} trips per day (flows)

		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**

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						

Thanks



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