TRANSFORMING TERRITORIES • LESSONS FROM THE LAB

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DECARBONIZING MOBILITY.

PROPOSALS TO INCREASE THE USE OF SUSTAINABLE MODES OF TRANSPORTATION

Picture: The Lujiazui Traffic Circle in Sanghai, China, Corentin BOUYER, Cassandra DAHMANI, Alex J. KICZALES, Maxime TEILLEUX, Jiayi WANG:

FRANCE 2030

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ABOUT **THE COLLECTION**

The “Lessons from the Lab” collection aims to fuel public debate on major contemporary territorial and urban issues, drawing on the results of collective projects carried out by students at the Sciences Po Urban School. Some forty collective projects are carried out within the Urban School each academic year, with as many institutional, public, private and associative partners. This is the fruit of intense work by nearly 200 students in the first year of the master’s program as well as the Executive Master program in territorial governance and urban development. They are accompanied throughout the year by a tutor who is an expert in the subject in question. It is a comparative and forward-looking work on various territorial issues, covering French, European and international fields, from metropolises to small and medium-sized towns. The question of transitions, and first and foremost, the ecological transition, occupies a central place. Our partners have taken the gamble of relying on the reflections of the younger generation of urban governance professionals to understand better what is at stake in a context of uncertainty and to identify possible responses to these numerous and sometimes contradictory challenges. We believe that dialogue, organised and fueled by field surveys conducted using robust social science methods, is the only way to move forward collectively.

The purpose of this collection is to provide information for professionals. Each issue is a transversal synthesis, on a given theme, of the main lessons from several collective projects carried out in the master’s programs of the Urban school. The collection is part of the TIERED* project (Transforming Interdisciplinary Education and Research for Evolving Democracies), a strategic institutional project for Sciences Po that aims to respond to the challenges facing democratic systems in the context of significant environmental and digital transformations. To this end, the project launches a new phase in developing research, education and disseminating knowledge on these two themes. The results of collective projects by Sciences Po students are part of this dynamic, supported by TIERED through this collection.

This synthesis contains information exclusively from the collective projects of the Urban school students, which you can access in the "Sources" section. ■

** TIERED is funded by a French government grant managed by the Agence nationale de la recherche under the France 2030 program, under reference ANR-22-EXES-014.*

PRESENTATION OF **GROUP PROJECTS**

MOBILITY AS A LEVER FOR THE ECOLOGICAL TRANSITION

Master Governing Ecological transition in Cities, 2024

Students : Daniele GIUSTI, Mateo GOMEZ, Eva MARTINEAU, Adele STEBACH

Partner : Transdev Group

Tutor : Loïc DELHUVENNE, deputy Director territorial Strategy for Digital and European Affairs at IDETA – Agency for territorial development

In their report, students state that the transport sector should become a key driver of the environmental transition, from a problematic source of emissions to a solution to face climate change. Green mobility is a multifaceted concept in hardly consensual terms but most of the actors from the sector agree on one thing: we must reduce transport emissions. And, what a better lever than public transportation to achieve the Paris Agreement targets? Yet, financial gaps and institutional obstacles prevent a range of local actors from accessing eco-friendly public modes of transport. Therefore, the report aims to empower local authorities and generate discussion between different actors by providing them with a few keys that foster public transport as a real lever for the ecological transition.

DEVELOPING SUSTAINABLE MOBILITY. INCENTIVES FOR PERSONAL ELECTRIC VEHICLES IN THE WORLD. EXAMPLES FROM CHINA AND RWANDA

Master Governing the Large Metropolis, 2024

Students : Corentin BOUYER, Cassandra DAHMANI, Alex J. KICZALES, Maxime TEILLEUX, Jiayi WANG

Partner : FIA (Fédération internationale de l'Automobile)

Tutor : Philip PURNELL, consultant

Electric Vehicles (EVs), especially when powered by renewable energy sources, are a promising solution in reducing the transportation sector's overall emissions. However, despite recent growth and increased awareness about their environmental benefits, widespread EV adoption remains a challenge. Governments and other actors around the world have tried to increase adoption through incentive schemes to make them more accessible and more attractive for road users. But the question remains: what barriers remain to EV adoption? And are current EV incentives effective in overcoming these barriers to achieve affordability and sustainability? Students delved into two contrasting examples of countries that have developed incentive schemes: China, a leader in EV adoption with well-honed incentive programs, and Rwanda, a developing nation struggling with low car penetration but with strong ambitions for EV deployment.

THE FUTURE OF HIGH-SPEED RAIL. ACCELERATING CONNECTIVITY AND SUSTAINABILITY ACROSS EUROPE.

Master Governing the Large Metropolis, 2024

Students : Nathan BENAMOUZIG, Joshua CLAXTON, Rachel KOVINSKY, Jiaqi LI, Anna WARD

Partner : AREP (Architecture, Research, Engagement, Post-Carbon)

Tutor : Alice PEULTIER, SCET consultant (Caisse des Dépôts group)

This Capstone aims to address knowledge gaps surrounding the potential adaptation and creation of high-speed rail (HSR) stations across Europe, particularly considering growing demand for HSR and EU-level commitments to funding sustainable mobility. The goal of this project is to provide an overview of specific and promising opportunities to apply such expertise across Europe. Through analyzing railway investment plans, reviewing governance and institutional frameworks, and conducting site visits and stakeholder interviews, this project gives further insight into funding mechanisms, market solicitation, environmental objectives, and the socio-economic and political contexts surrounding fifteen HSR stations of interest across Europe.

COMPARING MOBILITY MODES: A NEW SET OF INDICATORS

Master Governing Ecological transition in Cities, 2024

Students : Louise RENAUDIE, Finn SCHLICHENMAIER, Berfin SEMO, Paul SERVAIS

Partner : Futura-Mobility

Tutor : Adrien SARTRE, technical advisor for the City of Paris

Imagine you were asked to go from point A to point B, and to choose between the following means of transport: car, train, bus, bike, walk and plane. If we then asked you to explain your choice criteria, what would you tell us about? Price, duration and CO2 emissions, perhaps. But probably not much else. Indeed, the indicators comparing modes of mobility, which can inform both passengers and decision-makers, are currently limited, and do not allow us to grasp all the dimensions of the mobility sector. The aim of this study is therefore to respond to this shortcoming by proposing eight new, relevant indicators to compare current and future modes of travel in Europe.

THANKS TO OUR **TUTORS**

LOÏC DELHUVENNE is deputy Director in charge of new technologies and European Affairs at the Belgian Agency for territorial development IDETA. He holds a master's degree in political science from the Université Libre de Bruxelles (ULB), obtained in 2008, and he completed his curriculum with executive training at SciencesPo Paris and at the London School of Economics and Political Science (LSE).

Prior to his current role, he held several strategic positions in public administration and territorial cooperation. From 2016 to 2024, he was Managing Director of the Agence de l'Eurométropole Lille-Kortrijk-Tournai. Previously, from 2012 to 2016, he worked as an expert for Wallonia and the Wallonia-Brussels Federation, on European cohesion and territorial cooperation policies.

A recognized specialist in European regional policies, he also shares his expertise as a lecturer at SciencesPo Lille and SciencesPo Paris. In 2022, he co-published a weekly newsletter for the Centre de recherche et d'information socio-politiques (CRISP), entitled "L'Eurométropole Lille-Kortrijk-Tournai, instrument au service de l'institutionnalisation de la coopération transfrontalière".

PHILIP PURNELL

A communications expert with a background in developing innovative personal mobility projects, currently consulting to various organizations in the areas of advocacy, road safety and sustainability. Recently supporting the development of strategies that foster sustainable, impactful change, He has been consulting to the FIA (Fédération International de l'Automobile) since 2023, working with mobility clubs around the globe to develop a more sustainable business model..

ADRIEN SARTRE is a political advisor to the City of Paris, teacher and engineer specialized in energy and in the implementation of local ecological policies. He is currently in charge of pedestrian and bicycle policies in the office of the Deputy Mayor of Paris responsible for the transformation of public space, transport, mobility, traffic law and roads, in particular. In particular, he is working on the implementation of the City of Paris 2021-2026 Bicycle Plan and the 2023-2030 Pedestrian Plan.

He also teaches the course "La fabrique des politiques locales face au dérèglement climatique" (The making of local policies in the face of climate change) at master's level at Sciences Po's School of Public Affairs.

ALICE PEULTIER With a double master's degree in territorial and urban strategies from Sciences Po Paris and the London School of Economics (LSE), Alice is currently a planning consultant with the Group SCET (Services Conseil Expertises et Territoires), a 100% subsidiary of Caisse des Dépôts (N.B. Caisse des Dépôts et Consignations and its subsidiaries represent a major public financial institution, at the crossroads between the public and private sectors). After several internships with the RATP (Paris public transport network) and the City of Paris, she now assists local authorities throughout France with the implementation and operational security of their urban projects.

Part 1

CONTEXT AND CHALLENGES

The four selected projects on which this issue is based underline the significant part of the transportation sector in global emissions and its consequences on individuals and the environment. Though some solutions have recently emerged, several challenges remain to attain decarbonisation and limit climate change.

DECARBONISING THE TRANSPORTATION SECTOR: **AN ECOLOGICAL AND HEALTH EMERGENCY**

A TRANSPORT SECTOR AT THE ORIGIN OF GREENHOUSE GAS (GHG) EMISSIONS AND AIR POLLUTION

The transport sector currently accounts for 15% of the total GHG emissions and 23% of the global energy-related CO2 emissions[1] To be on track with the Paris Agreement's goal of limiting global warming to 1.5°C above pre-industrial levels, the transportation sector's growth should fall by 3% per year until 2030[2] . It is now growing at 1.8% per year[3] Additionally, in 40% of the countries, transport (especially freight and passenger road transport) represents the most energy-consuming sector.

Cities play an ambivalent role as significant contributors to emissions and frontline bearers of the consequences of climate change. Urban mobility is responsible for 40% of the transport-related emissions and 8% of the global CO2 emissions. It is consequently urgent to integrate the transportation sector into broader climate actions, especially as GHG emissions lead to higher levels of air pollution[4].

Despite the general improvement of air quality, thanks to a local, national and European emphasis on air quality regulation, European air quality standards are consistently exceeded each year in France. Concerns over air quality have thus increased, alongside a growing awareness of the risk of exposure to high levels of air pollution with devastating consequences for human health and for the environment. Air pollution is indeed one of the world's leading risk factors for death with 4.2 million premature deaths being attributed to ambient air pollution in 2019, according to the WHO. This mortality is due to the exposure to fine particles, which may cause cardiovascular and respiratory diseases, and cancers[5].

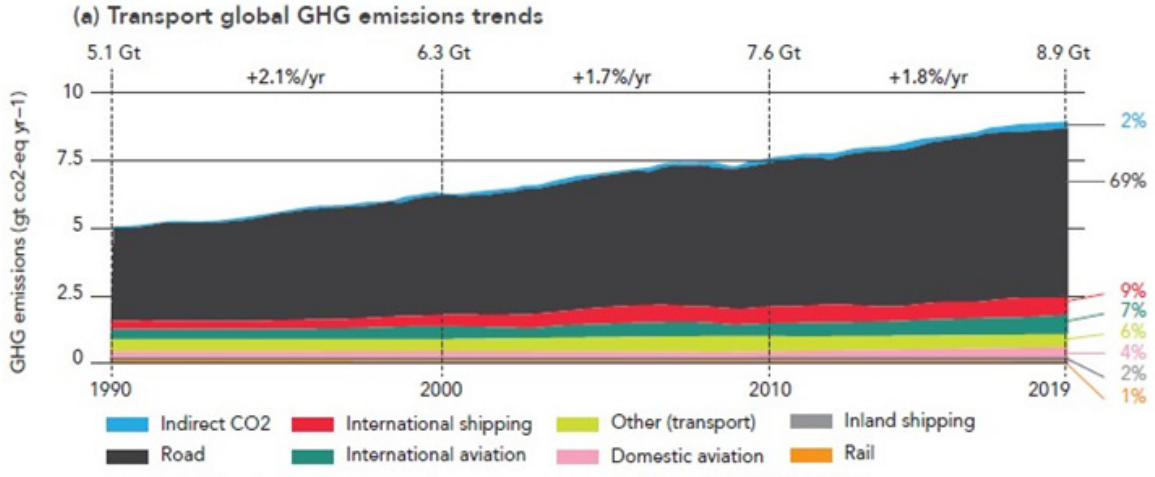
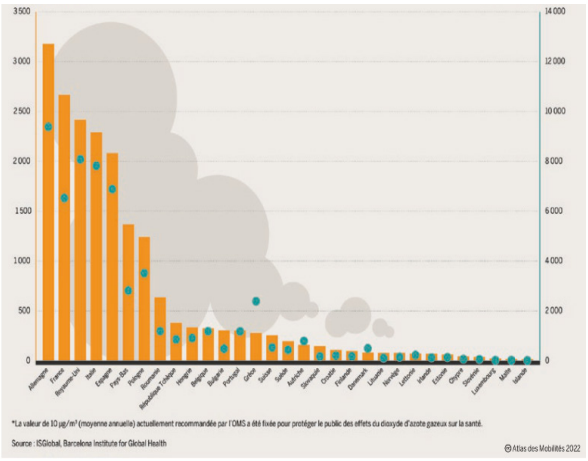


Figure 1: Global and regional transport greenhouse gas emissions trends | Source: IPCC AR6 WGIII (2022)

[1] International Energy Agency - IEA, 2020
[2] IEA, 2023
[3] IPCC, 2022
[4] Air pollution refers to the "con¬tamination of the indoor or outdoor environment by any chemical, phys¬ical or biological agent that modifies the natural characteristics of the atmosphere" (World Health Organization. (n.d.). Air pollution. Retrieved from https://www.who.int/health-topics/air-pollution#tab=tab_1)
[5] World Health Organization. (2022). Ambient (outdoor) air quality and health. Retrieved from https://www.who.int/news-room/fact-sheets/detail/ ambient-(outdoor)-air-quality-and-health



Deaths that could have been avoided by respecting WHO's guidelines regarding air pollution levels

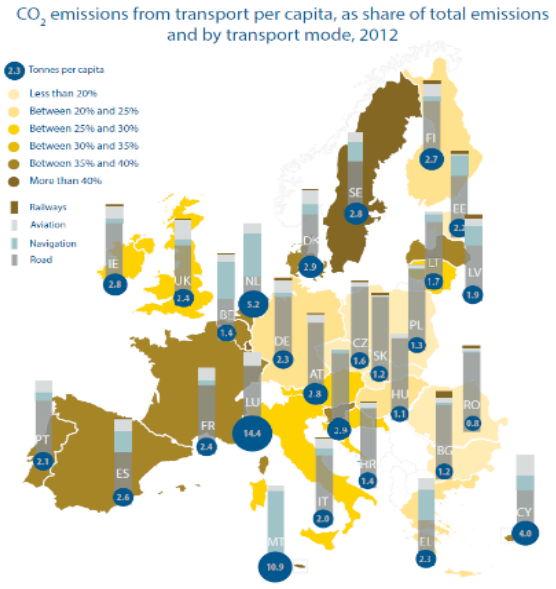
THE SECOND MOST EMISSIVE SECTOR IN EUROPE

Transport is currently the second most emissive sector in Europe (after energy supply): it amounts to a quarter of Europe's GHG sources, with emissions that continuously grew in the last decades. Between 2000 and 2019, the GHG emissions caused by transport have risen by 24% in the EU[6]. About 60% of transport emissions are related to the mobility of passengers, which therefore accounts for 10 to 15% of the total emissions in the EU.[7]

Although all European countries need to decarbonise their transport sector, the importance of this challenge varies across different national contexts[8]. This is partly explained by the carbon intensity of respective national energy mixes: while countries like Poland and Germany still rely on emissive sources like coal for electricity and heat production, others have a rather decarbonised electricity mix, which makes transport the most emissive sector.

The predominant technology used for passenger transportation, namely cars, largely depends on fuel sources such as oil. This reliance on oil presents challenges for decarbonising this sector, even in countries like France, which have low-emission electricity sources.

However, these rankings hide the absolute GHG emissions produced by mobility in every country. It is therefore more interesting to compare European countries in terms of yearly per capita emissions due to transport. Luxemburg inhabitants, who emitted 14.4 tons in 2012, produce by far the largest amount of GHG in the EU because of transport [9] (which accounts for half of Luxemburg's emissions). In France, the mobility carbon footprint per capita was of 2.4t, and dominated by road transport.[10]



CO2 emissions from transport per capita in the European Union, 2012 from Claros et al., 2015

[6] International Transport Forum. (2021). Decarbonising transport in Europe: The Way Forward. Retrieved from https://www.itf-oecd.org/sites/default/ files/docs/decarbonising-transport-europe-way-forward.pdf
[7] European Council. (2024, January 3). Clean and sustainable mobility. Retrieved from https://www.consilium.europa.eu/en/policies/clean-and-sustainable-mobility/
[8] European Commission. (2022). Climate action tracking Report: Italy. Retrieved from https://climate.ec.europa.eu/system/files/2023-04/it_2022_factsheet_en.pdf
[9] Claros, E., & Marketa, P. (2015, November 19). Transport CO2 emissions in focus. In Epthinktank. Retrieved from https://epthinktank.eu/2015/11/19/ transport-co2-emissions-in-focus/
[10] These statistics do not distinguish freight and mobility in the accounting of transport emissions.

STATE OF THE ART OF **TRENDS AND POLICIES** PUSHING FOR THE DECARBONISATION OF MOBILITY

THE IMPLICATIONS OF MEGATRENDS FOR MOBILITY

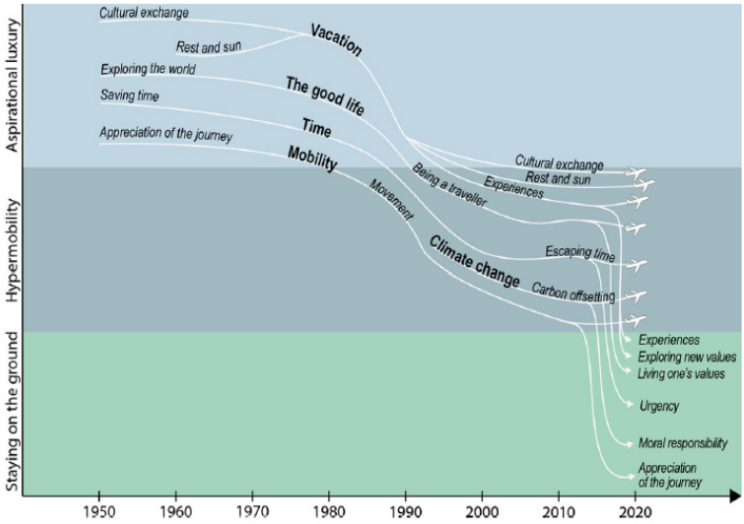
To understands the current stakes of mobility, the students of the Futura mobility group identified megatrends, i.e. largescale and long-term transformations which impact our societies and their mobility. The last identified megatrend is the emergence of changing behaviors and lifestyles leading to a "new green culture".The evolution of mobility patterns is evident in various aspects: there is a growing trend in the number of journeys, driven by factors such as urbanization, increased access to transportation options, and shifts in work patterns. Simultaneously, the number of modes employed for transportation has expanded due to the rise of multimodal options. Indivi duals now combine various modes like public transit, ridesharing, biking, walking, and even micro-mobility choices such as electric scooters for their journeys. The COVID-19 pandemic has induced a shift in behavior and transport energy use patterns[11] , prompting reflections on sustainable practices in a post-pandemic world. The rising interest in sustainable and eco-friendly travel options is evident for part of the population, influencing preferences for shorter distances, local travel, and a shift toward multimodal transportation. This transition also reflects a preference for minimizing travel time, leading to a greater emphasis on faster and more sustainable modes of transportation

MEGATREND	DESCRIPTION	IMPACT ON MOBILITY
Aging of the population	The share of older people grows in relation to the total population. Aging is a pattern observable in all countries.	Older people rely increasingly on the car because of issues of availability, affordability and accessibility of public transportation.
Urbanisation	The increase of people living in urban areas. Today, most of the European population lives in cities of 250 000 to 1 million residents (European Commission). There is a twofold trend of growth in big European cities: suburbanization and urban expansion.	Commuting has increased in many European countries over the last three decades. The demand for public transport and car-related infrastructure is thus expected to rise in European capitals and major cities.
Rising health concerns	As societies increasingly prioritize health and wellness, health becomes an important component to address to change behaviors regarding mobility.	The need for health indicators is driven by the potential positive influence of mobility on public health. Those concerns for health also point to mortality, or safety, as a potentially relevant indicator that would influence people's mobility choices.
Digitalisation	Large scale deployment of numerical technologies, deeply reshaping a society (job market, public services, public infrastructures, etc.).	O The deployment of "smart networks" and 5G could lead to the creation of "Connected and Automated Mobility", which would require collecting and treating great amounts of data in real-time. O AI and automation might play a crucial role in enhancing transport systems. O Calculation of new mobility indicators made possible by the new data available, accessible in real time by consumers.

Simultaneously, the cultural and ideological context reflects a generational ethos that values sustainability, social responsibility, and a desire for systemic change. The new generation, witnessing firsthand the consequences of climate change, seems to be motivated to actively engage in sustainable practices and become advocates for policy-driven solutions. The regulatory landscape, epitomized by transformative initiatives such as the European Green Deal, acts as a pivotal catalyst in shaping this emergent green culture, fostering a sense of responsibility towards the environment. The new green culture represents a commitment for a part of the population to prioritize environmental sustainability, particularly among younger generations and in urban areas. The extent and duration of this generational phenomenon have yet to be quantified, but the evolving landscape of behaviors and lifestyles significantly influences contemporary mobility patterns.

[11] International Energy Agency. (2024). Changes in transport behavior during the COVID-19 crisis. Retrieved from https://www.iea.org/articles/chang¬es-in-transport-behaviour-during-the-covid-19-crisis

An in-depth analysis of data reveals an uptick in interest in sustainable travel options for a part of the population. New words emerged, such as 'flygskam' in 2018 in Sweden, translating into 'flight shame' associated with the carbon emissions of air travel. The "Staying on the ground" discourse seeks to challenge the established norms surrounding holiday air travel and encourage a change in behavior[12] , presenting the avoidance of air travel as an ethical imperative as well as something positive for the individual, highlighting the discovery of new values, experiences and enjoyment of travel. However, this remains a minority phenomenon as flying picked up the pace again after the pandemic.



The discursive development of holiday air travel in Sweden, Sara Ullström et al., 2021 (Journal of Sustainable Tourism. (2021).

There have been real evolutions regarding other transportation modes. While the volume of passenger transport in Europe increased between 1996 and 2016 for almost all transport modes (except ships), the modal share of passenger cars decreased from 73% to 71%. In the same period, the modal share of trains increased from 6.2% to 6.6%.[13] The uptake of electric cars has seen considerable fastening in the last few years. In 2022, 21,6% of newly registered cars were electric vehicles. In Norway, this figure rose to almost 90%, followed by Sweden and Finland with rates between 50% and 60%[14]

The confluence of generational values and evolving mobility choices paints a comprehensive picture of the transformative impact the green culture has on shaping the future of sustainable mobility in Europe.

HOW NATIONAL STRATEGIES FOR CLIMATE CHANGE MITIGATION MIGHT CHANGE EUROPEAN AND GLOBAL MOBILITY IN THE FUTURE

Several regulations collectively aim to transition towards a greener and more sustainable future which has an implication on mobility and transportation. In the United States, the Green New Deal encompasses a range of regulations aimed at addressing climate change and promoting sustainability. It involves clean energy standards, investments in green infrastructure, energy efficiency regulations, carbon pricing discussions, and emission standards. The European Union has launched several plans aiming to decrease the GHG emissions of the State members, in a perspective of "climate change mitigation", i.e. the action of reducing the production of GHG emissions to limit human-induced climate change. The European Green Deal sets ambitious targets for renewable energy, introduces a carbon border adjustment mechanism, strengthens the emission trading system, and implements sustainable finance regulations. It aims to achieve a full decarbonisation of the European economy by 2050, and the plan Fit for 55 set objectives to achieve a 55% reduction of the continent's emissions by 2030 in comparison to the 1990 levels. In 2020, the European Commission has delivered its Sustainable and smart mobility strategy report, which gives ambitious directions for the development of mobility in Europe over the next few years. If followed, this strategy should help decrease 90% of emissions from transport by 2050. It gives optimistic milestones for 2030 (e.g. "high-speed rail traffic should double"), for 2035 (e.g. "zero emission aircrafts should be market-ready") and for 2050 (e.g. "all cars, vans, should be zero emission"). The strategy is built on three axes: "sustainability", that consists of developing green mobility technologies, "smartness", that aims to use AI and automation for new mobility developments, and "resilience", which aims to increase accessibility and fairness in mobility.

Recently, the European Council has agreed on new targets for mobility: from 2030 to 2034, new cars should emit 55% less CO2 (50% for new vans). In 2035, all new cars should produce zero emission. In 2030, 6% of air-

[12] Journal of Sustainable Tourism. (2021). Retrieved from https://www.tandfonline.com/doi/full/10.1080/09669582.2021.1998079
[13] European Union. (2018). Research for TRAN Committee - Modal shift in European transport: a way forward (p. 34).
[14] European Environmental Agency. (2023). New registrations of electric vehicles in Europe. Retrieved from https://www.eea.europa.eu/en/analysis/indicators/new-registrations-of-electricvehicles#:~:text=Considerable%20progress%20in%20the%20uptake,1%2C74%20million%20in%202021

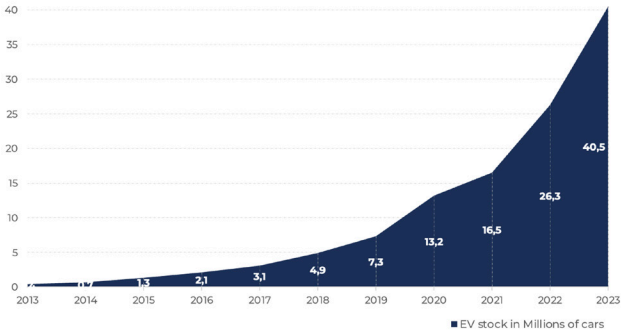
planes should use sustainable fuels, 20% in 2035 and 70% in 2050[15]. In France, these targets are converted into precise objectives by the recently released report *La planification écologique*. Between now and 2030, there should be an approximately 30% decrease in emissions. France bets on the development of light electric vehicles (whose share in the automobile park should evolve from 1% to 15% in 2030), public transport, bicycle and car-sharing practices. As for Sweden, it aims to decrease its transport emissions by 70% before 2030, in comparison to 2010 levels. They bet on the electrification of the sector, by developing state-funded incentives to invest in electric vehicles, taxing vehicles that use fossil fuels, using a "no-claims bonus" system that rewards electric car-owners. In Poland, where the importance of the transport sector grew by 84% between 2005 and 2019, the state bets on the development of efficient technologies based on liquified natural gas (LNG), on electrification and on the development of public transport.

Most European countries thus bet on technological developments, public transport and a large electrification to support their transition towards a low-carbon mobility. Governments have instituted policies aimed at curbing transport emissions and mitigating the environmental and health impacts of the transportation sector. By implementing measures such as motor vehicle restrictions, cities seek to raise awareness among citizens regarding the impact of their transportation choices on air quality. Consequently, there has been a concerted effort to promote public transportation, establish low-emission zones, and impose bans on cars, all aimed at reducing urban traffic congestion and air pollution.

OVERVIEW OF THE CURRENT STATE OF ELECTRIC VEHICLES IN THE WORLD

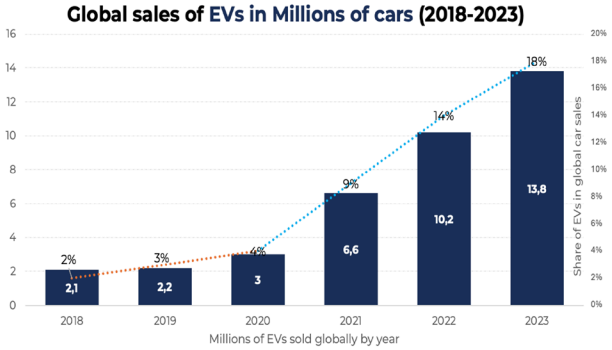
The FIA has concluded that electric vehicles (EVs) are currently the prominent route for delivering sustainable personal transport. EVs appear to be a critical component in helping reduce air pollution and greenhouse gas emissions and are a significant element in mitigating climate change. EV growth has really taken off since 2020, carried by sales in China, Europe and the United States. Battery Electric Vehicles (BEVs) are the leading type of electric vehicle sold globally, making up 70% of annual sales. Europe today stands as the one of the regions with the most developed EV market and infrastructure globally, while the United States accounted for 13% of global EV sales in 2023, positioning itself behind China and Europe.

Global plug-in EV stock growth (2013-2023)



Source: (IEA, 2024)

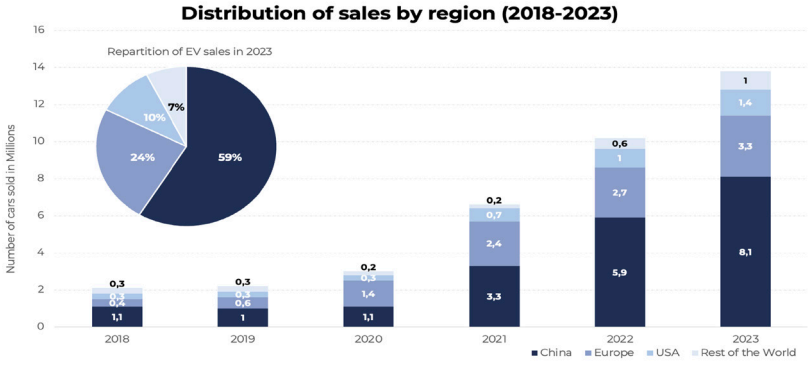
Global sales of EVs in Millions of cars (2018-2023)



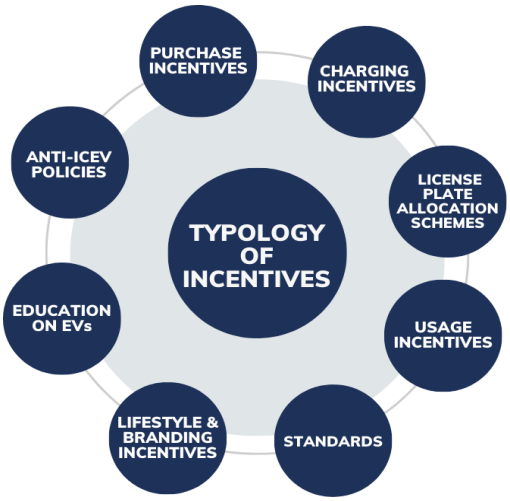
China is the world leader in the EV market, accounting for nearly half of all global EV sales in 2023. They also lead the manufacturing sectors for cars and batteries. Chinese brands dominate the EV market in China, and they are conquering other markets, with BYD being the leading manufacturer in the world. Tesla remains the most popular brand in Europe, followed by electric models from traditional European manufacturers. Europe boasts the most developed infrastructure, while the US grapples with slower-than-anticipated adoption.

While some developing countries have started experiencing rapid EV growth in the past couple of years, significant disparities remain compared to the three main regions. This is particularly evident in Africa and the Middle East, where EVs make up less than 1% of total car sales (IEA, 2024b). Disparities in terms of EV adoption are present across countries and regions but also within single markets, for example between urban and rural areas. Cities are driving the EV transition globally, while rural areas are still facing difficulties in properly developing a strong EV market. However, there is a great potential for EV market growth in developing countries as the overall vehicle market increases fast. In Rwanda, it grows 12% every year. Finally, two-wheelers can represent a large portion of the vehicle stock.

[15] European Council. (2024, January 3). Clean and sustainable mobility. Retrieved from https://www.consilium.europa.eu/en/policies/clean-and-sustainable-mobility/



Source: (IEA, 2024)

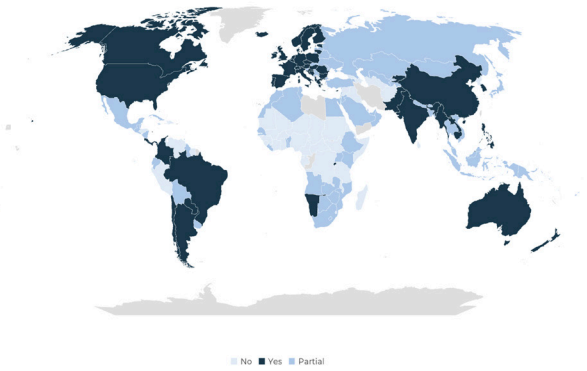


National governments, local authorities, and even private companies can offer a range of incentives, encompassing purchase subsidies, tax breaks, charging infrastructure development, and usage benefits. However, not all countries have a comprehensive EV policy that encompasses different types of incentives. For instance, Rwanda, which does not have domestic manufacturing, focuses its strategy on tax and custom duty reduction on vehicles, parts, batteries and charging equipment.

Developed car markets with established internal combustion engine vehicles (ICEV) industries tend to have more EV incentives compared to developing countries with limited infrastructure and affordability challenges.

If other numbers show that Europe, China, and to a lesser extent the US, are leading the EV transition, this map shows that other countries around the globe are also implementing comprehensive policy strategies, that mix financial and non financial, at purchase and long term incentives. South America sets an example, but many countries across all continents and even Africa, have at least partial incentives that aim at promoting EV adoption (partial means at least one incentive is in effect in the country). ■

Presence of a comprehensive EV incentive policy in the country



CHALLENGES TO DECARBONISING MOBILITY

THE ELECTRIFICATION CHALLENGE

Electrification is the action of replacing an energy source (e.g. fossil fuels) with electricity, through technological reconfiguration.

The decarbonisation of mobility comes with two immediate challenges for the energy systems:
(1) the need for an electrification of usages, - vehicles must become electric -, and
(2) the decarbonisation of the electricity mix, through the development of non-emitting electric power plants (e.g. renewables, nuclear).

The second challenge has deep implications on the transition strategy of the different European countries. Indeed, countries with a high proportion of fossil-fuel based power plants (coal, gas) must first develop their non-emitting technologies, before organising the modal transfer towards electrified mobility modes.

Though Battery Electric Vehicles (BEVs) produce no tailpipe pollutants, manufacturing BEV batteries can result in high GHG emissions - potentially 200 kg CO2 eq/kWh - and in countries like China, BEVs may have higher life cycle CO2 emissions than internal combustion engine (ICE) vehicles due to coal-based electricity. This suggests promoting BEVs might be counterproductive until the power sector is sufficiently decarbonised. In

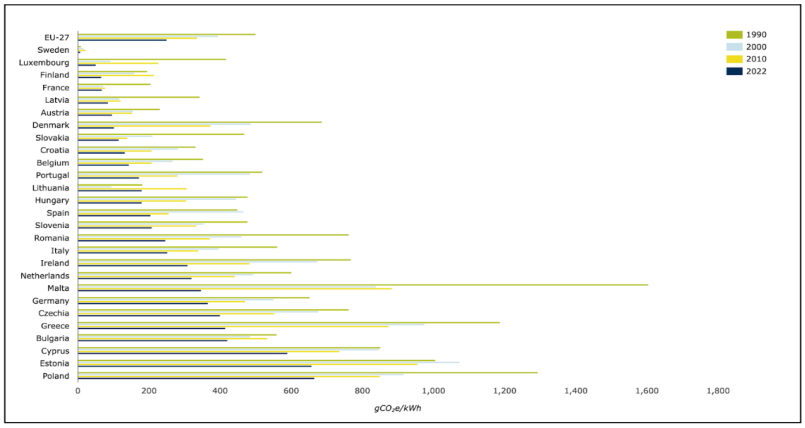
countries like Sweden, the “electrification challenge” is essentially driven by the electrification of usages, because Swedish electricity is already very low-emitting. In comparison,

Poland, which is still relying on coal, must massively change its electricity sources and electrify usages in a few decades. That partly explains why Poland also relies on technologies other than electricity to support the transition of their mobility sector.

EV adoption still faces several barriers:
• Price: EV prices are decreasing but there is still a gap of affordability at the entry level. The lack of EV presence on the secondary market is a strong barrier to their spread in the developing world.

• Diversity, though the EV market is catching up with the ICEV one in terms of diversity of design and price ranges. For the e-motorcycles, each company has a unique model.

• Charging and batteries: Concerns about limited driving range, reliability, and battery lifespan continue to deter potential buyers. A lack of awareness and education about EV capabilities can perpetuate these anxieties. The density and reliability of charging stations outside urban areas remains a concern. Time constraints associated with charging also play a role and might become a bigger issue as the EV stock grows. Furthermore, battery size limitations confine full electrification to small passenger cars. Electric city buses and delivery vans are feasible but expensive. Significant changes in electricity generation and distribution are needed to support widespread BEV



Carbon intensity of the electricity mix in the EU (gCO2e/kWh), European Environment Agency. (2023, October 24). Greenhouse gas emission intensity of electricity generation in Europe.

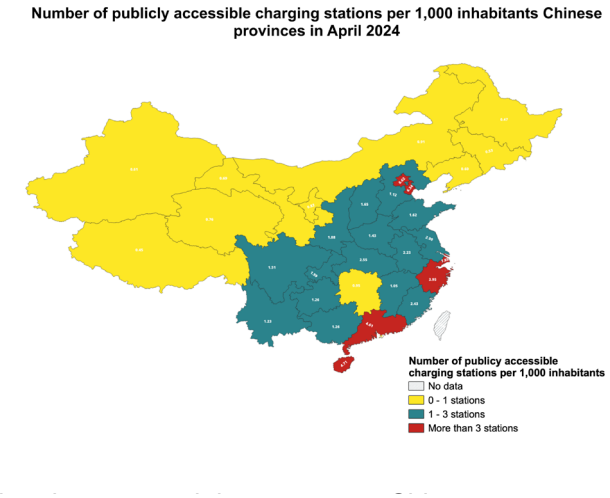
adoption. For instance, converting all U.S. passenger cars to electricity would require a 25% increase in electricity generation (Smil, 2010).

Electric bus (La Rochelle, France

• Governance: Limited government funding and capacity in developing countries can hinder the development of the EV sector, the charging infrastructure and other support systems.

• Maintenance: The perceived complexity of EV technology raises concerns about repair costs and availability of qualified technicians, especially in developing countries with limited experience in servicing EVs. The limited presence of EVs in Rwanda translates to a lack of qualified technicians and readily available spare parts and raises concerns about repair capacity.

• Geography: The informal urban layout of cities in the developing world can be unfavorable to the possession and circulation of personal vehicles. The size of a country is a challenge when it comes to developing a national charging infrastructure, even for a country



Unequal distribution of publicly accessible charging stations across Chinese provinces. Source: (China Electric Vehicle Infrastructure Promotion Alliance, 2024)

THE LACK OF RELEVANT INDICATORS

If the transport sector accounts for such a large share of GHG emissions, it is because the functioning of our society depends on people's ability to move. Consequently, the crises we face today are also mobility problems. Addressing these crises hinges on how well we adapt our transportation systems. Yet, our ability to analyze today's mobility in comprehensive ways is limited. The advantages, downsides and effects of transport modes often hide behind the complexity of data.

Most importantly, there is a lack of meaningful indicators that enable cross-modal comparison. Students from the Futura mobility project discovered the need to create indicators designed to play a pivotal role in informing policy decisions towards the promotion of sustainable transportation. The goal was to provide information that would help individuals choose between different modes of transportation for a specific journey. Therefore, instead of measuring the effect of a given mode on biodiversity per territory or region for instance, the indicators should rather produce values that break down the effect to the level of each passenger for each journey. Indicators should be easy to understand and to read in order to reach a broad audience and meet their expected outcomes.

To be relevant to both passengers and decision-makers, the indicators resonate with contemporary mobility issues. In essence, these indicators represent an intelligent choice addressing and engaging with our time.

Three aspects are fundamental in this choice:
• To be relevant to the general discourse, the indicators must be informed by and address the megatrends affecting mobility today and tomorrow.
• To be relevant to decision-makers, the indicators need to capture the current mobility challenges faced by mobility in Europe (see table).
• To be relevant to passengers, the indicators need to relate to their important needs.

The answer to these questions forms the map in which the indicators are developed and situate: which new mobility indicators do decision-makers, entrepreneurs, and consumers miss to jointly shape the best passenger transport mix in the future?

	Aging	New green culture	Rising health concerns	Urbanization	Digitalization
Accessibility	1.1		1.2	1.3	1.4
Climate change mitigation		2.1		2.2	2.3
Climate change adaptation			3.1	3.2	
Air pollution			4.1	4.2	4.3
Biodiversity		5.1	5.2	5.3	

A challenge is the will to improve a situation that is deemed unacceptable, requiring collective action and strategic planning. It is therefore associated with collective value judgments and might change over time. Here are a few examples of links between megatrends and challenges identified by students:

1.1 Making mobility offerings more accessible – especially public transport – is a core way of dealing with decreasing mobility among elderly.
2.2 Encouraging a modal shift away from the car has a high reduction potential and is most likely in urban, particularly suburban areas.
3.1 With climate change, cities will become increasingly difficult to live in: excessive heat and higher risk of infrastructure failure in mobility poses serious threats to health.
4.1 Excessive levels of air pollution pose significant health risks, especially given how concentrated it can be in some transport modes (such as the metros): measures to improve air quality within transportation are crucial.
4.2 Reducing car traffic is a key measure to curb both emissions and air pollution.
5.1 Mobility choices that are sustainable in terms of climate change usually also weigh less on biodiversity.

CHALLENGES IN TERMS OF GOVERNANCE, URBAN PLANNING AND FINANCE

Transdev aims to foster the green transition from the transport sector but faces a major issue: local authorities are difficult to convince for investing in more costly green transportation systems.

Therefore, students aimed at developing a support tool for local governments, starting by identifying challenges faced by the local authorities:

1. Governance

The environmental crisis impacts all societal domains, making current governance frameworks inadequate for managing the transition. There is a pressing need to rethink politics at all scales to create sustainable and resilient environments, particularly in the realm of public transportation.

• The progressive consideration for transport as a key solution at the international level. Initially secondary in COP debates, transport gained prominence post-Paris Agreement (2015), which set ambitious climate targets.

• The push for electrification at the European level. The EU has been proactive in pushing for sustainable urban mobility through policies like the Sustainable Urban Mobility Plans (SUMPs) and the Green Deal. A central measure includes ceasing gas vehicle production by 2035, focusing on electrification. However, this strategy, while environmentally focused, appears to prioritize support for industry over social and environmental justice. The revised TEN-T regulation (2024) mandates significant emission cuts and requires urban nodes to adopt SUMPs by 2027, directly addressing local governments for the first time.

• Navigating the multiple layers of decision making from a local perspective. Urban areas are economic and cultural hubs with significant political and financial influence. Most of the global population will live in cities by the end of the century which comfort cities' key position in pursuing sustainable development. Moreover, local authorities are closer to the daily lives of their residents, allowing them to implement and adjust policies more responsive than higher levels of government. Public transportation systems are also essential for adaptation and social equity, providing affordable and accessible mobility options for all residents. Finally, local authorities can pioneer innovative solutions and set trends that other municipalities and regions may follow.

But local governance faces two main challenges: responsibility within a multilayered framework and capacity to implement effective solutions. In Italy, for instance, unregulated urban sprawl has led to high private mobility reliance due to poor public services. Spain's post-dictatorship exemplifies how decentralization created fragmented local governments with varying objectives, complicating coordinated efforts.

When coordinated, local authorities have the agency to foster the transition from the urban scale in a multi-governance framework. They can plan efficient public transit systems that can stimulate economic growth by improving access to jobs, reducing traffic congestion, and enhancing the overall attractiveness of the city.

Public transportation stands out as a backbone in urban environmental policies. The collaborative efforts across urban, regional, national, and international levels of governance ensure that public transportation systems not only meet local needs but also contribute to broader environmental and societal goals.

Credits: Transdev.

2. Urban planning

Urban strategic planning is essential for creating sustainable cities and making the distance between global and local visions smaller, thanks to the mediation of the nation-state. Strategic planning represents a management tool that determines the direction in which an organisation is moving, and how it will get there.

Even though current emission reduction commitments are insufficient to meet the targets, some EU countries have already set ambitious targets for increasing the share of public transports and public investments. Yet, urban planning is often considered separately from transportation networks, leading to an increased risk of “lock-in” (i.e. European city’s infrastructures are already built and adapting them to new challenges increases the costs). This underlines the importance of integrating transport systems to urban planning, to avoid inefficient investments and improve services. Indeed, mobility patterns are influenced by the existing urban structure. The way infrastructures and settlements evolved over time largely impacts the current share of transport emissions. Emissions are a function of distance and public transport is easier to plan in dense areas.

Moreover, public transport planning faces the decrease in land availability. Most of the still-growing cities face the issue of “sprawling”, inducing an overconsumption of land by large cities. The extension of mass transit networks is often confronted with the lack of available land: apart from road infrastructure, public authorities generally do not have the land needed to develop subway, tramway, or light rail transit (LRT) schemes.

Credits: Transdev.

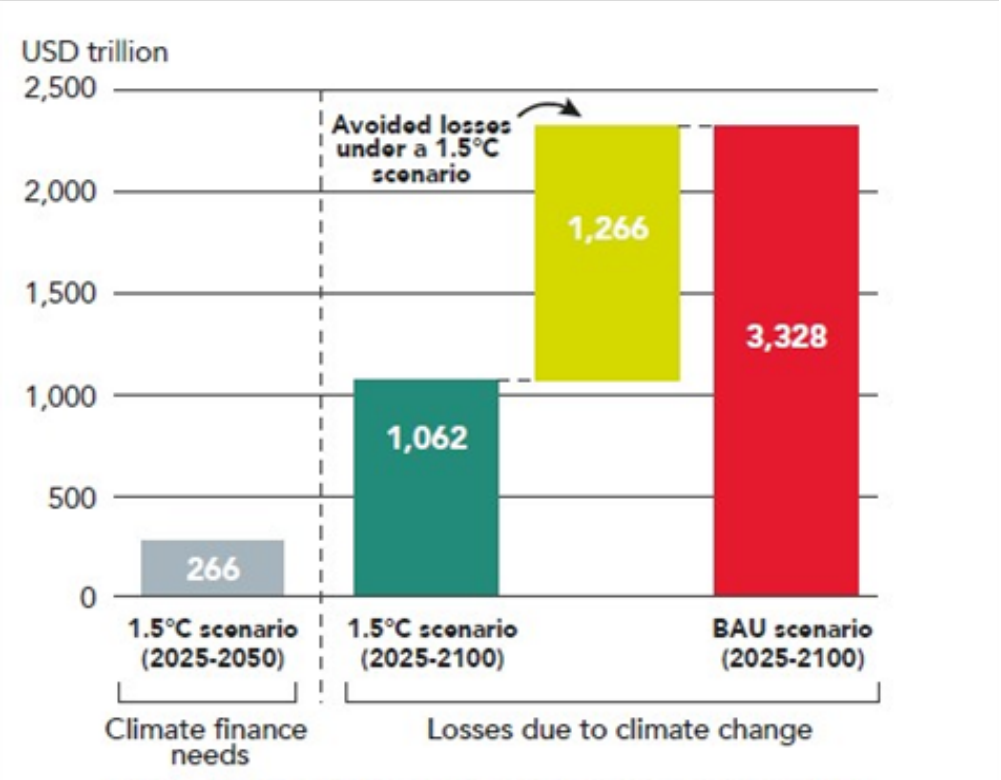
3. Finance

Moving to a greener transportation system is extremely costly for local authorities as it requires additional investments for new technologies and infrastructure. In the European Union, meeting climate objectives from 2021 to 2030 is expected to necessitate an annual investment increase of €130 billion for vehicles and alternative fuel infrastructure. Additionally, approximately €100 billion per year will be needed for additional investment in green transport infrastructure.

Climate finance has seen significant growth in recent years, but the current level of investment is still far below the required €8 trillion annually by 2021/2022, escalating to approximately $11 trillion by 2030, to meet the 1.5°C targets set by the 2015 Paris Agreement. As of 2022, about 90% of global climate investments are focused on mitigation (maintaining individual flows but electrified) instead of fostering adaptation for meaningful change (massifying mobility flows). This does not provide the adequate incentives to change our existing urban models into more sustainable ones. This focus is driven by the immediate need to reduce emissions and the economic viability of mitigation efforts. Over half of mitigation investments are managed by the private sector, while public actors fund 97% of adaptation efforts, which are currently less profitable.

The limited investment in public transportation is partly due to its low profitability and the inability of public actors to fund initial investments. Local and regional authorities often spend more than they collect in taxes,

relying heavily on external financial support. Local authorities' abilities to finance infrastructure projects vary greatly depending on national legal and political contexts. This disparity affects the development of local public transportation networks, with federal countries generally having more extensive networks compared to centralized countries with fewer financial capacities devolved to subnational bodies. The Cities Climate Finance Leadership Alliance notes that only 4% of public development bank funds are earmarked for local government projects, worsening the unaffordability of new public transportation schemes for local authorities. ■



Cumulative climate finance needs vs. losses under 1.5°c and "business as usual" scenarios. Source: Climate policy Initiative (2023)

Decarbonisation of mobility is crucial to limit greenhouse gas emissions and air pollution. A raising awareness of the health hazards linked to the latter allows for the emergence of changing behaviors and national strategies for climate mitigation, as well as the development of alternative means of transportation, such as electric vehicles.

However, challenges remain in terms of indicators to help commuters make their decisions, electrification, governance, urban planning and finance.

To tackle the remaining obstacles to decarbonisation, students have put forward several suggestions, that will be detailed in a second part, after a presentation of a report on the high-speed rail sector.

THE SPECIFIC EXAMPLE OF THE **HIGH-SPEED RAIL** (HSR) SECTOR

High-speed rail is gaining importance across Europe. In the coming decades, European HSR networks are projected to expand significantly to meet rapidly rising demand. Indeed, they will play a key role in enabling a sustainable urban future, and many European countries view HSR as a promising and environmentally friendly alternative to short-haul flights. However, the current infrastructure cannot support projected increases in ridership and demand. In the coming years, increased funding and the development of new HSR lines will thus be crucial – as will the renovation of existing stations and the creation of new ones.

As a multidisciplinary architecture and consulting firm, AREP is a leading expert in HSR station design and retrofitting. Given the complexity of implementing such infrastructure projects across varying socioeconomic and geopolitical contexts, the goal of the Capstone was to provide AREP with a comprehensive tool for analyzing the challenges and opportunities of upcoming HSR projects across Europe that align with the firm's commitment to advancing sustainable mobility and a post-carbon future.

Specifically, AREP mandated the creation of a an "Atlas of European Stations", studying upcoming station renovation and construction projects pertaining to high-speed rail across Europe. 15 stations located across seven European countries were selected by students for further study. They conducted an in-depth analysis of the station context, the level of environmental engagement, solicitation processes and funding mechanisms. Students concluded that renovations of the following HSR stations were the most viable potential opportunities for AREP to consider: Frankfurt and Berlin Südkreuz (Germany), Jastrzębie Zdrój (Poland), Linköping (Sweden), Vilnius (Lithuania) and Hamar (Norway).

This Capstone confirms that the future of HSR remains a high priority for the European Union and its members. National and local governments are coordinating innovative policies, projects, and financing mechanisms to expand the European HSR network and increase its capacity. Here are a few examples of the most viable HSR stations to consider:

Station: Berlin Südkreuz

Berlin Südkreuz is one of the city's smaller high speed train stations. The station is connected to major hubs of the German HSR network, including Berlin Hauptbahnhof, Munich, Frankfurt, and Hamburg. It is also situated within the German north–south axis, connecting Berlin to major cities such as Rostock, Dresde, and Prague. Approximately 180,000 passengers travel through Berlin Südkreuz each day to reach long distance trains, regional trains, S-Bahn and bus lines. Key stakeholders involved with the stations, operations and corresponding HSR lines include Deutsche Bahn and Flixtrain.

HSR platform at Berlin Sudkreuz (photo by Rachel Kovinsky)

The larger district of Schonberg-Tempelhof, where Berlin Sudkreuz station is located, is currently undergoing redevelopment to meet climate adaptation objectives and improve the flow of all modes of transportation in the area. Given the lack of an exact timeline and funding mechanism for future renovations, this station does not present an immediate or significant opportunity for AREP – but given its many connections and placement near the district of Tempelhof, which is slated for overall future development, this station warrants further monitoring and research. Notably, there may be a role for AREP to play in relation to the station's mobility hub and the larger work of Smart City | DB.

Station: Vilnius

Vilnius is the second most populous city of all the Baltic states. The city's main train station, Vilnius Central Railway Station, is thus an important transportation hub. Vilnius will serve as an essential point of connection within the context of Rail Baltica (RB), a major infrastructure project aimed at developing 870

kilometers worth of high-speed railways to integrate the Baltic States into the European rail network. The project aims to connect the capitals of the three Baltic states to Warsaw and the wider rail network of Western Europe by 2030.

Map of Rail Baltica network (source: RB)

France is viewed as a key partner in the RB project, particularly considering the country's presence within the frameworks of the European Union and NATO. Moving forward, French companies could play a pivotal role in station renovations and railway development across the RB network.

Vilnius Central Railway Station will be adapted to meet the needs of passengers and make Vilnius a local hub and source of connection for pedestrians, cyclists and railway passengers alike. An architectural competition for the reconstruction of the station was launched in 2021, but the design phase will last until roughly 2026. After that point, a public procurement for the implementation of the contract works will formally be announced – presenting an opportunity for potential collaboration and partnership. The station may also serve as a case study and precedent to better understand the priorities, selection criteria and potential challenges of future architectural competitions within the overall Rail Baltica network.

Aerial shot of Vilnius Central Station (photo by Augustas Didžgalvis)

Station / Local Mobility Hub: Jastrzębie Zdrój

Centralny Port Komunikacyjny (CPK) is Poland's new HSR system that will be centrally located within the Three Seas Region, connecting the Baltic, Black, and Adriatic areas, with a dual emphasis on air and rail travel. The new development and line renovation will radiate from the new airport located between Warsaw and Łódź. It will be the future multimodal heart of the Central and Eastern European transport system as elaborated by the EU's Trans-European Transport Network (TEN-T) development plan.

CPK is researching a Local Mobility Hub design plan to locate various means of transport in one place, giving travelers and residents a flexible approach to shaping transport behavior. Jastrzębie- Zdroj is a consequential transfer hub and will enable a convenient change of means of transport. The presence of railway services at a transfer hub increases its importance in the region and the range of impact of the hub due to its connections with other elements of the transport system. The inclusion of Jastrzębie-Zdroj, the largest Polish city (90,000 inhabitants) without railway connections, in CPK and the creation of this specific corridor element of the TEN-T will shorten the journey, among others, from Rybnik, Żory and Wodzisław Śląski to Katowice, as well as use of the existing corridor through the center of Mikołow and the A1 motorway. It will be the city to benefit most from the planned launch of a high-speed railway in the entire Silesian Voivodeship (with a planned operating speed of up to 250 km/h).

The implementation of this project is intended to adapt the railway infrastructure to the current needs of carriers and contractors and the forecast direction of development. Additionally, it aims to increase the availability of rail transport, improve travel comfort and passenger service, as well as ensure the safety of rail traffic and transported cargo. An important aspect is also to enable nondiscriminatory access to the Polish railway infrastructure for operators from other countries. ■

Visualization of the modern Jastrzębie-Zdrój Centrum transfer hub (Photo: CPK)

Urban School students during the 2023 Lab Day, Didier Pazery.

Part 2

TEACHINGS AND RECOMMENDATIONS

To tackle the remaining challenges to decarbonisation, students have put forward several suggestions, including urban transition policies, the “avoid, shift, improve” strategy, the implementation of new indicators as well as incentives for individuals.

INVESTING IN **PUBLIC TRANSPORTATION**

Students have developed a systemic vision of transport highlighting the financial support mechanisms that are essential to its development. Their recommendations to achieve the decarbonisation of the transport sector are the following:

1 – Achieving a modal shift requires the recognition of transportation as a priority topic in the urban political agenda and coordinated action at all scales: urban actors (governments, businesses, citizens and academic institutions) have a better understanding of socio-economic disparities and can implement and adjust policies more responsively.

2 - Planning urban transportation systems requires an integrated approach, considering the location of jobs and the density of population, to avoid maladaptation and inefficient networks.

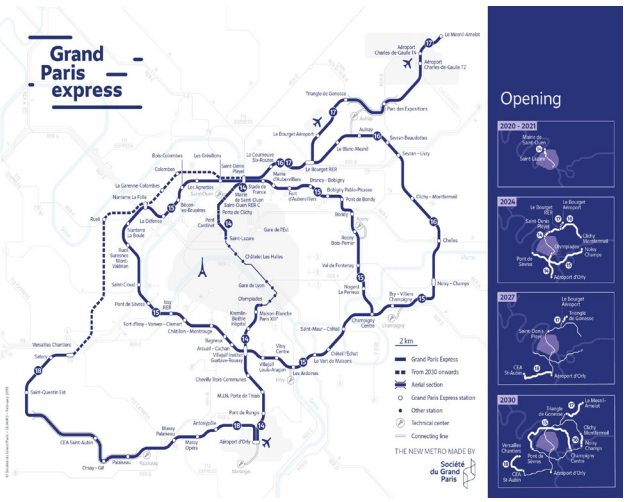
3 - The decarbonisation of the transport sector requires more investment at the global scale, and a better government funding basis at the local scale. Existing funds tackle either individual mobility, especially in terms of personal electric vehicles acquisition, or heavy infrastructure development for long distance travels, such as railways, missing day-to-day urban mobility as a key investment area that requires strong support from public and private financing sources. Given the public service obligations that weight on its economic balance, the industry requires more support than any other.

Transit-Oriented Development (see box) & Multimodal Metropolitan Public Transport are the two most efficient investment areas in the field of urban development to avoid climate change; however, these require integrated urbanism and transit planning at the right level of governance. Current funds do not enhance the emergence of such institutional set-ups and still give too much weight to national entities in terms of fund distribution and allocation decision-making.

Public Transit generates value; however, this does not appear today in companies' balance sheets. Financial institutions need to think holistically about an economic activity's impacts if they want to optimize investment where it has the most positive effects for communities.

Finally, having individual vehicles as the major referential of mobility in decision-makers minds does not enable accurate representations of what will build a truly sustainable future for all: efficiency and good use of resources through shared means is still today, by far, the most adequate answer to meet our generation and future generations' needs. ■

Transit-oriented developments (TOD) are long-term urban strategies mixing land use and transport planning to reduce emissions and enhance the quality of life, by pushing for denser housing near public transport infrastructure, triggering a virtuous circle of modal shift and density. Nowadays, density consistently comes after public transportation, and not the other way around. Curitiba (Brazil) is one of the historical examples of TOD, that paved the way for other cities such as Hamburg (Germany). Many North American cities such as Los Angeles, Vancouver and Toronto have also implemented or proposed plans to purposefully densify cities along public transport corridors (Zhu et. al 2021). TOD remains limited in European cities as most of the urban structures are stabilized.



Map of the Grand Paris Express, Europe's largest transit expansion project, which illustrates a city structuring itself around transport infrastructure (Credit: Société du Grand Paris)

THE "ASI" STRATEGY: **AVOID, SHIFT, IMPROVE**

"With the intention of decarbonising, we can give new meaning to local public transport [...]. Offering a service that works, giving it social prestige, convincing users that polluting less is a good thing. It is not about banning but about making those who engage in certain practices feel ashamed." Luciano D'Amico, former TUA president (Società Unica Abruzzese di Trasporto – The Abruzzo Transport Company)

This chapter aims to give a state of the art of research and political opportunities to reduce infra-urban emissions. Students based their reasoning on the avoid-shift-improve (ASI) framework (IPCC, 2022), a model that seeks to change behaviors by improving efficiency, and that can be applied to the transport sector to reduce emissions. Therefore, a reduction of activity per kilometer is needed (avoid), as well as a shift to low-carbon transport modes (shift) and an improvement of vehicles efficiency and fueling (improve).

AVOID

The first lever of action to reduce transport emissions is to reduce unnecessary motorized trips. Indeed, the limitation of mobility, whether it is absolute or just car-related, indirectly pushes for the development of public transport, among other forms of mobility. The promotion of alternative services coupled with effective urban planning are necessary tools to achieve efficient transportation networks.

The development of infrastructure and settlement highly impacts the share of transport emissions and the use of public transport. In most cases, the wide difference between urban shapes results from market incentives, favoring high-density urban centers and low-density suburbs. In Europe, the biggest challenge for public transport planners is to link the city to the low-density living area, as suburban mobility represents 1/3 of the emissions at the urban scale[16] and address the territorial inequalities of access to efficient mobility services.

In that case, the MEAPS economic model helped a better understanding of the challenges at stake: emissions are a function of distance and local authorities should privilege integrated urban policies to develop public transport and population density, taking into account the distance to jobs.

Modèle Ergodique à Absorption et Saturation" [MEAPS model] (Parodi and Timbeau, 2023).

MEAPS is an economic model developed to analyze patterns of mobility, with a focus on work mobility which represents 40% of the overall daily travels. Individuals mainly choose where to live in relation to their workplace, but there are some constraints as the price of living close by can be expensive. The modelisation tool allows to grasp all the mobility levers for the transition to greener networks: modal shift, reduction of the overall traveled kilometers, etc. MEAPS aims to do a cost-benefit analysis by dealing with the polycentric urban structure and encompassing all these factors. The model is designed to be a replicable tool, using public data, for dialogue with the local population and authorities. Until now, it has been only applied to La Rochelle but is in the process of scaling up to Marseille, a city forty times bigger.

The model was revealed to be impactful. Researchers worked with municipal officers. In 2019, the municipality was working on a 30% carbon emission reduction, part of the "La Rochelle Zero Carbone" by 2030 compared to 2019 levels. MEAPS in that case became a political tool to meet environmental targets. The model concluded that for daily mobility on an annual basis, the inhabitants emit on average 1.56t CO2-eq. Nevertheless, the shorter the distance to the city center, the less individuals emit. Therefore, the main challenge for public authorities is the steady-flow incoming population. The long-term urban planning strategy was to keep the same density across the territory, but it increased reliance on private mobility and urban sprawl. MEAPS reintroduced trust between urban and rural authorities and encouraged a long-term vision taking into account population and job density for transport planning.

[16] Coldefy and Le Gendre, 2020

SHIFT

The benefits of modal shift: the second lever of action to reduce transport emissions is to put more people into public transportation systems and out of cars. Other than emissions reduction and the reduction of air pollution, this so-called modal shift is also the most cost-effective way to reduce individual transportation emissions as it is cheaper for both supply (governments and operators) and demand (users) than EVs, and it reduces infrastructure costs in the long run for municipalities related to road maintenance and private parking. It also reduces socio-economic inequalities and is cheaper for emission reduction than the complete redesigning of cities. Economically, it can also have the advantage of decoupling emissions from growth, and finally, modal shift triggers changes in urban planning, with for example transit-oriented development (see above).

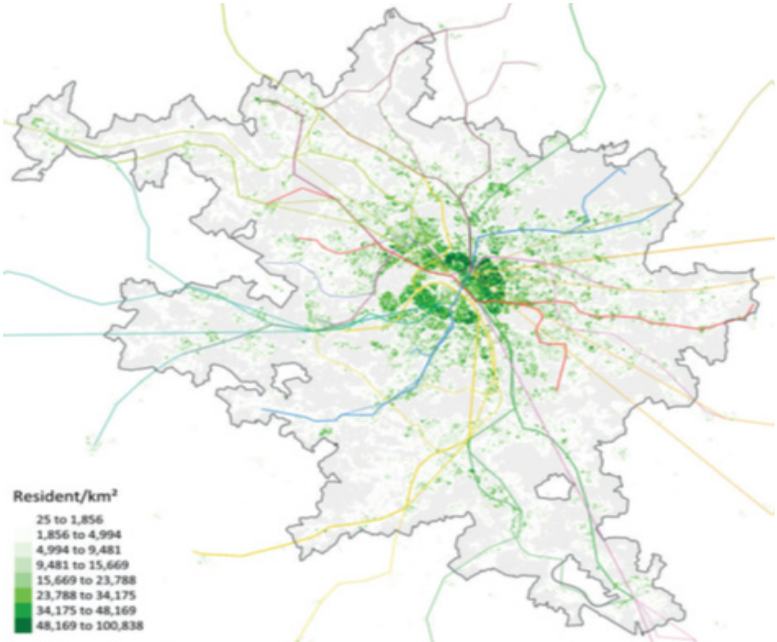
Overall, in dense urban environments, we can modally shift to two types of low-carbon forms of mobility: active mobility and public transport. Active mobility, while an important part of urban carbon neutrality objectives, is harder to shift to, because of the makeup of cities today - they are too large for cyclists and pedestrians to regularly commute to work this way. To achieve a modal shift towards active mobility, cities need to be transformed, a long-term and gargantuan task. Public transportation, on the other hand, is a much more feasible and short-term alternative. Another benefit of public transportation specifically compared to active mobility is that since it is easier to foment a modal shift towards it, it is more likely to indirectly lead to the transformation of cities. For example, in the Greater Paris metropolitan area, denser housing patterns are found around public transport stations.

In Europe, most Sustainable Urban Mobility Plans (SUMPs) as well as other urban development plans include modal shift. This insistence at the local level partly originates from a lack of it at the European level, which recently has seemed to prioritize electrification over modal shift, even though the former is far less effective in reducing emissions than the latter. But this local approach has allowed for policy innovation to flourish as cities attempt to figure out how specifically they could move people from cars to public transit.

International research (Dunedin City Council, 2023 : 36) shows that the main factor that plays into everyone's choice of transport is convenience. Several factors play into what "convenience" means, but there are two obvious main ones: cost and time. Overall, people want to commute in the least possible time for the cheapest possible price. There are two ways to push for modal shift, convenience and inconvenience for users:

1 - Inconvenience, or the stick.

Inconvenience is every way in which a municipality can make car use less convenient and attractive for commuters. To give out a few examples, low-emission zones (LEZs), parking restrictions or lower speed limits all serve to annoy car-users and might convince them in certain circumstances to switch to public transportation or soft mobility.
• The London LEZ has been a good example of a success story for modal shift, as the lack of alternatives for users pushed the city to invest in new bus lines to accommodate the increased demand for transport alternatives that EVs could not realistically fulfill due to their cost (Litman, 2005).
• Paris limited the speed limit on their Boulevard Périphérique, partly to make it safer, but also simply to inconvenience users enough so that they might take public transport. Paris has focused on tackling the time constraint rather than the cost constraint, mostly due to social justice reasons.
• Increasing bike lanes and introducing dedicated bus lanes were implemented to improve accessibility, but also to discourage car use.



Population density and public transport (metro) services | Sources: INSEE, Données carroyées (carreau 200m), population 2015 fidéli; IRIS (Aire Urbaine); IDFM, GTFS open source, 2020

2 - Convenience, or the carrot.

Convenience is the other side of the coin, aiming at making public transportation more attractive for commuters. An accumulation of small changes can be enough to tip the balance in the eyes of users. Multimodal nodes can be useful, the typical example being putting up bike infrastructure right around public transport stations and stops, but it also means making transfers from one type of public transport to another as convenient as possible, with bus and tram stops in front of integrated subway/train stations.

Integrated fares are also necessary and big exceptions remain today: in Paris, for example, a user without a pass must pay for two tickets if they use both the subway and the bus, even if they are part of a single journey. Instead of per-trip fare, cities could adopt a more convenient timed fare like the ones in Australian cities, where a user pays for a two-hour unlimited access to all modes of public transport, making modal transfers easier for users. Per-trip fares represent a real loss of potential earnings for operators by driving up average costs. Other important aspects of convenience that are sometimes overlooked are safety, as well as image and marketing. Correct upkeep of buses, trams, trains, stops, and stations can transform the image of a city and convince more people to switch to public mobility.

Finally, some policies aim to do both at the same time, for example dedicated bus lanes, also known as bus rapid transit (BRT), which both makes driving a car harder, and driving a bus easier. BRT has been very popular around the world, by lowering the travel time of buses and thus increasing their convenience, by having them avoid congestion.

Once again, it is important to keep in mind that this shift is easier to implement in dense urban areas.

IMPROVE

To decrease the environmental impact of transportation, improving the efficiency of existing vehicles and technologies is essential alongside promoting more sustainable mobility habits. The global transport sector heavily relies on internal combustion engines (ICEs) and petroleum-based fuels. This reliance stems from the high energy density, ease of transport and storage, and the extensive global infrastructure supporting liquid fuels. Approximately 95% of transport energy comes from petroleum-derived liquid fuels, and about 60% of all oil production is used to make transport fuels. The demand for transport fuels is immense, with the world requiring over 4.8 billion liters of diesel and gasoline daily. This demand is expected to rise, especially in non-OECD countries such as China and India, where vehicle numbers are increasing.

Although alternatives like biofuels, compressed natural gas (CNG), and liquefied petroleum gas (LPG) exist, they only cover about 5% of transport energy, with electricity and hydrogen having negligible shares. Projections suggest that by 2040, combustion engines will still supply around 90% of transport energy.

Credits: Transdev.

Electrification, particularly through lithium-ion batteries, offers significant potential outcomes that are not without challenges (see I.3.) Hydrogen fuel cell vehicles (FCVs) present another promising technology due to their efficiency and longer range. However, the high cost of vehicles and the development of hydrogen infrastructure are significant barriers. Hydrogen production is energy-intensive, and if the production process is not CO2-free, the overall emissions can exceed those of conventional vehicles. Significant investments, estimated in the hundreds of billions of dollars, are required for hydrogen supply infrastructure, including pipelines and refueling stations.

Overall, a combination of technological advancements in vehicle efficiency, electrification, and hydrogen technology, supported by substantial investments in infrastructure and a shift to renewable energy sources, is crucial for reducing the environmental impact of the transport sector.

Avoid-Shift-Improve Framework | Source: SLOCAT (UNFCCC)

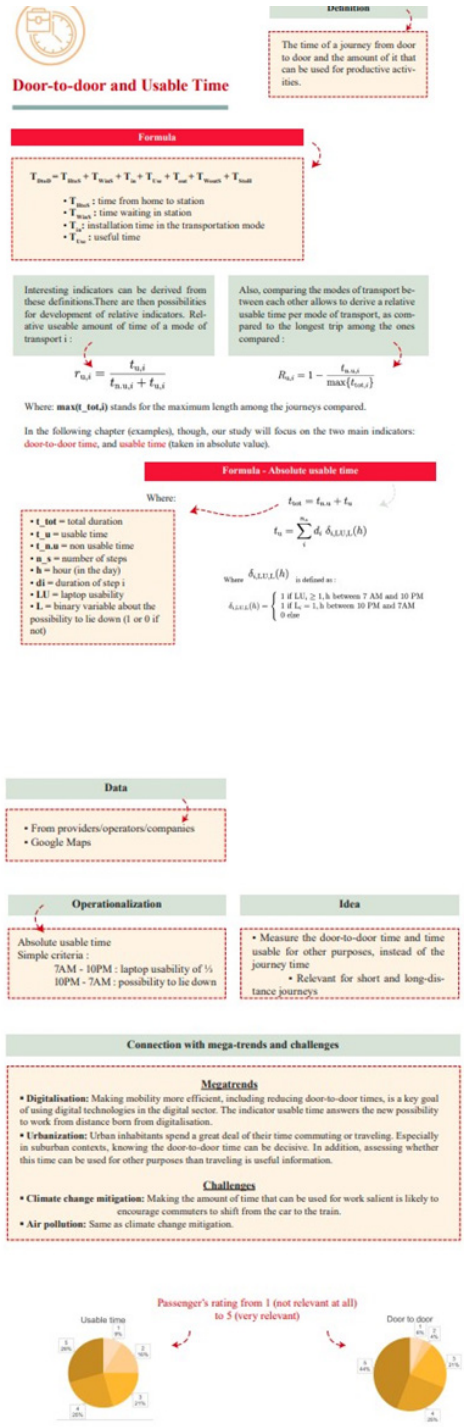
INTRODUCING **RELEVANT INDICATORS** FOR COMMUTERS

An indicator is a way of combining or recalculating existing data into a set of categories or a figure representing an aspect of the world in a meaningful way. Indicators are necessary to inform commuters, who are opportunistic actors, and help them make the best decisions.

Students developed eight indicators to help integrate trends and challenges into the problem: punctuality, comfort, elderly use, heating potential, door-to-door time, usable time, laptop usability and land used. They then proposed concrete ways of calculating their values and examples of how these indicators can be applied and tested them in real-life situations in four European countries with different specificities (in Amsterdam, Budapest, Bratislava and Castellon de la Plana). They also imagined several representative individuals of the European population, "persona" with different life, family and socio-economic situations, to test these indicators in the context of different journeys, both every day and exceptional.

Here are examples of indicators that decarbonised mobility modes should consider to be favored by passengers and thus encourage a modal shift:

• **Door-to-door and Usable Time:** the time of a journey from door to door and the amount of it that can be used for productive activities. This indicator is connected to the challenges of climate change mitigation and air pollution, as it underlines the amount of time that can be used for work, which is likely to encourage commuters to shift from the car to the train.



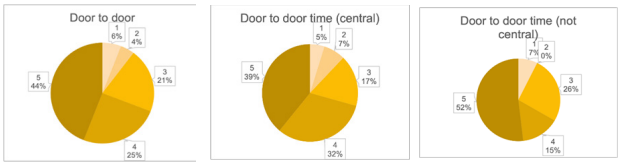
Students followed a precise method to determine relevant indicators.

• **Heating potential:** the likelihood with which passengers may experience thermal discomfort during a given journey. This indicator is connected to the megatrend of the "new green culture", as it answers an increased awareness of climate-related risks (among which is heatwave) as well as the megatrend of aging (the heat levels in mobility modes can impact their usage by old people, as they are among the people most vulnerable to heat) and rising health concerns (excessive heat can threaten the health of passengers, hence making it relevant to measure.) It also tackles several challenges including: o Climate change mitigation: Showing how mobility modes are heating up is likely to spread awareness. o Climate change adaptation: The indicator identifies climate risks and is useful to guide adaptation action as it relates directly to the tolerable amount of heat in mobility.

• **Laptop usability:** extent to which an individual can effectively use its laptop to work while in transport. This indicator answers the challenges of climate change mitigation and air pollution, as being able to work on the laptop is a key argument to take the train as opposed to the car.

Students conducted 69 street interviews. They introduced the topic of indicators for transport, which are usually focused on money and total time between stations, saying that they were working on new indicators to get a broader picture of passenger choice. They then presented a selection of indicators and asked passengers to range the relevance of a list of indicators that could compare different types of transport from 1 (not relevant) to 5 (very relevant) and explain why.

They observed significant differences between groups. People in central urban areas tended to respond differently than the rest regarding various indicators. In not central areas, door-to-door time was rated with the maximum relevance substantially more often. This is likely due to the more complex trajectories non-central dwellers must take. In line with their expectations, usable time was valued substantially more often in not central areas. The higher valuation is likely due to the longer trajectories that non-central dwellers must take. In central areas, by contrast, the trajectories tend to be shorter and not suited for work just because of their length and people tend to walk and cycle more.

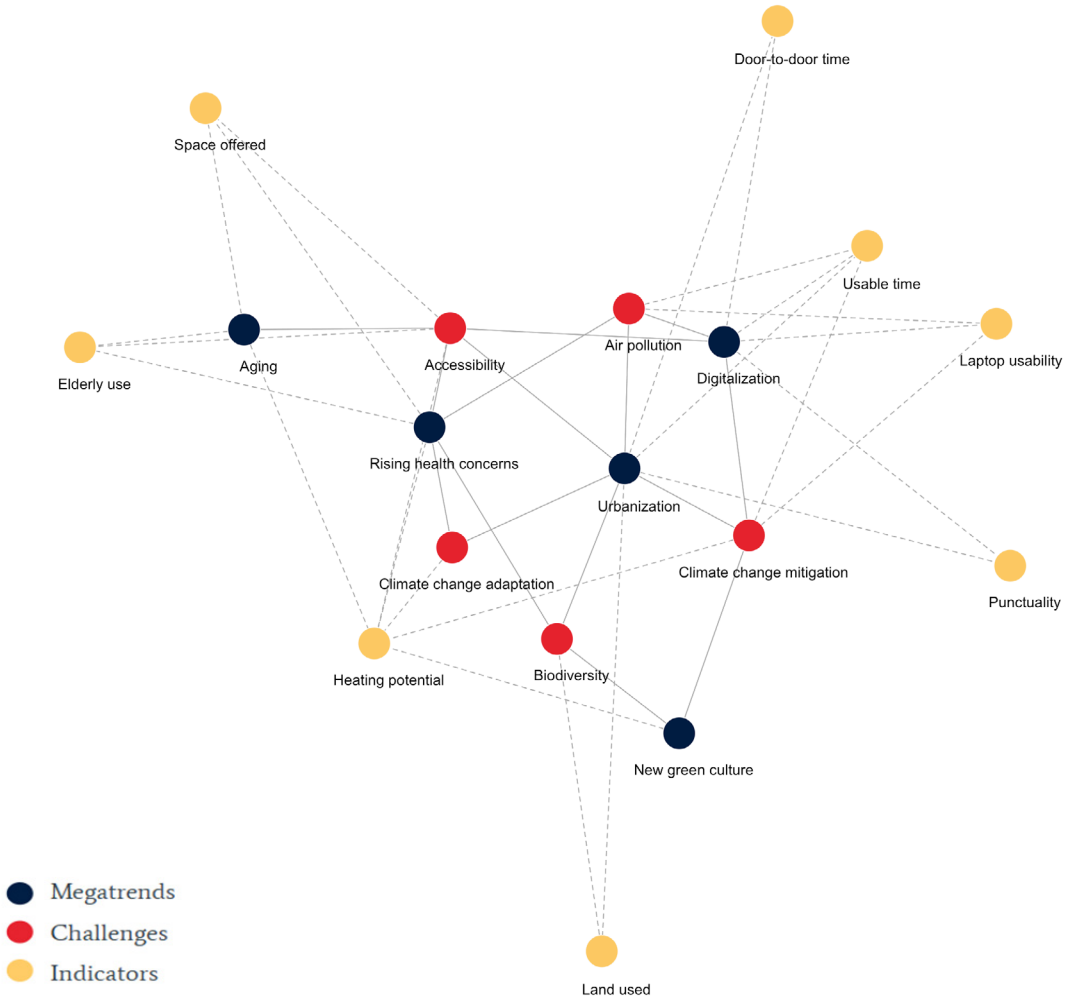


Case study: calculation of the indicators on a real journey from Amsterdam to Castellon de la Plana, in Spain.

You have a grandmother that lives there, and you would like to spend at least two days with her. Since your grandmother finds it increasingly difficult to move, you don't want to burden her with the way to Amsterdam, for you don't have a car and you know trains and metro in Amsterdam are not very accessible for old people. Hence, you would like to leave on Wednesday evening or Thursday morning to Castellon de la Plana and be back on Sunday evening before your work starts again. The following options are available: plane, train, bus and car. You want to compare each, knowing that you would like to (1) maximize the opportunity to work on the way, (2) have the least time traveling, (3) minimize land use, (4) have a comfortable trip that is not late (5). You are not interested in the price, as your company generously offers to pay for your trip because you have an interview there on Friday. In general, your company tries to limit the usage of planes, as part of the new green image that it tries to build. You are asked to choose between the four options.

Limitations of indicators and next steps. Although all indicators proved relevant in some ways and examples confirmed the validity of the proposed approaches, this work was limited by the amount of data openly available. Next steps should focus on the generalizability of the indicators produced. Identifying, accessing and harmonizing accurate databases in Europe will be an important work on the way forward. A wide foundation of usable data would not only allow to finetune the indicators but potentially broaden the scope of the study to rural areas and medium- and long-distance journeys. Similarly, the different modes could be looked at more exhaustively, taking walking, cycling, and the different types of public transport more precisely into account.

This work has focused on proposing indicators that could be relevant for passengers and decision-makers, to enrich current debates revolving around European mobility, from their perspective. Assessing empirically whether these indicators would in effect change the behavior of passengers, and whether they would supplement the current main indicators, was beyond the scope of the study. Further research could address this gap. ■



IMPLEMENTING **EFFECTIVE INCENTIVES:** THE EXAMPLE OF EVS AND POLICY TRANSFERABILITY

THE EFFECTIVENESS OF INCENTIVES

Incentives can be a powerful push, but their effectiveness hinges on the type of incentive and the specific market context. China's success in encouraging larger shares of its population to adopt EVs underscores the importance of a comprehensive approach. The country developed a mix of incentives that included purchase, charging, licensing, and usage incentives before progressively deciding to exit the program.

Pushing for domestic EV production and developing financial subsidies for EVs can be effective for kick-starting the market as they allow for a significant decrease in price and overcome the main barriers that exist today, like in the case of China. But from the moment incentive schemes are implemented, strategies for exiting need to be considered. China's experience shows that once the market is mature enough, a safe exit is possible without negative repercussions on EV adoption as markets become self-sustaining.

To be effective, purchase incentives need to be accompanied by charging infrastructure policies to increase convenience. China's well-developed charging infrastructure network, especially in major cities, highlights the crucial role of infrastructure in overcoming range anxiety. Rwanda's lack of financing for building charging stations is making their development difficult outside the capital.

A charging point for two-wheelers in China (students)

In Rwanda, the high cost of EVs and low car penetration in general, compared to local purchasing power, have limited the effectiveness of traditional incentive models for four-wheel electric vehicles, but these incentive schemes have managed to spur the broader adoption of electric two-wheelers and to favor overall personal mobility affordability. Financing and loan options in Rwanda make EVs more affordable by addressing upfront cost concerns and aligning the weekly payment with what the customers can afford. It has been very successful, as since 2019 the e-motorcycle fleet in Kigali grew from non-existent to more than 4,000, over an estimated total of 20,000.

A battery swap station in Kigali (Students)

Among the most common incentives worldwide are sales tax and import duty reductions. These programs are effective for countries without domestic production, and which lack the financial capacity to invest heavily in the market.

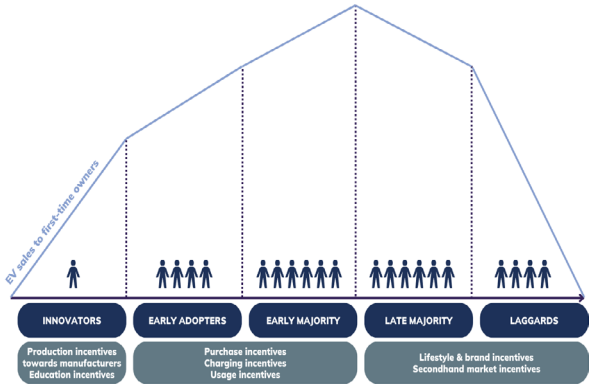
Incentives that increase the driving convenience of road users can be more effective than subsidies, especially after the market is established and the prices have decreased. They are also better received. In Shanghai, the most effective incentive is the licensing scheme, that reduces both ownership price and allows for more freedom when driving in the city. Indeed, in some areas of the globe, the government controls the number of plates issued each year and license plates can be issued through a lottery system, a queuing system, or they can be prohibitively expensive to obtain. Therefore,

to push consumers towards EVs, governments may either remove or reduce those licensing limitations for EV buyers.

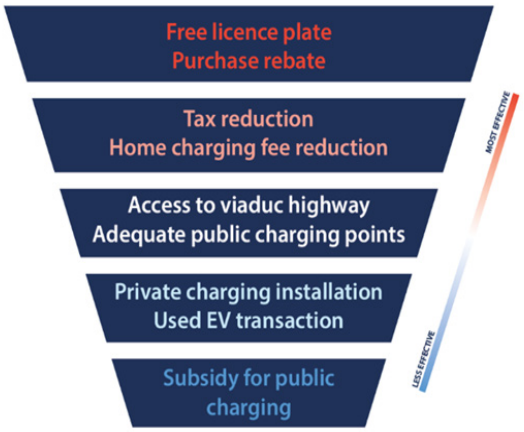
Educating consumers about EV technology's advancements can also significantly reduce adoption barriers, paving the way for wider EV acceptance, as demonstrated by China's experience.

In China's EV market, strong brand strategies emphasizing community building, targeted features, and competitive incentives have emerged as a powerful driver of consumer choice and price reduction.

Finally, anti-ICEV policies can be the most effective in organising the switch to EVs, but they are difficult to sell to road users. Taxing ICEVs, however, increases revenue to finance EV incentive schemes.



A representation of the complexity of targeting the right customers with the right incentives, at the right step of the EV transition Source: students



The development of electric vehicles at the international scale: the examples of Rwanda and China

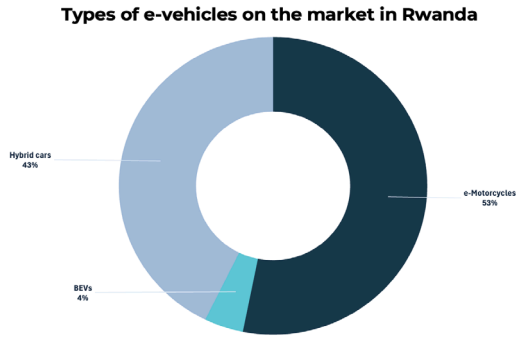
Rwanda sees EVs as a solution to oil dependency and a gate to globalization. It also aims to advertise itself as a "proof of concept country" with an open market for e-mobility companies to invest in and seeks to attract global events through the electric modernization of its vehicle fleet. Incentives reducing import and sales costs are a reason firms settle in Rwanda before expanding into larger markets in Africa, which is proving successful for e-motorcycle companies.

For new electric cars, current incentives structures have yet to bridge the gaps between the country's existing car culture, the purchasing power of the general population, and the high overall cost of a new EV. The situation is slightly different for used hybrids, which can now be cheaper than used ICEVs. The transition of the two-wheeler taxi fleet to electric is happening fast, thanks to micro-financing schemes and cheaper charging prices compared to fossil fuel. The supply is not matching the high demand.

In **China**, the need to promote EVs did not only come from environmental matters, but also to decrease their dependence on foreign oil and as an industrial strategy to gain an early competitive advantage in this segment of the car industry.

The government did not start with protectionist motives in mind. Instead, it incentivized all NEVs (New Energy Vehicles) and allowed market forces to determine which propulsion systems—Chinese or international brands and BEV, PHEV (plug-in hybrid electric vehicles), or HEV—would prevail.

Incentives in China are holistic and comprehensive and efficient in encouraging Chinese consumers to adopt EVs. As the Chinese EV market matured and gained in competitiveness, purchase subsidies from the central government were reduced and local incentives focused on usage incentives. The country now has one of the highest market shares for EVs, close to 40% of sales in 2023. Today's sales are not solely dependent on incentives, as despite the end of the national subsidies in 2022, sales have continued to grow in China.



Source: (GIZ, 2024)

POLICY TRANSFER AND TRANSFERABILITY

Incentives often require important financial backing to be successful, which is something that developing countries may not be able to do without foreign investment. Furthermore, while one incentive may work well in a specific context, it may not be adapted to all situations. Overall, the policy transfer process for electric vehicle incentives seems to be less fluid in the public policy realm than in the private and NGO sectors. While this varies heavily depending on a country's political and economic considerations for pursuing the electrification of their vehicle fleets, students' findings highlight that:

•In Rwanda, public policies developed in the country have been exported to neighboring countries with similar success. However, their long-term political sustainability and support is undetermined.

• It would be challenging to recreate Chinese EV incentive policy in any other country. China has a unique set of industrial strengths and strong financial capacity for wide-ranging policies. However, some individual measures should easily be replicable elsewhere, such as the non-financial convenience incentives.

• Some developing markets are still trying to replicate part of the Chinese industrial policy to increase EV adoption locally. They are still at an early stage though and their effectiveness cannot yet be estimated.

• Other strategies similar to Rwandan public policies, including financing and loan options on EVs, are also easily transferable to kick-start a market even if long-term political sustainability and support is undetermined.

• Incentives developed to promote the adoption of EVs may also experience similar degrees of success when applied to other vehicles powered by other sustainable fuel sources.

• The lack of a secondhand EV market remains a considerable barrier to global EV adoption that cannot necessarily be fixed through incentives but should develop by itself as worldwide EV stock grows and ages.

• In developing regions, electric two-wheelers are emerging as a promising alternative to gasoline-powered vehicles, particularly in countries with lower car penetration rates like Rwanda and can start a switch to electric vehicles ■

Kigali, Rwanda (students)

EXECUTIVE SUMMARY

This second issue of the Lessons of the Lab collection provides a transversal reading of the results of four group projects linked to the decarbonisation of mobility.

If firstly focuses on the context and challenges of the decarbonization process, underlining the significant part of the transportation sector in global emissions and its consequences on individuals and the environment. Thanks to a growing awareness of the dangers of air pollution, initiatives and solutions have recently emerged, such as the development of electric vehicles, and strategies at the national and European levels have been implemented. However, several challenges remain to attain decarbonisation and limit climate change, in terms of governance, urban planning and finance. Moreover, there is a lack of relevant indicators that enable cross-modal comparison to reach the perfect passenger mix and there are still many obstacles to the electrification of the transport sector.

Students have put forward several proposals to tackle these challenges. This issue focuses on what can be done to improve urban transition policies, firstly by recognizing decarbonisation as priority topic. The “avoid, shift, improve” strategy is then applied to mobility: reduce unnecessary motorized trips, push for modal shift by playing on the convenience or inconvenience factors for users, and improve the efficiency of existing vehicles and technology. Furthermore, the report shows the value-added of implementing new indicators such as door-to-door and usable time to achieve the transition to more sustainable modes of transportation, before analyzing the efficiency of incentives for individuals, by taking the examples of electric vehicles in China and Rwanda.

Finally, this issue also briefly illustrates the sector of High-speed rail with a few examples from the group project which worked with AREP on the creation of an “Atlas of European Stations”, studying upcoming station renovation and construction projects pertaining to high-speed rail across Europe. ■

SOURCES

To access the full reports, please send an e-mail with the project title to **ecole.urbaine@sciencespo.fr**

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FIND OUT MORE

If you want to go further, here are a few examples of papers written by teachers at the Urban school:

- Halpern, C. (2021). Policy solution ownership: road-space re-allocation as a new approach to urban mobility. In The Political Formulation of Policy Solutions (pp. 173-190). Bristol University Press.

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