The future of sustainable urban mobility

How will we move in 2035?

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Foreword

2035 marks a significant milestone. Following the European Committee calendar, this date is for many the moment when mobility, as we know it, will come to an end: new technological perspectives and new habits suggest a significant change of pace that is making smart mobility a turning point for the future and sustainability of our cities.

An approach that clearly emerges from the first activity led by the Center of Technology Foresight at Politecnico di Milano. The study considered the impact of a selected set of fifty technologies and innovations toward the achievement of the United Nations Sustainable Development Goals. Among the various findings, technologies related to mobility showed divergent tendencies requiring a more in-depth investigation.

As a result, this publication explores the future of the mobility of people in urban areas as one of the main challenges society is tackling in the transition towards more sustainable models and lifestyles. The context is particularly complex because of the many interactions between social, economic, political, and environmental issues related to urban landscapes, where the vast majority of the worldwide population is expected to concentrate by the mid-century.

Indeed, everywhere around the globe, big economies are investing public and private funds in what they refer to as “the seventh transport revolution”, a revolution that will be possible by evolving mobility along with some ongoing trends: urbanization, globalization, new ecology, connectivity, safety/security, and health. A crosswise approach that makes technology the enabling key.

Our ability to create innovation within complex ecosystems is therefore of primary importance. Our objective is to present an analysis of the potential offered by emerging technologies and innovations towards the definition of upcoming scenarios that are not only preferred but also feasible, highlighting both empowering as well as preventing factors.

This document summarizes the work done by a group of researchers at Politecnico di Milano together with experts and other stakeholders with the intent of broadening our perspective and share, as much as possible, different points of view, thus improving the foresight process itself. As a matter of fact, this report is meant not only to inform, but also to suggest actions: to highlight new opportunities to seize and give advice on possible risks to avoid. We need to be aware and ready to face one of the biggest challenges of our times.

Sustainable mobility starts today.

Ferruccio Resta

Rettore

Milano, Maggio 2022

Executive summary

1

Mobility is a key element of our lives and its evolution, in modes and means of transport, has been shaped by various drivers and uncertainties in our social, economic, technological, political, and environmental spheres.

In a rapidly urbanizing world, the quality of life experienced by the people living in the cities will determine the quality of our future. With this respect, technological advances and innovative approaches addressing the sustainability of urban mobility are fundamental for resource use, public health, and economic efficiency.

The introduction of the mass-produced car represented a revolution in mobility, nevertheless, it has led to many of the causes of the current condition of poor quality of life in many cities in addition to the depletion of fossil fuels: congestion, pollution, and mental stress. As far as public transportation is concerned, affordability, accessibility, safety, reliability are all important aspects that still represent challenges for many local administrations.

To move towards more sustainable urban transportation in the future, we need to look at mobility as a complex system, starting with identifying the social and individual factors that will guide people's travel choices.

This document is the result of an activity carried out over five months, consisting of desk research, expert's interviews, two workshops, and a survey, to gather opinions and have experts confront their visions of the future, discussing their assumptions, ideas, and concerns, allowing them to develop plausible evolutionary trends together. We engaged nineteen expert colleagues from various departments of Politecnico di Milano, whose expertise falls in multiple areas of mobility. Moreover, we interviewed eight experts from companies and public administrations involved in various aspects of urban mobility. The aim of the face-to-face interviews was to gather insights from people with a perspective not directly tied to technology, yet who are competent when talking about mobility and the ecosystem of social, economical, and environmental factors affecting it.

Numerous are elements emerging from this study, that can be summarized starting from the clear perception that today's **mobility must go through a transformation towards sustainability founded onto two main pillars: moving away from private cars to services and making public transportation smart and multimodal.** This transformation through **strongly depends on different combinations of political and strategic choices, supported by the development of technologies and actions.** Moreover, it is not only a matter of transportation means and technologies, but it is also affected by the evolution in the energetic domain and the consequent infrastructural renewal and upgrade. Indeed, **the seeds of this transformation are already in our society**, observing how car ownership is less relevant and active mobility is rather a health-related choice than an imposition. **These changes in society also include a trend to an increasingly aging population and migration towards the outskirt of the urban center,** therefore when designing future solutions and policies, these aspects need to be considered. As such, **we expect that in 2035 we will still be in an intermediate transition phase, with the existence of several co-with respect to both vehicle fuels and driverless automation.**

The study focuses on urban mobility and people, considering a European metropolis, such as Milan, characterized by an extensive public transportation system serving, for local and peripheral commuting, a population of more than 1.3 million inhabitants, spread of around an area of more than 180 km^2. Indeed, some of the emerged considerations are affected by the outsider experts' context of having Milan as a reference metropolitan city with respect to the commuting experience in terms of motivation, duration, and vehicles/services availability. Nevertheless, as the studies addressing different city contexts show, there are recurrent elements common to the future scenarios such that the drawn considerations can be tailored to different realities. Surely, the scale of the considered urban context, the administration organization and related political forces, as well as the cultural texture characterize the overall picture of the present and the future. Yet, the gathered evidence and trends are quite global, therefore we expect most of the emerged insights plausible for similar European metropolitan realities.

The adopted methodological path uses the *prepare*, *foresight*, *insight* and *action* framework (Figure 1) proposed by the Institute For The Future (IFTF). The method starts by gathering the evidence of elements, events and trends that might affect our futures, to enable the exploration of possible future scenarios, and to translate them into meaningful insights to act to be prepared for the future. In our specific context, the action phase, given the nature of the activity, gathers reflections and considerations on how to move towards the more desirable futures.

Figure 1.
The adopted methodological framework.

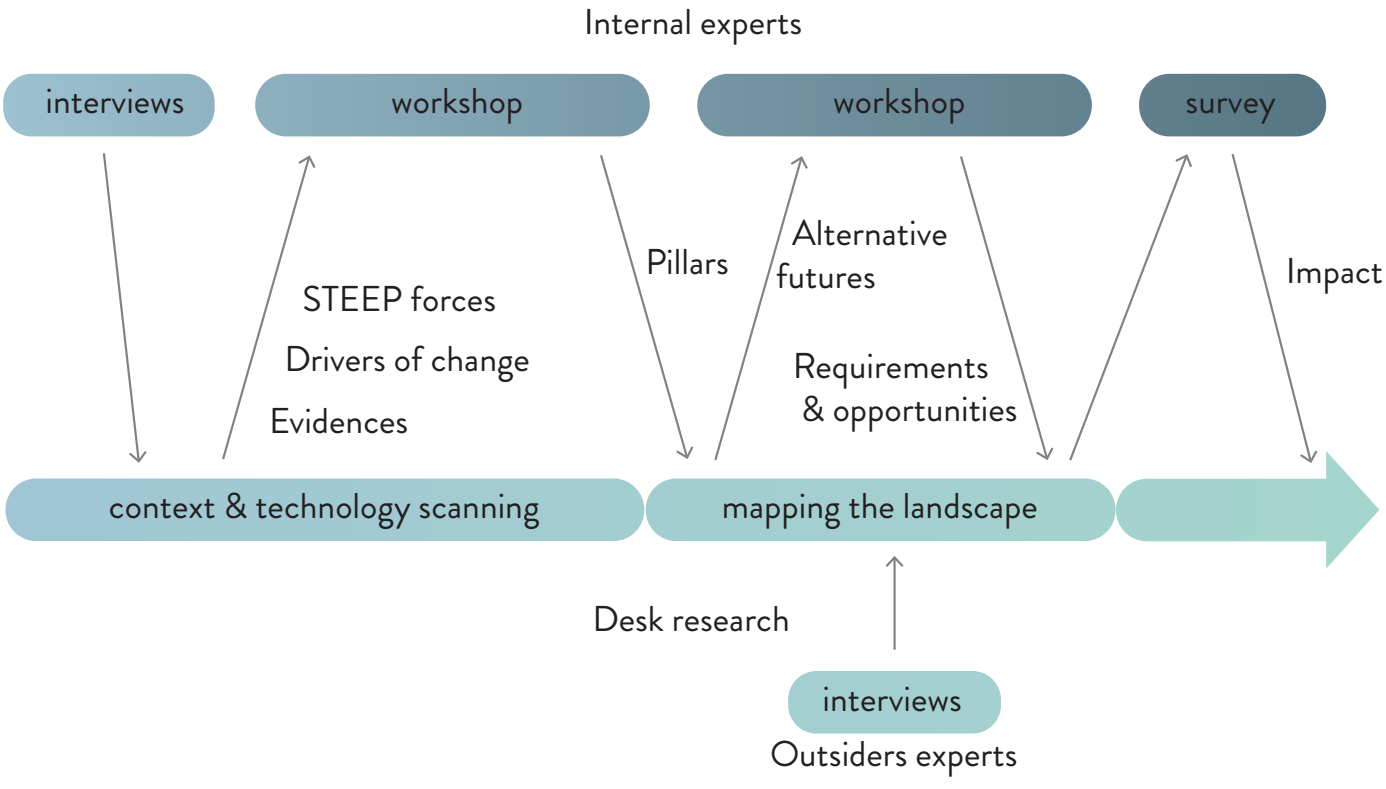
The multi-step process (Figure 2) gathered the contributions from different sources: desk-research activities, individual and group interactions with experts of Politecnico di Milano, and interviews with experts in mobility-related fields. Desk research activities gathered evidence, drivers of change associated with STEEP forces, to prepare the field and complement experts' pieces of evidences, serving as a guide to expand the area of research and reframing the landscape under analysis. A technology scanning activity allowed us to collect an overview of prominent technologies and innovations of interest for the mobility context.

Politecnico's experts have been engaged initially in individual interviews to gather their expertise and personal vision of mobility today and in 2035, followed by two in-person and online group workshops, as well as a survey. The group workshops led to the design of collective, integrated views alternative mobility scenarios (also prompted from the Alternative futures), the identification of its pillars, and the recommendations and opportunities for the stakeholders. With respect to technologies, innovations and policies that emerged during the activities, a survey provided feedback on their expected impact and role in achieving the envisioned sustainable mobility was released.

Finally, outside experts have been engaged in conversations on mobility at large to collect their vision in terms of needs, trends, and evidence of what is desirable and how a desirable sustainable future of mobility might look like.

This document follows the methodological path and reports the elements emerged from all activities, to provide an overview of the numerous facets of the mobility scenario, starting from the many findings that have been summarized in five take-away messages.

Figure 2.
The adopted process.



To work towards a more sustainable mobility in 2035, the technologies and strategic actions identified by the study move in two main directions: moving from private cars to services and making public transportation smart and multimodal, supported by key elements listed below.

1

The speed of the transition towards a more sustainable mobility strongly depends, for each context, on different combinations of political and strategic choices, supported by the development of technologies and actions that will better fit and be integrated into the existing, consolidated urban reality.

2

The prerequisites for sustainable mobility in 2035 are already visible today where travel habits are gradually changing: owning a car is no longer a status, walking or cycling is considered not as a necessity but for its health benefits, the choice of transport is also determined by the growing awareness of the contribution to the environmental impact.

3

key elements supporting the two main directions in key take-away #1

Private mobility: from ownership to service

Enabling technologies and innovations:

- » Connected and autonomous vehicles
  - Level 4 and 5 autonomous vehicles
  - Incremental upgrade kit for vehicles
  - Connectivity and data infrastructures
- » Personal transportation vehicles (micro-mobility)
- » Engines with new generation fuels (zero or net zero CO2 emission)
  - E-Fuels (e.g., synthetic fuels)
  - Biofuels
  - Green/Blue hydrogen
- » Electric vehicles
  - Batteries
  - Charging infrastructure
  - Electrifying roads
- » Multimodal mobility platform
- » Personalized services (journey as an experience)
  - Augmented Reality

Policies and strategies:

- » Vehicle ownership restrictions
- » Pollution-related fees
- » Restricted access areas
- » Reclaim of street parking areas

Greater attention will be required to adopt means of transport and policies capable of meeting, on the one hand, the growing demand for mobility of an aging society and, on the other, the travel needs of citizens who, because of an expected increase in migration flows, will be living on the outskirts of urban centers.

4

The future of mobility is strongly affected by the evolution of choices related to the energy domain and the consequent infrastructural renewal and upgrade. Its implementation could be longer than the time horizon considered and, therefore, in 2035 we expect to be in an intermediate transition phase, with the coexistence of several technological alternatives in relation to the type of energy vector for means of transport and autonomous driving.

5

Public transportation: smart, flexible and multimodal

Enabling technologies and innovations:

- Public connected and autonomous vehicles
  - Level 4 and 5 autonomous vehicles
  - Incremental upgrade kit for vehicles
  - Connectivity and data infrastructures
  - Flying taxi
- AI for mobility planning and orchestration
  - On-demand services
  - Data protection and privacy
- Alternative fuels
  - Batteries
  - Charging infrastructure
  - E-Fuels (e.g., synthetic fuels)
  - Biofuels
  - Green/Blue hydrogen
  - Electrifying roads
- Multimodal mobility platform
- Multimodal hubs for urban-peripheral connections

Policies and strategies:

- Private-public mobility partnerships
- Flexible demand-respond services
- Private car use restrictions
- Sustainable journeys incentives and rewards
- 20-minutes neighborhoods
- Work from anywhere

Systematic perspectives

2

The first phase of the foresight process focused on drawing a systematic view of the complex ecosystem around the sustainable urban mobility concept, by starting from an analysis of the forces that will possibly lead to changes in the future, that attain the social, technological, environmental, economic, and political fields, the so-called STEEP forces, by means of a desk-research on existing evidences and by involving experts in interviews to gather a comprehensive overview of the area under analysis. This landscape map was further expanded by the review of the literature on similar recent studies, to find commonalities and peculiarities, related to the specific boundary of the analysis, or the selected context of interest. The next sections contribute to define the systematic map of the landscape where the future of sustainable urban mobility will take form.

2.1 STEEP forces

Understanding the social, environmental, economical, and political forces that could have a significant impact on the scenario under analysis is essential to better understand the future of sustainable mobility, in line with the STEEP model analysis.

Social

Society is changing, driven by new demographic patterns and lifestyles to follow. People live longer and want to have access, when they get older, to the same possibilities available to the rest of society, in which mobility flows have adapted to different individual needs. Mandatory daily commutes are disappearing thanks to digital connectivity, which is changing the daily routines of workers and younger generations. Smart working is making people's lives more sedentary by changing the mobility demand during the day. This could reduce the stressful life in the urban area, thus creating more distributed flows around the city and returning to a quieter pace of life.

Even in megacities, people gather in communities to feel a sense of belonging and social support, overcoming urban individualism. The urban reconfiguration will enhance this social life by creating spaces in the neighborhood for people to gather and share ideas. Human-scaled neighborhoods, or 15-minute areas, are spreading to allow people to live by values and purpose to take care of social relationships and their surroundings. The experience within the city is changing because of people's willingness to be active participants in change. Society wants to raise its voice and lead a change by removing unsustainable behavior, where concern for protecting the planet is the main driver. In addition, the Covid-19 pandemic made people reflect on the importance of healthy living, achieved through more physical movement and less polluted air. Active mobility is spreading around the urban area and adopted by all social classes, becoming an occasion for daily movements. Even if the amount of people who want to stay healthy is increasing, at the same time, still substantial shares of society are becoming obese, resulting in potential risk for the health system.

Investments in micro-mobility and enhanced public transport are one way to reduce the social divide by ensuring equal opportunities for every citizen, however, dependence on digital tools could undermine this effect. Despite the ubiquity in people's lives of smartphones, apps, and digital tools, not all people can understand information from these tools and interact successfully with them. Functional digital illiterates risk being excluded from access to urban transportation without additional support to ensure seniors but also citizens from poorer social classes understand this new reality.

Technological

Fossil fuels and unsustainable energy sources will be phased out with less harmful and sustainable power sources. Hydrogen, e-fuels, and renewables are expected to play an increasing role even within the city infrastructures as long as electric vehicles are supported by increasingly efficient batteries. Urban mobility of 2035 is envisioned to be partially supported by autonomous vehicles to increase urban safety, better utilization of urban areas, and more efficient driving. The constant interest in reducing climate change supports the adoption of micro-mobility infrastructures. E-bikes, e-scooter, or even autonomous bicycles are envisioned to be used in daily commuting. To guarantee the same freedom as a personal car, without the stress of time wasted in traffic, and improved individual wellbeing. Changes in mobility could also affect air commuting, with more efficient and sustainable air vehicles for urban flights. Motivations for commuting could be influenced by improvements in virtual travel, supported by tools providing a seamless experience and the attractivity of life in the metaverse. Moreover, vehicles will be equipped with sensors that generate an experience tailored on user's needs, dedicated to minimizing the efforts required by commuters to deliver a superior experience. The pervasiveness of smart devices that track people's movements and sensors in cars provides the necessary amount of data for on-demand mobility and tailored solutions. However, cyber-attack and digital identity theft are the new downsides to overcome due to the high dependency on data exploitation. The key aspects of the new mobility are faster digital communication infrastructures, such as investments in 5G or 6G, and a widespread power grid without drops in efficiency.

Economic

Limiting the exploitation of resources and guaranteeing their equal distribution is one of the main drivers of urban re-configuration and mobility design with a view to sustainability. Traditional business models are changing and driven by sustainability concerns the market is moving into sharing solutions, which in the case of mobility aim to limit the number of vehicles on the road, pollution levels, and the livability of the city. The global economy and hyperconnectivity have impacted the way people live and their demand for fluid and seamless ways to move between different cities and within urban areas.

Multi-residential is a reality, and people demand ongoing and reliable commuting experiences to maintain an adequate quality of life. Indeed, powered regional connectivity and efficient freight mobility will influence these connections. The market and society aim to improve social equality and inclusivity. Taking into account individual peculiarities in terms of commuting requests, but also in including individuals with movements limitations and aging society to be served as mobility customers. Aligned with this, the market is demanding more transparency in giving information about how data, decisions, and investments are defined, to be aware of how the value is extracted.

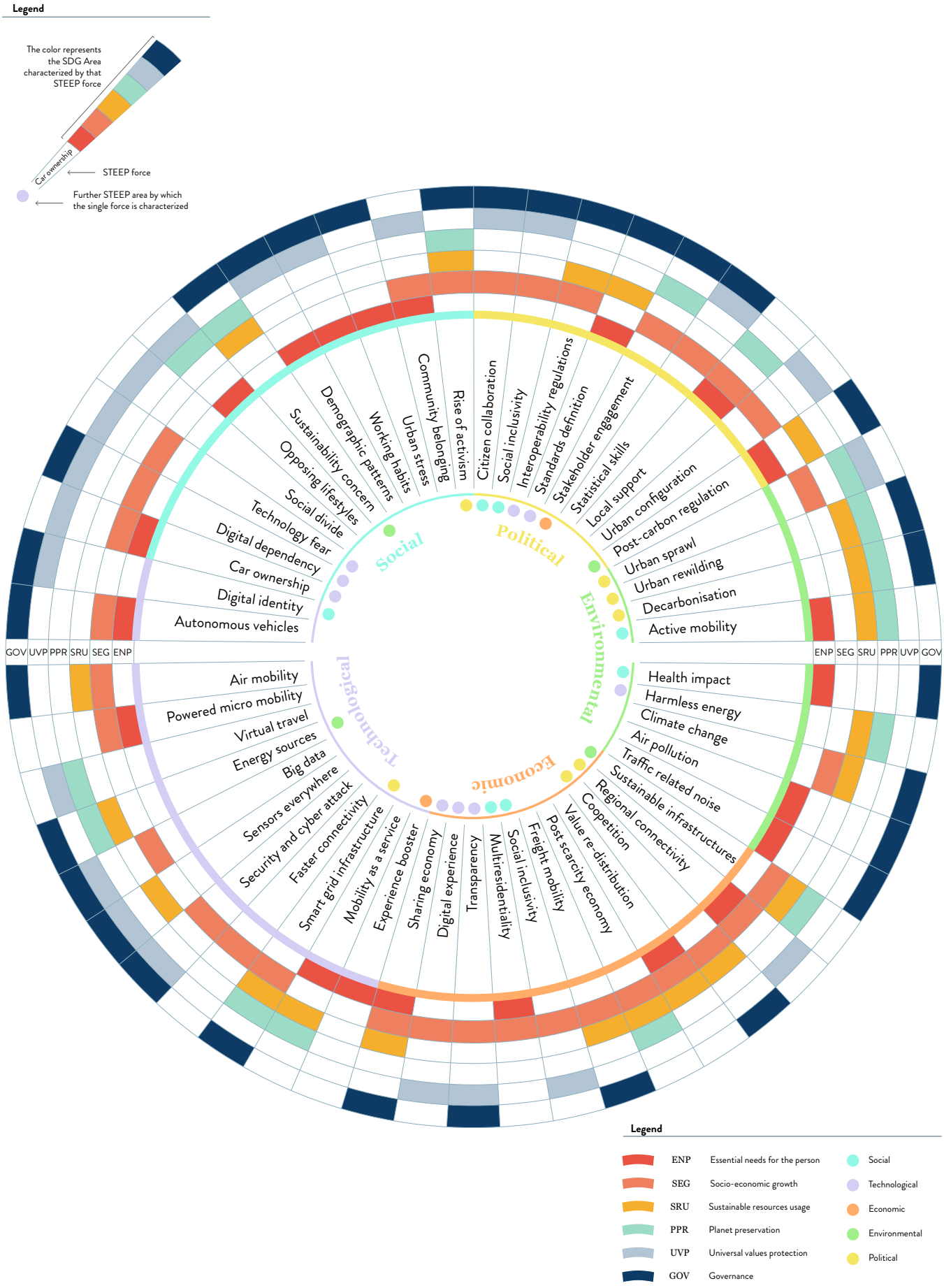
Environmental

Municipalities aim to substitute all the vehicles generating massive levels of CO_2 emissions and smog (PM10, NOx, ...) with more sustainable ones, driven by the awareness of the harmful impacts that these vehicles have generated over time in cities. Smog-covered skylines, unbreathable air, and the rise of city temperature are the more perceivable effects of the unsustainability of today's urban mobility. Affected by shocking climate change, people are beginning to drive change by embracing active mobility in their daily commutes. Communities are leading projects to improve urban redesign to fight the dangerous urban sprawl and soil occupation. Green areas are emerging within the city, with safe corridors designed to spread nature by planting lush urban vegetation. Urban reconfiguration aims to provide a different and better quality of life to citizens, to be aligned with their mobility needs and their demand for safety and a healthy lifestyle. Colored pavements materials with efficient drainage systems preserve the use of resources, as well as energy consumption and its distribution without system losses.

Political

In a paradigm in which municipalities should demonstrate city resilience and the ability to cope with new urban and social changes, policymakers demonstrate leadership by enacting environmental policies and supporting innovation. Solutions to support sustainable mobility in the urban area go in this direction, as does reconfiguring urban spaces to donate them to local communities. The city is becoming more inclusive to support individual wellbeing and social aggregation; people are operating to improve the living area, making neighborhoods come alive organized almost as stand-alone cities. Satellite urban centers are also becoming more attractive for the quality of life and ease of commuting to the larger urban area. Coping with a changing ecosystem demands the collaboration of all. Citizen-led innovations grow exponentially to shape a city aligned with real users' needs. Policymakers should embrace them while engaging with businesses to collaborate on mobility solutions that induce people to support the abandonment of private cars towards public transportation solutions. However, the exploitation of data to organize on-demand and more responsive solutions requires community regulations to standardize the data gathered, interchangeable infrastructure not to limit the commuting experience within city boundaries but to enable sustainable outward mobility as well. All these forces will play an essential role in the changes of the future to come, leading to different possible scenarios based on what eventually will prevail and how the entire context will evolve. As such, when trying to imagine the future, alternative futures are typically envisioned, exploring possible scenarios together with the elements that could lead in one direction rather than another. Having an overview of the forces, how they are connected and related, and what impacts they might have allows one to get a broader perspective in imagining the future. To get such an overview, Figure 3 maps the emerged forces within the STEEP categories as well as their impact/relation to SDG areas.

Figure 3.
The identified STEEP forces and their relation with SDGs.


Legend
The color represents the SDG Area characterized by that STEEP force
Car ownership
STEEP force
Further STEEP area by which the single force is characterized
Social
Political
Environmental
Economic
Technological
Rise of activism
Community belonging
Urban stress
Working habits
Demographic patterns
Sustainability concern
Opposing lifestyles
Social divide
Technology fear
Digital dependency
Car ownership
Digital identity
Autonomous vehicles
Citizen collaboration
Social inclusivity
Interoperability regulations
Standards definition
Stakeholder engagement
Statistical skills
Local support
Urban configuration
Post-carbon regulation
Urban sprawl
Urban rewilding
Decarbonisation
Active mobility
Health impact
Harmless energy
Climate change
Air pollution
Traffic related noise
Sustainable infrastructures
Regional connectivity
Coopetition
Value re-distribution
Post scarcity economy
Freight mobility
Social inclusivity
Multiresidentiality
Transparency
Digital experience
Sharing economy
Experience booster
Mobility as a service
Smart grid infrastructure
Faster connectivity
Security and cyber attack
Sensors everywhere
Big data
Energy sources
Virtual travel
Powered micro mobility
Air mobility
GOV UVP PPR SRU SEG ENP
ENP SEG SRU PPR UVP GOV
Legend
ENP Essential needs for the person
SEG Socio-economic growth
SRU Sustainable resources usage
PPR Planet preservation
UVP Universal values protection
GOV Governance
Social
Technological
Economic
Environmental
Political

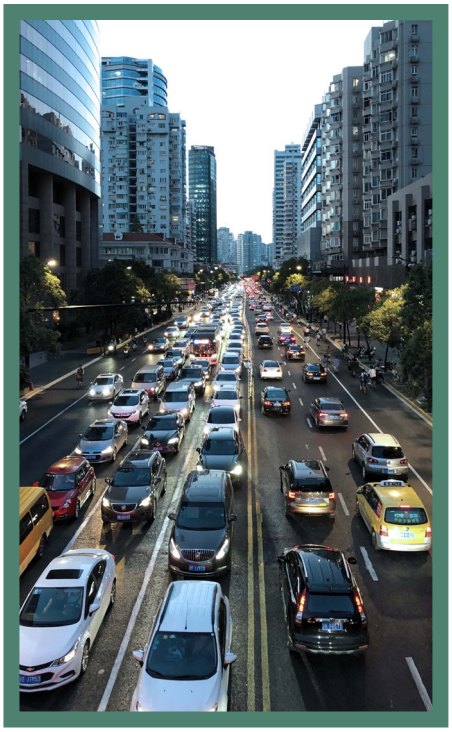
2.2 Outsiders' perspectives and insights

We engaged a number of external professional in areas related to mobility, dubbed *outside experts or outsiders in short*, for their different perspectives on the topic of interest. Their role is to broaden the perspective of the scenario under analysis, highlighting the critical points to be taken into consideration. Guided by their area of expertise, they shed light on new aspects that had not emerged before, and converged on the same themes discussed by the Politecnico di Milano experts, highlighting their pivotal role. Outside experts work in the municipal area, as councilor or mayor, in activism, in the communication market, in strategic consulting or in the shared mobility industry. To further get an idea of the global trends related to mobility, we also carried out an analysis of similar foresight activities related to mobility by other bodies, briefly reported in the subsequent part.

In particular, their contributions brought to the identification of three macro-categories of thoughts:

- *The factors influencing mobility evolution* such as unsustainability of the current situation, the technologies acting as an enabler of change, the political forces, and the possible barriers.
- *The transportation means of the future*, dealing with the means that may be used in the future, the evolution of the concept of private cars, the role that autonomous vehicles may play, and the urban structure implications of new means.
- *The evolution of life in cities* dealing with various topics like geographical boundaries, the concept of residence, frequency and patterns of movement and the motivations that bring people to move.

The findings of the interviews with outside experts are summarized in the following, presenting their personal educated perspectives and insights.



Overall factors

Today's urban mobility is at a tipping point and the experience is far from optimal.

Signals calling for substantial change and in a more sustainable direction are coming from everywhere, as more than 50,000 young people are walking Milan streets demanding rapid action against climate change.

In Italy, almost all urban centers exceed the EU limit values for air pollution, with levels of PM2.5 and NO_2 that could lead to premature deaths.

Mobility today is not sustainable

Today's urban mobility is far from being sustainable. In recent years, the evolution of urban mobility has fluctuated from crowded, noisy streets filled with cars stuck in traffic to empty streets without a single vehicle during pandemic lockdowns, returning back again to streets in the city center congested with traffic.

> *"[It seems to me that] we have reached a saturation point in terms of the negative aspects of private transportation in the city - such as traffic, noise, stress, and so on. There is real potential to introduce new opportunities and innovations at the level of public transport to address the needs of all users. There is a more systematic and reasoned awareness today on the limitations of private mobility in the city."*
>
> *(Fabio Fossa – Philosopher of technology)*

The experience of urban mobility today dramatically reports that its structure and configuration are at a turning point. Citizens' experience is far from optimal. Congestion on urban and suburban streets is unimaginable, especially when commuting during peak hours. The poor experience is not only about private car rides, but also common for public transportation. The crowded and noisy wagons, unpredictable travel times, and idle waiting times in the middle of nowhere do not encourage their use. The current complex system also reached its peak in the adverse effects on the mental stress caused in individuals and, above all, on the environment due to the critical level of pollution emitted every day by transport vehicles.

Mobility is part of a complex ecosystem where the As-Is paradigm is no longer sustainable. Outside experts brainstormed to focus on the fact that it is crucial to start from the hours of the day with the highest turnout in the city to trigger change. From there, like a snowball effect, the other parts of the system would follow the change.

Figure 4.
Most cited concepts emerging from the conversations with experts.


Big Data
Decarbonization
Incentivize
Cybersecurity
E-bike
Regulation
Purpose
UrbanSprawl
Electrified Streets
Multimodal System
Sharing
Infrastructures
Electric Cars
Community
Renewable Energy
Public Transport
Collaboration
Energy Community
Digitalization
Urban
Consciousness
Elderly
Sustainability
No Car City
Energy Production
Hydrogen
Fluid Mobility
Social Aggregation
Mobility
Sensors
CO2
Freedom
Connectivity
Health Concern
Comfort
Smart Grid
Flexibility
AugmentedReality
Car Ownership
Limitation
Reconfiguration
Air Quality
Autonomous Cars
Relax
Pedestrian
Multiresidentiality
Air Mobility
Megacity
Activism
Charging Stations
Virtual Mobility
No Traffic
Green Spaces
Education
Climate Changes
Freedom
DigitalIdentity
Silent Roads
Urban Planning
Inclusivity
Capillarity
LowerStress
Safety
Train
Comfort
Relax
E-fuels
Education
Energy Sources
Smart Working
Proximity
New Competences
Temperature
Maas
Elderly
Rent

Technology enablers

Urban mobility in 2035 will be highly dependent on the correct use of the data gathered by the system. Data exploitation, data analysis, and data standardization across stakeholders are all critical factors in providing a comprehensive and efficient service. Interviewees reflected on the importance of centrally managing all data from the administration to orchestrate on-demand transportation services and proactively aligning with people's needs. However, investments in statistical expertise and data analysis for proper orchestration are necessary to achieve this outcome. Moreover, given the sensibility of the information, data protection and security are paramount.

> *"Data will play a key role in making informed choices to structure urban mobility. Shared mobility collects a lot of data, and I hope that in the future data will be collected on private travel as well. Car manufacturers could invest in this service to collect more data for cities. [I imagine] that a local authority will process the data and work with decision makers, who will need to be trained in statistical data management."*
>
> *(Giulio Del Balzo - Public policy manager)*

Another triggering event is in the design of vehicle upgrades. All the vehicles of the future, both 2 and 4 wheels ones, will require a lot of sensors, electrical components, and features with a different obsolescence path. To remain in a sustainable framework, car manufacturers could design modular functional upgrades not to require a complete change of the vehicle but only specific adjustments. Another important aspect is a plan for flexible, easily maintainable network infrastructures, considering how future vehicles will be highly dependable on data and connectivity, trying to invest in long-lasting solutions. As technology evolves at a very rapid pace, the needed infrastructure of the future should be designed and developed to be usable and upgradeable frequently and easily.

Political forces and visions

The definition of restriction policies, street regulations, and bold environmental administrative choices are presented as critical steps to induce and sustain a change in citizens' behaviors. For example, policies restricting the type of vehicles circulating in the urban area, limiting the number of cars allowed in the center, and the consequent definition of areas exclusively for pedestrians and cyclists will induce citizens to adopt public services micro-mobility ones. In parallel, significant investments are needed to reach the goals of a green and inclusive city thus, the administration should build micro-mobility infrastructures (e.g., dedicated streets, parking spots) and remove all physical barriers. Other relevant political actions should focus on improving the quality of life in the urban area. The two most critical factors are the reduction of pollution levels and less noisy roads. The first step to achieving these goals is introducing rules to limit the number of cars and allow only electric vehicles to enter the urban area. However, two negative implications emerged. First, these practices may not be effective in smaller urban areas since they require different congestion policies to be sustainable. Second, electric vehicles limit the CO_2 level locally, where they are used, but not in the energy production site. Therefore, policy actions should consider the source of energy used to power vehicles, grant funding, and collaborate with research centers towards reducing the environmental footprint of vehicles in the system.

In general, the envisioned scenarios of the mobility of the future require strong political support, driven by visions and strategies, as well as funds, because most highlighted elements are game-changers but need a global strategy.

> *"Perhaps the most complex thing now is to figure out what kinds of political choices to make in order to maximize the benefits and minimize the side effects. Supporting the adoption of self-driving electric cars and sustainable mobility would mean fewer emissions, cleaner air, and less noise. This could improve the level of citizen well-being and quality of life in the city."*
>
> *(Fabio Fossa – Philosopher of technology)*

Possible barriers

Besides the political support to move towards sustainable mobility solutions, the technological innovations and the city configuration might drastically reduce the applicability and impact of these choices. Some outside experts pointed out that only small incremental changes usually occur in the Italian and European context because of the historical city structure, which imposes constraints that might create barriers to future sustainable mobility.

Dually to the government/administration force, there is the individual one. Private cars and ownerships versus sharing/public are two elements that might void the positive gains of alternative fuels first and AVs. Numerous envisioned future mobility scenarios are centered on pervasive, efficient, and prominent public transportation, which relies on a de-emphatization of car ownership. In conclusion, the straightforward vision and sensibility to sustainable causes will play a crucial role. If political forces and critical stakeholders lack the willingness to commit to reducing climate changes, their adverse effects might outperform all the efforts done to shape a sustainable mobility.

> *"The forces that could limit the implementation of sustainable urban mobility relate to the unwillingness of government actors who choose not to sign climate agreements, and thus increase the occurrence of extreme weather events that would change the structure of cities."*
>
> *(Roberta Bonacossa – Climate activist)*

The transportation means of 2035

It is a complex ecosystem that not only considers what is on the move but is also considering what is steady.

The change in the transport system responds to user requests for improved city quality of life, as 80% of Italians ask for healthier cities by giving more space to walking, cycling, and public transport.

Precisely the latter has exceeded pre-pandemic usage values, with a micro-mobility usage rate of up to 10 people per day, compared to the single user in cars.

Transportation means

Mobility in the urban context in 2035 is characterized by flows of people walking and moving with micro-mobility solutions. The streets will be populated by bicycles, including electric ones, shared and privately-owned e-scooters, easily parked and carried around, as well as pedestrians walking safely through the city.

Outside experts think that these mobility solutions will be widely used by everyone, including senior citizens, as people will replace urban private car journeys with micro-mobility ones over the years. Today small, medium, and large cities are experiencing a trend of widespread adoption of e-scooters and bicycles. Consistently, these solutions will improve over the years by innovating their environmental impact, usability and efficiency. Nevertheless, the cultural factor still plays a relevant role in micro-mobility adoption. For example, in the Italian context, part of the society should overcome the cultural barrier that considers the bicycle not a fashionable option, not ideal in unfavorable weather conditions.

> *"I foresee a steep decrease in the number of cars in cities and consequently an increase in public transportation and sustainable mobility such as bicycles, shared vehicles and walking."*
>
> *(Roberta Bonacossa – Climate activist)*

> *"To really encourage this kind of mobility it is fundamental to foster the educational aspect in schools and companies, also supported by economic incentives (from companies). Finally, an influential cultural factor making bicycles fashionable and cool is indeed pivotal."*
>
> *(Giulio Del Balzo - Public policy manager)*

Other sustainable solutions refer to a widespread and more efficient public transportation system. This is complementary to the active micro-mobility, necessary to offer citizens a more comprehensive range of mobility solutions appropriate for their abilities and preferences. The public transportation of the future integrates both traditional means (e.g., metro, buses) and shared services.

The value of public transportation is in being a complete solution, constituted by several options to serve the user's needs, making it critical by 2035 to reach a cohesive public network.

The turning point will be the ease of use of the public transportation service where the trip can be composed of different combinations of transportation means, based on the user's convenience, preferences, and accessibility, taking the present Mobility-as-a-Solution (MaaS) framework to a higher, more pervasive level.

> *"What the MaaS platforms have achieve is to reconnect the customer needs (location and destination), to the entire mobility network. It's not a question of reasoning with one preferred or usual transportation means, it's about dynamically building the smartest combination of solutions for an efficient and convenient journey."*
>
> *(Stephane Cretel - Consultant in marketing & innovation strategy)*

The driver of change in the design of transportation services in 2035 is the allocation of the right capacity of vehicles. This is a critical point because emerging solutions in recent years have moved in the opposite direction, reducing the passengers carried and favoring the individual's needs. However, although paying attention to the individual needs during the journey remains a must, the outside experts have emphasized the critical role of solutions that move a relevant number of citizens quickly (such as trains). Another driver of change for public transportation adoption is the travel quality, including the on-board experience, in terms of safety, cleanliness, and available space per person. The ease of travel and its quality is also generating a reduction in the mental stress that a chaotic, less reliable, and crowded trip might generate.

The improvement of public transportation should also target its economic, time-relate, and environmental convenience for all types of commuters, with respect to a private car, not only in the urban area but also for other destinations. Specifically, the tipping point will be when achieving the sustainability of trips longer than 30 minutes, computed not only in the environmental impact but also in the efforts required to plan the trip exchanging among different transportation means and the mental stress associated with it. Altogether, the sustainability factor refers to a broad area covering both the public and private sphere.

"For me the future of mobility is not about inventing something new but about making sure that what exists and has been conceived in the past is well used. (...) What will be the driver for change is capacity, and in most cases nothing can beat the train; but we don't like trains...not because they are not efficient and fast but because they are dirty and unsafe. By solving these two points, alternative solutions may not be needed."

(Stephane Cretel - Consultant in marketing & innovation strategy)

"We need to reprogram the mobility of cities, and the cities themselves, with more accessibility. As of today, many trips to cross the city involve mental and physical stress, related to long traveling times and numerous means ... this is not sustainable."

(Roberta Bonacossa – Climate activist)

Car ownership

For the future, the adoption of private cars remains a blurred factor envisioned from two perspectives: a radical one focused on attaining a sustainable paradigm and another one that preserves the current situation.

When considering the first one, the vision is that private cars will be banned from the urban area, a strategy based on the environmental impacts, the high economic cost for families, and the sub-optimal use of urban spaces devoted to parking lots (occupied by idle vehicles) or wide streets filled with one passenger per car). In this vision, individuals who want to move autonomously will use a shared car. However, the coverage area of the service will not be limited to one city but enable inter-city movements, supported by fleets of vehicles in the required destination. In this paradigm, a good portion of outside experts envisions the future of cars only as a service, comparable to other public means.

When considering the second perspective, the habit of getting to the city center or office by private car will remain. Indeed, some interviewees mentioned that the smart working trend might consistently reduce the flow of cars reaching the urban area, having, as a side-effect, the attenuation of the negative experiences associated with daily commuting. With fewer cars around, commuting by personal car will become even more attractive than today therefore abandoning the private car for public transportation will become even more difficult.

"Commuting to the city by personal car will continue to be there, although not every day of the week, with a possible reduction of 25-40% in flows to/from the city. If this is the case we will have smoother road traffic and consequently public transportation, where experienced as a faster alternative to individual vehicle, may become less attractive"

(Giorgio Gori – City mayor)

Autonomous Vehicles

Autonomous vehicles (AVs) are a powerful driver of change that could potentially disrupt the urban commute experience, although interviewees unanimously feel that fully autonomous cars (known as L5) will not be ready for urban context in 2035. However, discussing autonomous cars' implications can help in understanding their adoption.

AVs can be integrated with the public transportation system to increase efficiency and widen its capillarity, where urban streets are populated by autonomous buses or shared autonomous electric cars used as taxis. This integration might be used to solve the so-called "last mile issue" in areas underserved by public transportation. As a side effect, though, the distance traditionally covered with active mobility could be reduced or eliminated, with a negative impact on active mobility and personal health.

Autonomous vehicles generate two other effects at the individual level. First, by being driverless, the journey time gains a new value. People can engage in personal, work, or leisure activities within the cozy environment of a car or minibus. Second, AVs serve all categories of commuters, even more, those who cannot drive to move autonomously, offering a safe solution for older people, teenagers, and disabled. As one of the interviewers mentioned, this opportunity reverberates in a more significant effect: the self-determination of individuals. Indeed, AVs can enhance the city's level of inclusivity by supporting individual well-being allowing people to live the desired experiences without any physical or digital constraints.

These powerful effects are perceived as achievable as long as AVs remain a shared, public service without the need for vehicle ownership, as the cost of the technology is expected to make the AV cars an expensive assets. In conclusion, the consideration of AVs as a positive solutions for urban and individual mobility remains true, yet the power of their impact though will depend on the changes and adaptation of the entire ecosystem in terms of infrastructure, mindset, and policies.

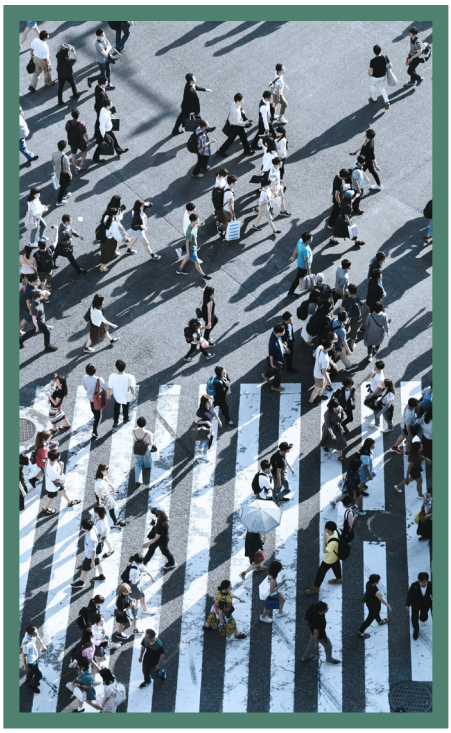
> *"Talking about inclusivity, level 5 self-driving cars could bring mobility to those who are now excluded from it and experience great difficulty in using public transportation - the disabled, the elderly, the minors, and so on. There is a strong connection between being able to move autonomously and personal well-being. Urban mobility is critical for citizens to enjoy wider access to medical care or healthy food, for example. Being able to move around the city autonomously means having a much greater opportunity for self-determination."*
>
> *(Fabio Fossa – Philosopher of technology)*

Rethinking urban configuration

The evolution of urban mobility requires city configuration and infrastructure adaptation to support its applicability. Specifically, the widespread adoption of micro-mobility solutions demands safer dedicated lanes in all urban areas and widespread parking slots, putting them on the same level as cars are today. The city can't move in an inclusive direction without introducing infrastructures that make the city transportation services accessible also for people with movement limitations and limited capacity toward a highly digitized, yet intuitive, service.

Some interviewers went further by envisioning the city to be likely organized as spheres, independent neighborhoods with all the needed goods and services, an organization that ultimately affects mobility, as citizens will need to travel shorter distances, in a specific area, possibly walking or using agile means rather than four-wheeled vehicles. The 20-minute neighborhood shapes a pattern of proximity life in which individual lifestyles become increasingly relevant, inducing changes not only in urban mobility but also in purchasing habits, use of services, and overall how the city is experienced.

> *"The rise of micro electric mobility solutions, both shared and private, require that we create a widespread parking structure for these vehicles, the necessary infrastructures and regulations. If we wish to use sustainable micro-mobility we must treat them as a main form of transportation, equal to cars today. (...) Mobility is not only made up of what moves but also of what sits still and occupies space, so figuring out how to redesign spaces freed up by private cars will be needed."*
>
> *(Giulio Del Balzo - Public policy manager)*



Life in the cities

To comprehend how sustainable urban mobility will be envisioned in 2035, we define the boundaries of the context.

By considering first the geographical extension and physical borders, then the population. One-third of the global population (2.59 billion people) in 2020 lived in metropolitan areas. By 2035 this value is expected to increase to 3.47 billion, equal to 39% of the global population, in metropolitan areas.

A new metropolis will arise every two weeks over the next 15 years, and megacities (with more than 10 million inhabitants) will be 48 in 2035 compared to 34 in 2020.

Defining geographical boundaries

Outsider experts unanimously feel that taking into consideration the urban area only is not enough. We must consider the city center and all the peripheral networks connected to the city since their synergies forge an interdependent ecosystem. By omitting the specificities of the areas surrounding an urban center, the analysis only accounts for about 10% of the problem.

> *"When you speak of cities depending on the scale of the reasoning you can encounter different landscapes, not only the geography but also the network where people and economical centers are. (...) Around a city there is an ecosystem and considering mobility of people only within the city center we are looking at 10% of the problem, which is indeed the most crucial one but we should consider the whole ecosystem."*
>
> *(Stephane Cretel - Consultant in marketing & innovation strategy)*

The evolution of this ecosystem for most outside experts will lead to the definition of megacities: large urban areas that expand, generating the dangerous effect of urban sprawl. This configuration will be plausible not only in Europe but also worldwide, with cities located within a train distance from each other. However, in this future landscape scattered with megacities, other interviewees argued that satellite cities will still exist, as far as people can decide to move away from large urban areas to improve their quality of life. In this scenario, better mobility connections with the outer area cities could strengthen their existence. The result will then be a more complex network, shaping an alternative structure to the centripetal one.

> *"Possibility of imagining a more balanced territorial structure, less centripetal (characterized by a single pole of attraction) since its growth has come at the detriment of other territories. Trying to create conditions to retain and attract new resources, creating territorial alliances to create a greater critical mass. We are like planets whose mass can attract people and capital (...) so becoming a large metropolitan city in turn will have the possibility to restore a more balanced set-up on a regional scale."*
>
> *(Giorgio Gori – City mayor)*

Residents turnover

The majority of interviewees feel that in 2035 people will still prefer to live in cities because of the attractiveness of offered services and social interactions. Indeed, when the quality and ubiquity of mobility improve at all levels, it positively impacts both those who live in the city and those who prefer peripheral areas.

More specifically, it is envisioned that high-quality mobility will allow people to choose where to live for a high-quality personal life according to their needs and preferences. On average, the urban population will be more stationary in the urban area, with a cyclical change. They will not be radically attached to a specific place but will tend to change it over the course of their existence, staying in that place as long as they can benefit from it. Pivotal to this opportunity to live anywhere is the quality and sustainability of mobility.

> *"What will change is where we as people live over the course of our lives. Before we were used to settle in the place where we started working while maintaining emotional relationships. Instead, I believe that in the future we will choose to live in more comfortable and beautiful places, in particular moments of our life. It will not be as stable. Even if the population of the city remains stable, it will still be changing (...) related to the quality of life that the Administration can give to all the neighborhoods of the city."*
>
> *(Arianna Censi - Councilor for Mobility)*

> *"New mobility solutions could help substantially simplify the process of reaching the city from outside without loosing too much time, energy, and money. In many cases, working in the city center implies living there even if this is not what people desire, because daily commuting is too stressful and demanding. With more efficient mobility, those who live in the city not by choice but by necessity could consider other options as well. At the same time, new urban transport models are necessary to serve the needs of all citizens as well. Both aspects should be supported by strong political commitment and adequate funding."*
>
> *(Fabio Fossa – Philosopher of technology)*

Frequency and patterns of journeys

The adoption of "work from anywhere" practices delineates a direct effect on the peak moments by leveling them, generating an evenly distributed demand during the day, even though some workers' categories and scholars will possibly return to pre-pandemic habits.

This configuration shapes a new equilibrium on a systemic level, where the overall mobility demand is mainly constant during the day, designing a variety of new mobility patterns, both in terms of destinations and modes of transportation. Within this new equilibrium, the city center will not be the only target.

> *"It is not a matter of volume but a matter of distribution. In the future the volume will be the same, but more evenly distributed, putting a different pressure on the system itself."*
>
> *(Stephane Cretel - Consultant in marketing & innovation strategy)*

The mobility of goods plays a critical role in affecting the pattern of movements. Firstly, by optimizing the number of trucks moving within the urban area. This guarantees more enjoyable routes, safer streets, and less crowded lanes. Secondly, the capillarity and improved sustainability of goods transportation can induce people to reduce "non-desired" trips by directly delivering such products to their homes. The individual's buying behaviors can come to change their movements if the individual is able to question him or herself what kind of activity is worth the extra time and what is not, thereby reflecting on what is essential and values movement.

Why people will move

When imagining the motivation that will induce people in the future to commute, the origin is again from a personal introspection on the value of the time spent to commute; all not necessary trips will indeed emphasize the experience and the unique value that makes it worth to travel, leveraging on the benefits provided by the reached location or event. People will move to improve their life quality, including active mobility for a healthier day. In addition, the spread of virtual reality (including travels) and its ease of access will further increase the value of physical travel. The act of choosing to spend more time traveling in the real world gives greater exclusivity to this option; virtual mobility becomes an alternative, but not entirely comparable to physical mobility.

> *"For people moving and meeting with each other will be tied to the quality, value and benefit we get out of that journey. Commuting will be matched with purpose. This will be the future. A hybrid future, where some movements have been eliminated. (...) There are things that we have done out of duty, in our personal and working lives, that we have been able to avoid in this period. And I think we would greatly benefit from further eliminating other few things towards a new equilibrium."*
>
> *(Arianna Censi - Councilor for Mobility)*

> *"I believe that virtual mobility will make the real world even more exclusive and interesting. Since you will be able to do everything in the metaverse, I will enjoy the real world much more by experiencing it with all my senses at 360°"*
>
> *(Giulio Del Balzo - Public policy manager)*

Putting it all together

"*Look at the world around you. It may seem like an immovable, implacable place. It is not. With the slightest push—in just the right place—it can be tipped*." Malcolm Gladwell.

In conclusion, Outsider experts presented how the evolution, improvements, or blocking of the future of sustainable urban mobility in 2035 critically depends on the willingness of citizens to play an active role in change. In line with the growing trend of active participation in community life, people want to propose their ideas, lead the change and make the difference. However, this active level of participation is found mainly in the younger generation, more cohesive and committed to environmental changes. They started to change their commute experience according to more compelling goals, such as reducing the amount of pollution and downgrading the importance of owning a car. This trend can further be supported by educating people about the use and value of alternative commuting solutions to the car commute. Here, far-sighted politicians, public institutions, firms, research centers, and universities should collaborate to explain and guide the adoption of new transportation means and the need for different energy sources to propel the vehicle. In this way, the adoption of sustainable mobility solutions will be a choice for the vast majority of citizens, who are used to commuting with public solutions, even at a later age.

> *"Young people want to be involved in choosing new forms of mobility, they are cohesive in defining its direction, and they are waiting for the opportunity to build a different future. However, if I look at other age groups I see less participation in change or exclusive to certain job sectors"*
>
> *(Roberta Bonacossa – Climate activist)*

2.3 Other visions

As part of the data analysis, a qualitative review of the main existing foresight reports has been carried out focusing on urban mobility and the related technologies. Accordingly, nine foresight studies have been selected as representative, covering a foresight period of 20 to 30 years, a more extended time frame with respect to the one here considered.

These studies were commissioned by private institutions, public bodies, and academic entities. They have a different scale of analysis: wide region, megacities, and urban centers within Europe and around the world, where emerging technologies, regulations, and policies are pretty similar to Milan in terms of scale and context. Table 1 and Table 2 give an overview of the main existing foresight reports.

As a whole, according to these studies, the main trends, directions, and changes associated with the future of mobility are mostly related to social and technological changes as we summarize in the following.

Shared Mobility and Car-ownership

Previous studies mostly identified shared mobility services and car ownership as the key game-changers shaping the future of urban mobility. The development of new shared mobility services is likely to increase the vehicle usage intensity and lead to new business models. At the same time, however, this is expected to decline private vehicle ownership (European Commission, 2019). Car sharing, ride-sharing, and ride-sourcing (also known as transportation network companies or ride-hailing) are already widely popular in several urban areas worldwide and have a remarkable effect on road transport (European Commission, 2019). For instance, companies have invested billions of dollars in developing successful user-centered technologies and services (Arbib and Seba, 2017). In total, these companies drove 500,000 passengers per day in New York City in 2016 (Schaller, 2017), tripling the number of passengers driven the previous year. Likewise, in the Americas, car-sharing companies had a 4-fold increase in the number of their customer from 2009 to 2014 (Shaheen and Cohen, 2014).

As an additional example, Spieser et al. have claimed that Singapore's vehicle population could be reduced by two-thirds if everybody used shared mobility (Spieser et al., 2014). According to experts in Singapore, people in other parts of the world are increasingly adopting shared mobility because they believe that owning cars that spend more than 90% of the time not driving is not an effective use of their limited financial resources (SUTD, 2019). In fact, according to the Government Office for Science (2019), the average proportion of time UK car is parked accounts for 96% of the time. Moreover, studies indicate that car use and ownership are less prevalent among young cohorts than in the past. For most people, access to mobility services is more important than car ownership. More than 50% of adults licensed to drive in the EU do not own a car (European Commission, 2015).

Foresight report	Commissioning Entity	Published	Foresight year	Focus/Location of the Study
The Future of Road Transport	European Commission	2019	2050	European Urban Centers
The Future of Mobility	ETH Zurich	2020	2040	EU Cities
Smart Sustainable Mobility	European Commission	2015	2040	European Urban Centers
Rethinking Urban Mobility	London Transport Museum	2018	2040	UK
A time of unprecedent change in the transport system	Government Office for Science	2019	2040	UK
Tomorrow's Transport Starts Today	Netherlands STT Center	2014	2040	Cities in the Netherlands

Table 1. Reports focusing on cities within Europe.

Foresight report	Commissioning Entity	Published	Foresight year	Focus/Location of the Study
Insights into Future Mobility	MIT Energy Initiative	2019	2050	Megacities in US and China
A foresight study on Urban Mobility in Singapore	SUTD	2019	2040	Singapore
Future Demand	Ministry of transport, New Zealand	2014	2042	New Zealand's megacities

Table 2. Reports focusing on different megacities around the world.

Aging population

Social changes, such as the growing and aging population, overlay and interact with mobility. For example, active travel (walking and cycling) tends to decrease with age, while car use increases. This combines with the challenge of keeping the older population healthy and living independently for longer times (London transport museum, 2018). Today, 13% of the world population and 25% of the EU population are aged 60+. In 2050, this share is bound to increase to almost 21% of the world population and 35% of the EU population. Therefore, changes in the transport system need to account for the elderly population with limited mobility (European Commission, 2019).

E-commerce and virtual travel

Currently, shopping is the most common reason for personal travel, with commuting coming second. The rise of e-commerce has led to a decline in off-line shopping, as more people shop and order meals online, which has led to an increase in home deliveries. This, combined with growth in service vehicles, may help to explain the significant rise in van use in the UK (London transport museum, 2018). According to the study conducted by the Singapore University of Technology and Design, Internet and telecom technology will disrupt how people work, shop, socialize and learn by eradicating the need to be physically present. It will make [telecommuting] a norm. This provides tremendous opportunities for transport planners to disperse demand, and apart from that, it will spread peak demand over different times of the day as work hours become more flexible (SUTD, 2016).

Environmental reasons and electric vehicles

Environmental reasons will favor the use of electric vehicles and energy vectors like hydrogen, biofuels, and natural gas, which are crucial to break the European transport sector's dependence on fossil fuels and reduce greenhouse gas (GHG) emissions (European Commission, 2019). According to the London transport museum, transport in the UK is the largest energy consumer, accounting for 40% of total energy consumption in 2016, compared to 25% in 1980. Of this, 74% of the energy consumed is through road transport. Vehicle and engine efficiency improvements, electric vehicles, and alternative fuels will help the UK meet its decarbonization targets. The UK government is planning to ban the sale of new petrol and diesel cars by 2040.

Further, they are directing extensive investments that reach up to 500 million pounds to encourage the uptake of electric vehicles. (London transport museum, 2018). Electric vehicles (EVs), including battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs), are increasing their market penetration. In the near future, a reduction in the cost of key EV components (especially batteries) is expected, which can further accelerate their adoption (European Commission, 2019).

Automated and autonomous vehicles

Experts believe that commercial AVs will hit the roads in the near future and may even become mainstream as early as 2030. Even though it would take many years for AVs to completely replace conventional vehicles (SUTD, 2016), some optimistic estimates anticipate that by 2030, 95% of US passenger miles traveled will be served by on-demand autonomous EVs owned by fleet operators, accounting for 60% of the entire US vehicle fleet (Arbib and Seba, 2017).

Other authors (Litman, 2016) conservatively estimate that by 2050, between 50% and 80% of distance traveled will be in AVs, constituting between 40 % and 60 % of the vehicle fleet (European Commission, 2019). Moreover, many studies have predicted that by the year 2030, the safety level of driverless cars is expected to be higher than that of 'regular cars' (operated by human drivers), and by consequence, AVs can accelerate the adoption of shared mobility by reducing one significant operational cost: the driver (Corwin et al., 2015; European Commission, 2018c).

Figure 5.

The map of the landscape emerging from research and experts' conversations.


Electric vehicles
Railway mobility
Air mobilty
Autonomous vehicles
Micro mobility
Transportation Means
Big Data
Energy infrastructure and sources
Internet connection quality
Virtual travel
Data security
Mobility enabling technologies
Sensors for on board experiences
Community involvement
Income inequality
Working habits
Social
Sustainable Mobility
Urban People
Sharing services
Mobility services
Shopping habits
Demographic changes
Individuals' lifestyles
Insurance
MaaS
Administration trust
Area access policies
Political regulations
Urban configurations
Mobility supporting infrastructure
Urban safety
Effects of climate changes
Interoperability framework
Roads changes
Urban boundaries
Legend
Number of signals found
High
Low

Foresight

3

In a fast-moving and complex world, there are significant uncertainties about the future that may have a strong impact on organizations and their capacity to meet their objectives in the long-term. As a systematic and inclusive approach, exploratory scenarios are adopted in foresight practice as a means of dealing with critical issues of innovation and to offer alternatives against which predictions may need to be validated.

Within the process of scenario development, it was decided to use four archetypes—growth, collapse, constraint, and transformation—help us envision futures that are neither variations of a single future, nor simple mirrors of the present.

Images of the future are critically important to how we respond to change and envision better worlds. Our images are often dominated by extrapolating trend lines forward. Sometimes, we make specific forecasts about events or directions of change. But when change is deep and hard to see, we need to take many alternative possibilities into account. We need stories that we can compare and contrast, and even choose among to make the future we want. That's when we turn to scenarios.

There are many ways to develop scenarios. The most commonly used scenario planning method focuses on exploring two critical uncertainties. Some frameworks compare pragmatic, utopian, and speculative futures, but they all focus on distinguishing different possibilities.

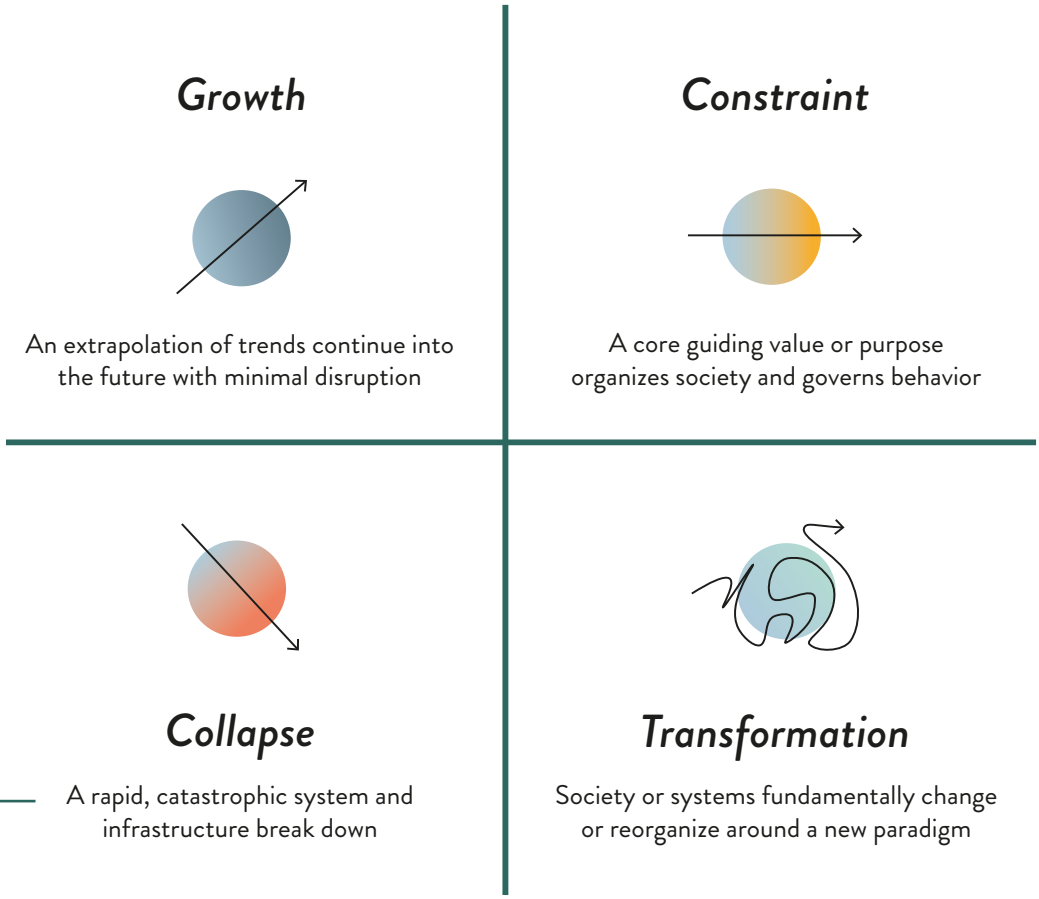


Figure 6.
Alternative future directions.

Using multiple scenarios offers a way to think outside "one true future" or even a "most likely" future.

The Alternative Futures framework in particular pushes our minds outward to the edges of our imaginations. If you're only thinking in terms of more or less "growth" or "progress," you're missing the very real possibilities for collapse and radical transformation that we have seen throughout history.

When Jim Dator and his team at the University of Hawaii at Manoa created the Alternative Futures framework, they collected thousands of images of the future from all over the world. After careful analysis, Dator identified the underlying story archetypes, or generic shapes of change. Dator found the same four archetypes repeated by indigenous myths and think tanks alike: growth, constraint, collapse, and transformation (Figure 6).

- *Growth*: An extrapolation of trends continue into the future with minimal disruption.
- *Constraint*: A core guiding value or purpose organizes society and governs behavior.
- *Collapse*: A rapid, catastrophic systems and infrastructure break down.
- *Transformation*: Society or systems fundamentally change or reorganize around a new paradigm.

Scenarios are a unique blend of researched facts (drivers and signals of change) and creative extrapolations. Scenario writing takes practice and true virtuosity comes from repeated learning and improvement.

Scenarios can take many forms, including documentary style, a "day in the life," a report or historical account, or critical analysis. But all good scenarios have the following characteristics:

- Allow a reader to understand a different world in a way that draws out insights.
- Are logically coherent and internally consistent, where the external events and human actions make sense in relation to each other. The world might be quite provocative, maybe even ridiculous at first glance, but deeper engagement generates deeper understanding and plausibility.
- Are based on evidence from drivers, signals, and other research, but make a leap from the foundations into new territory. A set of scenarios should explore a wide range of possibilities and be distinct from each other in fundamental ways.
- Elucidate both the dynamics of the external world, and what it feels like to be a person in that world.

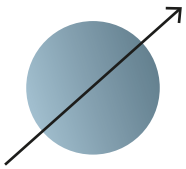
The four alternative futures have been used by the experts at Politecnico di Milano to develop sectoral scenarios on mobility and identify impact requirements and opportunities for sustainable urban mobility in 2035, also targeting Sustainable Development Goals.

3.1 Four alternative futures

In our working context, imagining mobility in a metropolitan city like Milan, the alternative futures take the shapes presented in the following (Figure 7).

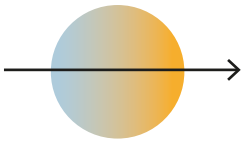
While climate change disrupts the physical environment we escape with immersive digital technologies

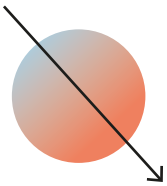
Growth



We experience heavy restrictions on carbon and luxury, and a walking is a mandatory civic duty - all in order to survive climate change

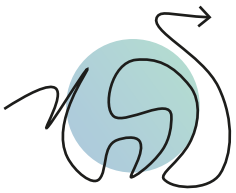
Constraint





Collapse

This is a world where compounding climate crises cause social and political disruption faster than we anticipated



Transformation

A future where we effectively cooperate with others to achieve sustainability and produce compounding benefits

Figure 7.
Peculiarities of each of the four alternative futures.

Growth: moving across the metaverse

We experience immersive digital technologies, while climate change disrupts the physical environment

On a stable day, leisure is the main reason to move around Milan. A large portion of its people commute digitally, bringing with them their phygital office spaces wherever they go, while others share physical smart infrastructures that provide better bandwidth and holographic immersion technologies. Millions of people walk the digital streets of Milan everyday, stepping in from many different continents to work, play, shop and tour. Every year, thousands are even granted e-citizenship after buying a piece of Milan's virtual real-estate. But these are the lucky ones.

The caregivers, clerks and blue-collar workers, whose technologically enhanced jobs require them to be more physical than digital most of the time, venture daily into the uncertainties of 21st century's extreme weather. In Milan, the issue is not so much about a digital divide, but a presence divide. Being able to be fully remote became Milan's ultimate luxury.

In Milan's "earthverse", goods, parcels, and emergency energy batteries "commute" toward people's locations on a regular basis. Fleets of autonomous eSUVs swarm in and out of the city, while ground and air drones provide last-mile deliveries to citizens wherever they are. However, many people still ride the streets. And when they do, their journeys are curated and automatically coordinated between different modes of transport.

The city has one of the world's largest fleets of semi-autonomous cars, but driving in Milan is nothing but a privilege. The wealthy and famous preserve the tradition of parading with Ferraris and Lamborghinis, except they're required to sign up for temporary permissions and pay expensive fees proportional to the length of their rides. But non-autonomous and carbon-powered vehicles are increasingly becoming a rare sight in the streets of Milan. On one hand, insurance for human-driven cars is extremely expensive. On the other, only a handful of gas stations still operate in the city.

But stable days are rare in 2035. The milanese live in a constant state of emergency, waiting for the moment they'll have to pack their belongings and relocate *en masse* due to an even more extreme storm or blizzard. This emergency scenario is a permanent simulation at Milan's metaverse, so it can be rehearsed at schools, government buildings and corporations in the earthverse on a constant basis. And though the city might seem to have the right tools and infrastructure to deal with this challenge, the algorithms governing the city hint that such disruptions might not be overcome by use of infrastructure alone.

Supporting evidence:

- A “mere” 0.5°C increase causes exponential shifts in weather.
- Climate nationalism is how geopolitics is being played.
- Milan is the 3rd most-hit city by climate change.
- Corporations are migrating due to climate change.
- Climate migration can be a strategy for urban economic growth.
- Korean smart city selects its first residents.
- Major municipalities exist partially in virtual reality.
- Communities are being digitized into the metaverse.
- Metaverse technologies capture involuntary biometric data of users.
- Collaborating in a holographic metaverse.
- Facebook is developing photorealistic avatars for the metaverse.
- AI automates policy-making.
- Distributed systems simulate and orchestrate users’ journeys autonomously.
- Hagglebots can curate and orchestrate transactions on our behalf.
- Metaverse equipment is rapidly becoming more user-friendly.
- New business models are complementing inter-city energy distribution infrastructures.
- Former AOL CEO called the real-world the “Earthverse”.
- The UK will require homes to have EV stations.
- Reduced latency in 5G networks enables connected vehicles.
- Singapore develops a digital twin.
- Public transportation will be automated.
- Seamless mobility, a concept that blurs private and public transportation.

Impacts on SDGs

- ***Affordable clean energy:*** Access to clean and affordable energy are key differentiators for climate migrants.
- ***Industry, innovation and infrastructure:*** Digital technologies and data increase exponentially.
- ***Decent work and economic growth:*** An experiential divide emerges as a consequence of the metaverse.
- ***Sustainable cities and communities:*** Climate supremacy emerges, as cities and communities compete over who's more sustainable.
- ***Climate action:*** The world did just enough to hold climate change at 2°C.
- ***Partnerships for the goals:*** Public and private companies cooperate, but economic, political power is largely privatized.

Highlights of Impact Requirements

- Policymakers will have to manage the digital divide by investing in digital infrastructure and platforms to support the public and create a more inclusive digital environment.
- Organizations and policymakers will have to mitigate the impact of artificial intelligence and cybersecurity on the public.
- Verification of digital identity.
- New regulations around metaverse business models and policies around an open metaverse structure.
- Re-skilling of workers to adapt to the phygital world.
- Actively contribute and promote green solutions and behaviors to mitigate the impact on climate change.
- Regulate energy communities or distributed energy markets.
- Private and public sectors to form new partnerships and initiatives around managing mobility in the city.

Highlights of Impact Opportunities

- Drive new initiatives in transportation and mobility management from planning, vision and design to implementation and infrastructure as vehicles become more connected.
- Designing the mobility software and hardware with a great focus on security and safety as well as defining and implementing new services and applications that will arise on the way by utilizing the knowledge and input from new generation students entering the university.
- Better capture, communicate and visualize the climate impact of mobility systems to users and the public by introducing new city environmental metrics.

Constraint: the emergency brake

In this scenario, we experience heavy restrictions on carbon and luxury, and a walking is a mandatory civic duty - all in order to survive climate change.

Milan's radical plan involves an aggressive carbon budget that encompasses the whole city. People, companies, infrastructures and services are allowed to generate only a few grams of carbon per day, with penalties varying from heavy fees to dissolution. But it also involves an increasingly aggressive carbon shaming culture trying to ban anything carbon-related. This includes cars and their variations, which are heavily associated with greenhouse gas emissions and unsustainable supply chains.

In Milan, fossil fuels are outlawed and the few EV cars in circulation may only enter the city up to the outer viales. Electricity is highly regulated, but essential heating, cooling and health is guaranteed with EV ambulances being the most common vehicles in town. In general, ground transportation is highly taxed, and as a response, low-altitude, low-carbon airships are starting to dominate the city's skyline.

For the Milanese, walking is a civic duty enforced by both culture and law. One of the last massive mobility infrastructures approved by the city council includes La Corsia Verde, a multi-kilometer pedestrian lane criss-crossing the city that converts the kinetic energy of pedestrians into electricity. Every able Milanese citizen has to perform a number of regular walks in La Corsia Verde every month in order to generate enough power for the city's public infrastructures. The lane became a symbol of unity and sacrifice for the Milanese. Religious processions, sustainable fashion shows and quarter-marathons all happen in the Corsia Verde, which was designed to provide maximum shelter from extreme weather conditions. But as the walkability revolution moves forward, both citizens living in the suburbs and disabled people alike have started complaining about how isolated from downtown Milan they have become.

If asked, most Milanese will say they hate how restricted their lives are. They might even agree that Milan's version of the Emergency Brake is oppressive. But sadly, they'll also be quick to point out that climate change is an even worse tyrant.

Supporting evidence:

- US city impose limits to car ownership.
- New technology enables people to generate electricity by simply walking.
- China wants to curb excessive income and urges the wealthy to return more to society.
- Time millionaires are surging in the middle of the great resignation.
- Annual carbon budgets become national policy.
- Degrowth economics accelerate into the mainstream.
- Airships offer cleaner but slower flight.
- Emotions of populations can be tracked, analyzed and guide policy.
- New Zealand is outlawing bad habits.
- Air pollution also impacts mental health.
- Sustainability is dead.
- Carbon taxes could finance green services and improve the lives of people.
- Zombie fires can accelerate climate change.
- Extreme weather events isolate Canadian communities.
- The Nap Ministry uses rest as a revolutionary act.
- The world likely to experience 2.7°C increase in global temperatures.
- Cities play a pivotal role in climate adaptation.
- Universal Basic Income might be key to a post-carbon transition.
- Networks of civic and climate volunteers are on the rise.
- The rise of climate anxiety.
- Immigrants commute way more than locals.
- Increased awareness on the value of data.
- Urban designers are reducing space for cars.
- Paris plans to focus on walking and cycling.
- Global policymakers are creating new standards for sustainable transportation.

Impacts on SDGs

- ***No Poverty:*** The world faces massive unemployment, but in part it's voluntary and seen as a duty.
- ***Good Health and Wellbeing:*** There's a shift toward community health and wellbeing that leads to collective sacrifices.
- ***Affordable and Clean Energy:*** Clean energy becomes the only type of energy available, but its systemic impacts are highly regulated too.
- ***Reduced Inequalities:*** Excessive wealth from individuals and organizations is forcefully redistributed.
- ***Sustainable Cities and Communities:*** Communities are hyper-local, self-sufficient and mainly self-contained, to the point of risking to become isolated.
- ***Responsible Production and Consumption:*** Luxury and excessive wealth is illegal and culturally perceived as immoral, while carbon-based products are banned.
- ***Climate Action:*** Inaction led to a tipping point, which led to desperate measures to contain climate change.
- ***Peace, Justice and Strong Institutions:*** Communities agree on highly restrictive emergency measures that are enforced by both law and culture.

Highlights of Impact Requirements

- Reduction of mobility requires improved autonomous neighborhoods at a local scale, which means a need for increased investments in the local economy, activities, and communities.
- Decreased income from tourism requires new social and economic models and levers for local neighborhoods to survive.
- New urban services and business models to support different types of mobility services: basic/essential public transportation, goods and commerce mobility, and active mobility.
- Mobility policy-making is about the urban economic organization, as the global economy is disrupted.
- Need to create social acceptance around restrictions imposed by policy and government by focusing on trust-building in the local communities.

Highlights of Impact Opportunities

- We will have "more space and more time" as we move around more locally, opening up new opportunities to socialize and enjoy the local environment and community in newly found leisure time.
- New business opportunities between e-commerce and local businesses.
- New models to measure climate impact and footprint at the scale of the individual.
- Societal constraints can open up doors for new types of partnerships between organizations, citizens, and policymakers to come together to fight a common threat. While considering who might resist these new partnerships, collaborations, and initiatives.

Collapse: hardly mobile Milan

This is a world where compounding climate crises cause social and political disruption faster than we anticipated.

Between climate catastrophe and the resulting state of unrest, it's not easy to move around Milan. Most people stick to their 20-minute neighborhoods and don't venture beyond streets they are intimately familiar with. Micro-mobility is the preferred means of transport. Electric bikes that recharge as you pedal are one of the most coveted and stolen items. Many people take a DIY approach and assemble their own bikes and boards. Some share their vehicles with their neighbors, unable to afford their own vehicles. Many of the vehicles and the infrastructure are unregulated, and not always safe.

With so much wealth inequality, steep cost of housing, it's all most people can afford to own. Anyone with a 3D printer and blueprints for micromobiles is in a position of power they must guard carefully. Elites prefer their luxury autonomous vehicles; no drivers means fewer people who can turn on them. Those who are employed by the elites are treated as part of the family.

An underground transportation system becomes a necessity if Milan wants to keep autonomous vehicles in operation. Flash floods make it almost impossible to maintain above ground electric and autonomous infrastructure. Since these vehicles were not designed with local conditions in mind, they are not equipped to deal with Milan's extreme and erratic weather. At the very least, their software and hardware must be altered. When the Teslas and Mercedes of the world demand money in exchange for locking climate and local condition features, these vehicles become very expensive investments. Limited global supply of chips and other critical hardware pieces makes it difficult to procure enough vehicles, anyway.

Erratic weather conditions and frequent flooding make driving above ground a precarious activity. Without continuously updated, predictive tracking that everyone can access, mobility is easily derailed by day-to-day hardships. It takes data lakes to navigate floods, and Milan lacks the infrastructure.

Disaster strikes when bad actors hack vehicles and/or the systems to reroute and confiscate valuable supplies or hurt enforcement officials. While city infrastructure is cut off at its border, designated "out of city vehicles" are allowed to bring goods in and take them out in the rare case they need to. No external vehicles are allowed in and must be left outside the walls. Mobile security is the only way to stay safe.

Forza Milan, but only for Milan.

Supporting evidence:

- A 4-degree Celsius temperature increase will be highly destructive and devastating.
- Gulfstream currents are already at their slowest point in at least 1,600 years, but the new analysis shows they may be nearing a shutdown. For Europe, this may increase storms and lower temperatures, while triggering a global food shortage crisis.
- Earthquake in Japan disrupted the global electronics supply chain.
- The US and other countries were accused of PPE confiscation during the onset of the pandemic.
- The West is only now facing with challenges that the East and Global South have faced for years.
- Relationship between extreme weather and violence.
- Growing conversation around city-states.
- Blockchain may play a critical role in autonomous vehicles, with emerging use cases.
- Emerging conversations about the 20-minute neighborhood.
- Elites securing bunkers in potential climate havens.
- Toronto's underground city structure (known as The Path).
- A roaming ecosystem of data lakes may help optimize mobility data.
- A post-car city may come about out of necessity, crumbling infrastructure.
- Boom in micro-mobility.
- Increase demand for e-bikes.
- 20-minute neighborhoods due to lack of mobility, affordability.
- Surveillance for crime and cohersion, not safety with Amazon Ring.

Impacts on SDGs

- ***No poverty:*** Poverty is exacerbated by climate disasters and growing wealth disparities.
- ***Zero hunger:*** Hunger increases when inequalities are exacerbated.
- ***Reduced inequalities:*** Racial, gender, and other forms of inequalities are projected to increase as climate change worsens.
- ***Sustainable cities and communities:*** Cities and communities deteriorate with climate disasters.
- ***Climate action:*** Not enough climate action is taken to mitigate disaster in this scenario.

Highlights of Impact Requirements

- Need for flexibility in local and shared mobility systems as we move into virtually gated communities enforced by the impact of climate change.
- Designing mobility systems based on local, not global, conditions.
- Essential services like access to education, healthcare systems and energy will be distributed and require new models of local support, resources and initiatives.
- New business models for sharing goods and services within and between communities.
- "Green and clean" energy has to become default and not optional by introduction of new policies.

Highlights of Impact Opportunities

- Mobility will be a key enabler for urban survival as we move towards smaller local communities.
- Localization will open up new spaces for opportunities at a community level, e.g development of micro energy resources, DIY and custom made approaches for employment and micro community infrastructure, new definitions of community values as a local currency.
- Multimodality between neighboring community car sharing systems, shared electrical bikes and societal flexibility in transportation systems.
- Leisure time will be spent more within closed communities thus opening up new spaces to explore more local events and cultural engagement opportunities.
- Explore ways to support potentially beneficial grassroots, hyperlocal, improvised and unregulated initiatives.

Transformation: mindful mobility

In this scenario, we effectively cooperate with others to achieve sustainability and produce compounding benefits.

Milan embraces an ethos of mindful mobility. A mobility that is intentional, conscientiously designed, and beneficial to planet and people. Energy generating roads help charge autonomous electric vehicles and e-bikes, while producing additional energy for the city and its suburbs. Outfitted with solar panels, these vehicles require little to no charging, reducing Milan's charging footprint. Effective car sharing solutions, less emphasis on ownership, single passenger vehicles, and traffic coordinating algorithms allow Milan to convert parking spaces into urban farms, community centers, outdoor patios, and green spaces. Few cars are seen in Milan's core. Not everyone (especially the wealthy) are willing to give up their cars. Residents are incentivized to opt for greener and cleaner solutions.

Remote work is the norm and most commutes are eliminated, with the exception of frontline work. Public transportation is free and easily accessible to all. Those who do own cars have personalized vehicles built for them at local microfactories. People begin to experiment with the structure of these vehicles as an extension of Milan's fashion prowess. Because most vehicles are autonomous, they are redesigned to provide experiences. Mobility is not simply about getting from one place to another, it is a journey that is coupled with learning, work, play, entertainment, and connection. Transportation is a public-private partnership that benefits the city's residents.

The mobility of birds, bees, and even pollen is taken into account to ensure that Milan remains a multi-species city. More parts of Milan are redesigned as 15-minute neighborhoods to help us move in ways that improve our happiness, serendipity, and connections to others.

When Milan moves, it inspires.

Supporting evidence:

- Amsterdam adopts doughnut economics.
- China pursues “common prosperity” not growth.
- Spain introduces a country-wide UBI program.
- UK woodlands save £185m a year in mental health costs.
- The term “nature positive” is used at G7.
- Costa Rica’s ‘Sweet City’ gives citizenship to bees, plants, and trees.
- Aptera’s vehicles are solar powered.
- Finland gives free housing to the homeless because it’s cheaper.
- Ikea reimagines cars as hotels, coffee shops, etc.
- Tony Hsieh’s vision for cities maximized “collisions”.
- An AI-powered model easily measures whether firms climate goals match up with their actions.
- G7 aim to close cross-border tax loopholes.
- Millennials and Gen Z are dissatisfied with governments and businesses.
- Vision Zero: reducing human-generated accidents.
- Modular autonomous buses.
- Single-seat electric vehicles (new forms of micro-mobility).
- Edge computing: enhancing analytics and reducing latency.
- Robots may enable 4-day work weeks.
- Post-car cities allows for re-purposing of space once taken up by cars.
- Melbourne popularizes 20-minute neighborhoods, emphasizing active transport.
- Recovery Fund, an opportunity to re-organize our cities as 15-minute city.

Impacts on SDGs

- ***Affordable and clean energy:*** Aggressive shifts towards clean energy and renewables.
- ***Industry, innovation, and infrastructure:*** Emphasis on green infrastructure and redesigning systems.
- ***Sustainable cities and communities:*** Accelerated action towards sustainability
- ***Climate action:*** Meaningful climate action and adaptation.
- ***Peace, justice, and strong institutions:*** Strong institutions that act in the best interests of people.
- ***Partnership for the goals:*** Collaboration between key stakeholders including government, industry, and youth.

Highlights of Impact Requirements

- Sustainable shared mobility and city infrastructure without personal ownership of vehicles.
- Mobility is designed for the citizens and not for the cars.
- Top down enforced policy changes require educating the population around a shared understanding for the role of sustainability in the development of mobility infrastructure.
- Critical collaborative partnerships between policymakers, organizations and citizens to build trust and engagement around the responsibilities the different actors play and provide everyone with an active societal role.
- Tech transparency is critical for trust and ethical use.

Highlights of Impact Opportunities

- Focus on three axis of opportunities: knowledge creation, knowledge sharing and knowledge transfer.
- Developing novel ways to validate economic and sustainable models while running urban pilot tests to demonstrate, convince, and educate policymakers and the public in what a sustainable mobility transformation would look like.
- Economic incentives for citizens and organizations to transition into more sustainable households and businesses (e.g., by sharing resources).
- Envisioning, designing, developing, and deploying info mobility systems and green, efficient, sustainable infrastructure for micro-mobility and macro mobility.
- Experiment with citizen design solutions for improving the livability of public space and accessibility by proximity.

3.2 Emerging macro drivers

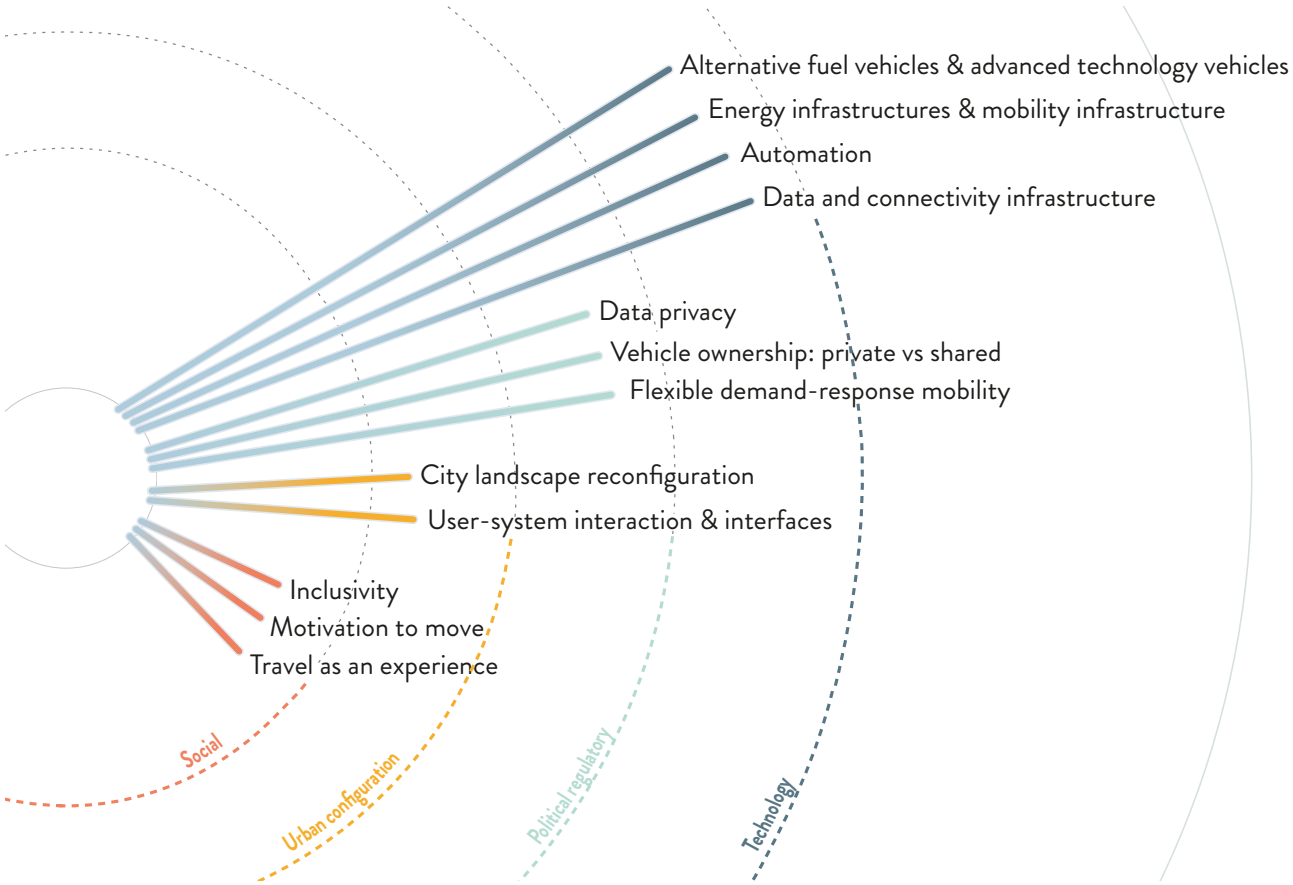
The future of sustainable urban mobility in 2035 is a complex environment that goes beyond the definition of the main transportation means that citizens will experience by commuting in the urban area. It considers what might be immutable as the urban infrastructure, what is on the move regardless of the source that propels it, the broad digital world that supports the mobility and the complex human sphere concerning individual's behaviors, desires and needs.

Besides the various forces that could impact such mobility in 2035, twelve main drivers have been recurrently highlighted by internal and outside experts as crucial aspects to take into account when considering urban mobility (Figure 8). These considerations have been pondered on the Italian context, in particular referring to the Milan metropolitan area, however they apply to many European metropolis.

#1 Alternative fuel vehicles & advanced technology vehicles

Electric vehicles are envisioned to become the status quo. Gradually in the city center no more vehicles propelled with fossil fuels will be allowed to circulate. Driven by restriction laws also new other typology of fuels will be commercialized to enable different typology of vehicles to circulate. They are presented in form of e-fuels or biofuels to provide solutions that compensate the amount of CO_2 emitted by the vehicle during the production system, or for example using organic materials that can be easily renewed and do not harm the ecosystem. Despite the mixed adoption of energy sources, the pressure on the electric system remains high.

Figure 8.
Emerging macro drivers



This expected rise in request of electricity will force public administrations to invest in urban transportation propelled with hydrogen, helping to reduce the electricity demand on the system, another valuable solution could be the zinc batteries. Although electric vehicles are presented as the main solution to reduced vehicles carbon emissions, their sustainability is also linked to the design of more efficient batteries that are composed with less critical raw materials, to avoid critical bottlenecks in the life cycle of batteries and to assure long term sustainability of e-mobility.

Food for thought

- *Pay attention to family costs*. Requiring a new electric vehicle can create social discrimination since not everyone can afford it.
- *New rituals in the driving experience.* A different car engine (along with a likely change in vehicle ownership) could change the crucial activities while driving, to the point of changing even the most stressful ones. So it is possible that the driving experience we are used to conceiving of will no longer be relevant in 2035.
- *Impact of leisure travel on daily commuting.* The different requirements during leisure commuting (more independence and freedom) compared to daily commuting risk having a negative impact on the willingness to switch to more sustainable solutions. Undermining the efforts made towards more sustainable mobility.
- *The destiny of fossil fuel vehicles.* The massive demand to abandon fuel-burning vehicles in favor of more sustainable solutions directly raises the question of how institutions will deal with the disposal of these vehicles. It will be possible, in order to be more sustainable, to reuse some components in new cars or to use them for a new purpose. Important to speed up the conversion will also be the economic incentives allocated.

#2 Energy & mobility infrastructures

A critical point that cannot be put aside when reflecting on urban mobility of 2035 is the development of physical infrastructures that guarantee the proper mobility experience. The triggering point is the investments in the construction and capillarity of electric vehicle charging stations, which are underserved today. In this way, with widespread accessibility of charging stations in the urban area, EV adoption can spread. However, their construction requires expansion of electricity supply, standardization of vehicle charging methods, and thus the political will to invest in this solution over other forms of charging. Along with the development of widespread electric infrastructure in 2035, electric vehicles could themselves become carriers to transport electricity, a means of providing ubiquity in distribution supported by smart grid infrastructure. Relevant to be considered is that despite EV vehicles reduce the amount of CO_2 emission in the city, they do not improve the traffic road conditions and stress of urban life without law restrictions. Indeed, electric vehicles could slow down the pollution level in the urban area, but in the long term cannot improve the sustainable urban mobility. Another infrastructure investment is to support the desire to safely commute by bicycle, e-scooter or other personal micro-mobility solutions. Dedicated lanes should be built around the entire urban area to allow for these movements, as well as dedicated parking solutions for these soft vehicles. In addition, these vehicles also require a dedicated charging station since most of them are powered by electricity. However, with a different structure than 4-wheeled vehicles. Relevant to note is that bold political choices are required to influence the number of vehicles on the roads to balance the effects of aforementioned investments. Since by investing in ubiquitous charging stations

the car adoption might be incentivized, as the widespread number of charging stations outweighs the risk of running out of charge. On the other hand, the construction of lanes dedicated to active mobility is done by eroding road lanes traditionally dedicated to cars, so the municipality chooses to limit the number of vehicles on the road by reducing their space to circulate.

Food for thought:

- *The use(lessness) of charging stations in the city.* If only shared cars will circulate in the city, will it still be necessary to create charging stations scattered throughout the city? It could be more efficient to have a single collection point where they can be recharged with clean energy sources.
- *Enlarging the scope of analysis.* In a paradigm where cities are banning cars within the city center, policymakers should decide to confine the future of cars to movements among different urban areas, focusing on intra city movements to support individual needs.

#3 Automation

Despite the great potential that autonomous vehicles can provide to urban mobility and people's lives, their future is quite controversial due to liability management and the definition of dedicated spaces within the city center. Autonomous vehicles (AVs) have the capability to change the value of commute time, since once on-board the cozy environment enable commuters to do whatever they prefer, the travel time becomes itself a moment to work efficiently or to dedicate to relax. However, due to the high unpredictability of city environment, maintaining the contemporary city structure will prevent to have a safe circulation of AVs by 2035. To circulate they might require dedicated areas, but this opens up a controversy: if AVs are confined to specific areas how they could enable the freedom in moving everywhere and a new quality of time in respect to traditional cars? For this reason, waiting for the proper evolution of the system, the adoption of AVs in 2035 is more likely on highways and used in support on public transportation. Specifically, autonomous buses or robotaxi can become a substitute of public services, to cross along specific paths but with easily adaptability of user's demand. Finally, the impact that AVs will ensure is to improve accessibility to urban mobility for an increasingly wide range of people. Incentivizing not only those who had difficulties or were excluded from the use of public transport but also those who by choice preferred a private vehicle. Becoming a plus to shared mobility, bringing more and more people closer to it.

Food for thought:

- *The eclipse of public transportation.* With the development of widespread AVs in the urban area, the role of traditional public transportation has been challenged. Will buses and subways still be needed in urban areas if AVs enable ubiquitous, on-demand travel for everyone and greater privacy during travel?
- *The advantage of the rich.* If AVs are limited to specific urban areas, the presence or absence of such a service may widen the social divide if the administration prefers central and more wealthy areas of the city over more peripheral ones. This situation is further exacerbated if the use of AVs will not be integrated with that of public transport, with the risk of becoming an elite service.
- *AVs shouldn't be owned.* The benefits of introducing this service are only guaranteed if the vehicles are shared and publicly available. If their adoption remains as private cars, the improvements on urban spaces, city traffic, and inclusivity would vanish.

- *The effect on the job market.* The shift in the mobility paradigm, especially driven by the introduction of AVs, generates considerable effects in the labor market. New types of workers emerge, along with car and public transit drivers losing their positions. However, the cost savings achieved by labor automation will have to be balanced with government efforts to find a new purpose and position for these workers.

#4 Data and connectivity infrastructure

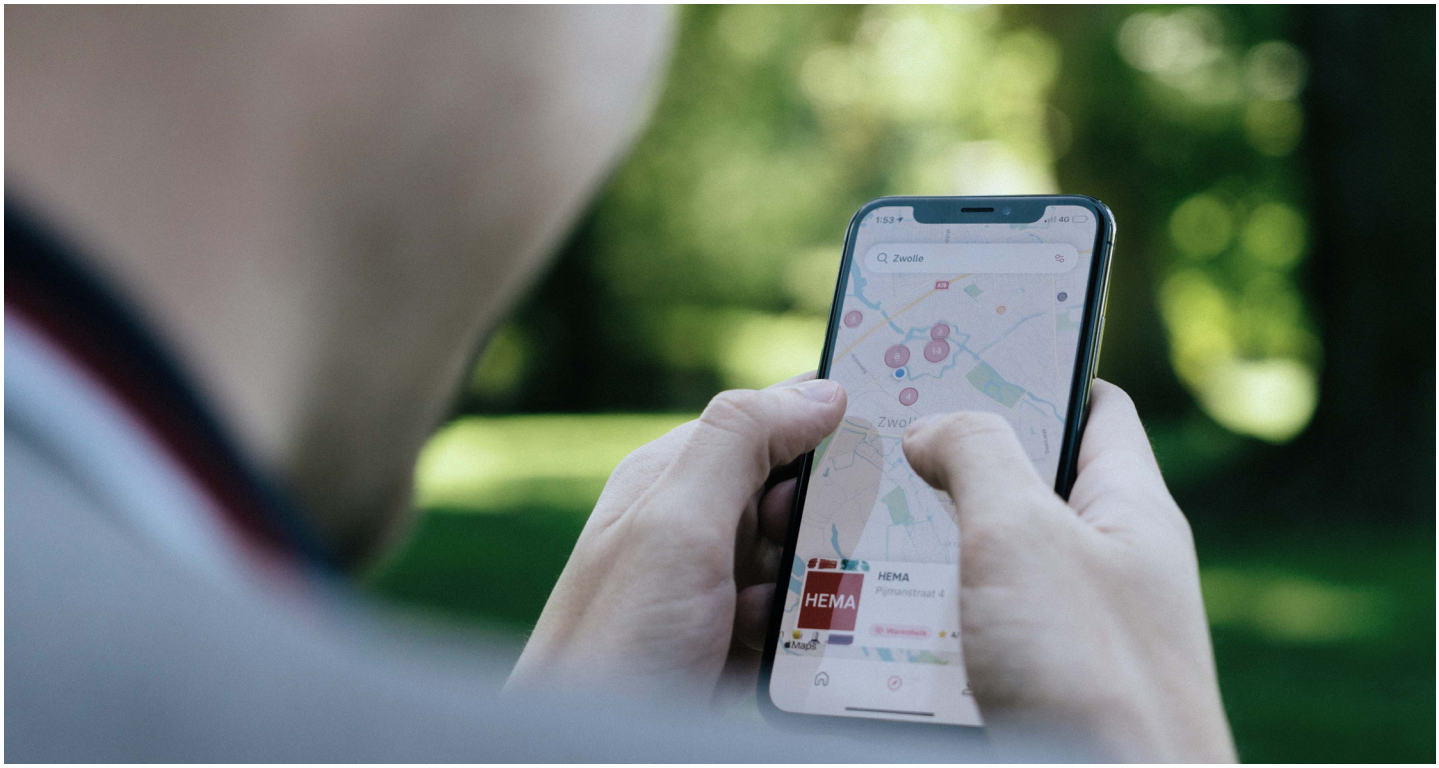
The mobility of the future is envisioned as a solution that is shaped on daily users' needs, without forcing the individual to adjust his or her daily schedule according to it. This means a generalized and unified management of data coming from different sources to deliver the right service in the right time and in the right place. Data will make the difference in the mobility of the future and users are raising awareness of it, with the demand to exchange them in favor of a customized and on time service. Data should be analyzed and handled by a single entity, despite the fact that mobility services will be operated by private or public institutions. By reaching this objective, the adoption of an effective MaaS could be achieved with an easier integration of mobility network (trains, buses, shared services etc) managed as one single mobility solution. However, investing in the proper level of connectivity infrastructure is important to deploy on-demand mobility also in area outside the central one. Investing in 5G or infrastructure connectivity will enable more sensibility and timing in data transmission, to have a more reliable exploitation of network data.

Food for thought:

- *Data are the new gold.* Users are becoming more accustomed to the value of their data, they require full transparency and ease access of data exploitation and management to be sure that the value extracted is not wasted.

#5 Data privacy

The huge amount of collected data will impact numerous aspects of citizen's future life, mobility included. As the urban mobility will strictly depend on data exploitation and usage, two critical



aspects mentioned in association with the innovative solutions offered are data privacy and security. This point is related to who will become the central authority that manages the data. Not all the participants converged in presenting public government as the preferable choice to organize them, as for someone an external party will be more reliable and faster in responding to cyberattacks. Pivoting point to increase the services offered is to improve the reliability and trust of sharing personal data with the central authority. Data will become a public asset to be protected and used to enhance the community welfare. Citizens and businesses are increasing their awareness, asking municipalities to extract more impactful value from them. In addition, complete transparency in its use and storage will be needed, to be sure that privacy is guaranteed.

Food for thought:

- *Privacy trade-off.* Talking about data privacy might become a paradox in a world dominated by data where all movements and choices are traced. For someone, data privacy won't be a concern and municipalities can access data without constraints. For others, the knowledge of a central authority that is aware of every move will cause people to be more cautious about sharing data and request more information about their use.
- *Fear of being threatened with data.* The awareness of the value of data shared might induce in people an increased concern about loss of personal information, risk of eavesdropping, and effects on personal lives. These might make people more cautious about sharing data and accessing to all public mobility services.
- *Data security is a matter of trust and compromise.* Users are exchanging data for (mobility) services, expecting them to be worth and matching their expectations and data to be securely handled. Are all involved players aware of the values and expectations at stake?

#6 Vehicle ownership: private vs shared

Quite unanimously the experts envision the future of cities with no car circulating around, private cars will be no more perceived as an essential asset. The need to own a private car will gradually decrease and the destiny of cars will be a shared one. By building a network of services

(sharing both two- and four-wheelers vehicles and with public transport) people will obtain the same freedom of moving with a personal car and the need to buy it will decreased to almost zero. This is supported by the trend that today's youth give less and less importance to buying a car, preferring to rely on sharing services. Over time, using a car through a service will become more competitive even for long trips both in duration and in distance. In the future, owning a car will not grant the same social status compared to the past; rather, it will retain the benefit of freedom of using it, which, however, will increasingly be compared with other, even more sustainable, forms of mobility. Abandoning a private car will be driven by the economical savings but mainly by being more sustainable while moving as car commute is not a sustainable choice. Some participants reported that these years are the starting point of a real revolution in the mobility sector, in which it is the individual that proactively demands for alternative sustainable solutions and car manufacturers cope with it.

Food for thought:

- *To own or not to own a car.* The easy accessibility of sharing services, the rise in fuel, electricity and maintenance costs as well as growing restrictions will make the car an asset that only rich people could afford. So, as far as the aim is to disincentivize the adoption of private cars, rising ownership costs could benefit to their reduction. However, keeping in mind the effect it could have on widening the social divide.
- *The cars are smaller and "hybrid" but still there.* Since private cars will not be allowed to circulate, solutions such as the quadricycle (hybrid between car and motorcycle) will take hold, ensuring safety in movements and comfort in a less physical fatigue. But this way the traffic, land use, and CO_2 emissions in the system will still be there.
- *People push the paradigm shift.* For the first time, the change in paradigm is not driven by increased vehicle performance but by the willingness of users to assert new values. Ride this urban mobility momentum to trigger the adoption of new sustainable behaviors in other sectors as well.
- *No more all-purpose cars.* Today, cars are purchased both to be functional and to give fun/adrenaline. However, in the future the functional one might be overtaken and replaced by robotaxis or shared AVs. Some people will still prefer the pleasure of driving by desiring emotional cars. Although this activity could be performed with owned cars it is not impossible to imagine shared services in this segment too. But still confined to spaces outside the urban area.

#7 Flexible demand-responsive mobility

The structure of urban mobility in 2035 is expected to move towards a more flexible mobility offer. This becomes reality by leveraging on the available data to predict mobility needs generating an on-demand service, the possibility to be flexible in schedule the public transport time tables and with the possibility to relocate vehicles where demand is higher. In this way, the number and times of rides could be dynamically adjusted to actual demand, lowering costs without lowering users' satisfaction and quality of service. Achieving this will lead to the adoption of an effective MaaS. Moreover, the location of multi-modal stations in the most crowded areas of the city (or in the peripheral areas) enable the commuters to use the most sustainable means of transport (both for the environment, time spent, comfort) according to the location or destination. This fluid exchange of transport solutions will be at no additional costs to the user (calculated as monetary expenditure and mental efforts required to switch from one network to another).

Food for thought:

- *Public administrators need new expertise.* Orchestrating on-demand mobility requires a lot of data, the capacity to extract value from them and foresee the strategic impact. This requires data analytics skills, that need to be part of public administration employees.
- *In the urban area might be too difficult.* The high number of commuters in the urban area and their different mobility demands could make it really challenging to adapt on-demand solutions in the city center. In less populated areas it could be the game changer.
- *Expectations mismatch.* On-demand public transportation can be arranged by a variety of means, from mini buses to cabs. All options meet the requirement, albeit in different ways, but it may not match users' expectations. To reach a high level of satisfaction and therefore capillary adoption, on-demand mobility must take into account user preferences and requirements.

#8 City landscape reconfiguration

The urban landscape will gradually come to define itself as a megacity due to the social and service offerings. Although, the future of smaller and satellite cities is not necessary fated to disappear. The change in urban mobility and the different number of vehicles commuting within the city will change the urban structure not only in the configuration of streets lanes but also in freeing urban areas to be dedicated to new purposes. Indeed, the urban city configuration return to a people centric approach, where streets, squares and neighborhoods are organized to support the desire to get outside by giving additional stimulation and opportunities to move. Some participants stressed the vision of a human centric structure based on a proximity life, where people can easily access services without investing time and effort for long commute. The definition of 15-minute neighborhoods spread around the urban area guarantees a city at a human scale even in large urban cities in which social relations and active mobility are preserved. Indeed, the areas obtained by vacating parking spaces, no longer needed, will become social places where the community can meet and rediscover a new precious sense of community.

Generating a people centric structure means offering an urban quality of life that minimizes the mental stress of commuting with no more wasted time in parking or traffic congestions, leading to lower environmental noise and poor air quality. Thus, a new city structure with interconnected and available public spaces will gradually generate a more equitable society and reduce social inequalities between areas, returning the same urban value, opportunities, and thus quality of life to the former suburbs as well.

Food for thought:

- *Support social aggregation.* The new configuration of the space will certainly give impetus to a people-centered city, but the political will to support aggregation and social activities is necessary. Otherwise, the risk is to have large unused urban spaces creating social discontent.
- *Ease of movement could damage the planet.* The easier mobility accessibility and commute rise the risk of urban sprawl, using the soil to an unimaginable level. If people will increasingly need to move, the use of airspace could become an answer. By resolving political, legislative, and liability issues, urban air mobility could also take hold, but beyond 2035.
- *Cars wait outside.* If car travel is increasingly limited in the city (in favor of some shared vehicles) cars will be used primarily for outdoor travel. Is it possible that the boundaries of the urban area and those with less accessibility will become large parking lots for cars that people will seldom use, to move outside the urban perimeter only?

#9 User-system interaction & interfaces

Another frequently discussed topic is how users will interact with the urban mobility service. The future of adoption of sustainable mobility is based also on a widespread accessibility of the service considering the geographical diffusion and ease to interact with it. The first aspect requires both solutions to decouple from one transportation means to another one (as multimodal stations) and infrastructures that enables people to commute to reach different areas of the city (such as capillarity in streets for bike and pedestrian areas).

The second aspect regards the touchpoints within the vehicles and in the stations. Sensors will enhance the mobility experience to improve the driving safety and security (such as Augmented Reality experience); or providing extended features within the vehicles (such as voice-based interactions, extraction of biometric information). New touchpoints in the stations or before entering the public wagon allow for more flexible mobility options with automatic payments and enable an ease flow from different transportation means.

However, how this complex system will cope with inclusivity needs, to enable users with different digital and physical capabilities, requests and needs to be equally satisfied, cannot be neglected. For this reason, despite the potentiality of digital connections, for some users categories a traditional physical touchpoint will be required to access the service.

Food for thought:

- *A simple interface that aims for inclusivity*. Easy access to urban mobility ensures that individuals can choose from endless possibilities, connect with realities that were previously inaccessible, and thus express their potential. Through equitable mobility, people can self-determine and become who they want to be.
- *Flexibility might mean no stations*. The value of multimodal stations as a place to decouple

transportation is clear, however, their location must be worthy according to people's demand for mobility. But if demand will be more evenly distributed throughout the day (in hours and locations), will there still be a need for stations? Rather, it might be necessary to create smaller multimodal "stations", without fixed interfaces that can be moved over time according to the demand of citizens, providing an adequate level of flexibility in the urban configuration and better adaptation to the needs of users.

#10 Inclusivity

A long-debated issue that must be touched upon in the sustainable urban mobility of 2035 is to broaden the level of inclusivity of transportation means. The envisioned implementation of public transportation will allow many more people to move within the urban area (and even more when AVs will take place). The accessibility of transportation without depending on other people with driving skills or physical capabilities enable elderly, disable or children to safely reach their destinations. A mobility system that is easily accessible means to define equal society that overcomes the differences that still exists among social classes. So, enabling fair access to all transportation solutions can reduce or even solve the social gap in the society.

However, the push to structure an inclusive city should cope with barriers regarding digital touchpoints and physical accessibility. Municipalities should on one side allocate funds to invest in sliders, sidewalks and other investments to physically enable the access to mobility services. On the other hand, municipalities should collaborate with research centers and the community to support less tech savvy to comprehend the digital world, simplifying platform interfaces, thus enabling accessibility for all.

Food for thought:

- *Sustainable mobility is not for all.* Inducing widespread active mobility is good for the planet, but is it really inclusive? Not all people feel safe or able to move in this way. While these solutions are the most sustainable, they do not allow all citizens the same mobility options.

#11 Motivation to move

The endless possibilities given by digital tools and connectivity have induced a radical change in people's lifestyles. Traditional shopping habits and the daily commute to the workplace will no longer be taken for granted, as everything could be done remotely with a seamless experience. Both Politecnico di Milano and outside experts, presented how despite this digital influence in 2035 people will always need to experience the world and meet their beloved ones Digitization has brought a change in the daily routine as well as in the commuting experience. The need for mandatory travel has been radically reduced as almost everything can be done remotely, dedicating commuting to leisure travel. This change will induce a re-evaluation of the value of commuting: moving away from home becomes a choice, as an individual intention to devote time to that activity conferring a greater value on it. People will move pushed by the achievement of added value through the destination reached, the people met and the means of transport used. For the latter, for example, people will be motivated to commute driven by the awareness that moving by bike or on foot is not only a sustainable choice but also a way to stay active and support a healthy lifestyle.

Yet, the value that will induce people to physically commute could be negatively impacted by the adoption and improvements of virtual mobility. Digital tools create virtual travels that resemble the real world, giving a much more powerful second life that makes equally valuable virtual interactions with people and travel. However, along with presenting this threat to sustainable urban mobility, experts reflected that the very act of making interaction easier through digital tools encourages people to value physical commuting even more, supporting its unique meaning.

Food for thought:

- *The digital effect.* For now, virtual travel gives a new and unique value to real commuting. However, how long will real-world travel remain a value-add in a world where the metaverse will offer a more powerful second life with endless possibilities?
- *Engage also the laggards.* Awareness of the new value of mobility could be driven by schools, municipalities, and societal efforts to explain the benefit of embracing a new paradigm in urban mobility. Although people are driving the transformation of such mobility, some citizens still need support to understand their role in this change, the value they can extract, and how new means may come to change their motivations to get around.
- *Buy what is sustainable.* Motivation to move will also be influenced by the sustainability of freight mobility. First, people will choose solutions that have a lower environmental impact while still involving a physical move rather than having it delivered to their homes by unsustainable means. Secondly, in order to make the transport of goods in the city more sustainable, municipalities are changing the organization of mobility, thus influencing also the individual's mobility by making it more pleasant to travel in the city (with fewer trucks and heavy traffic).

#12 Travel as an experience

Personalization of the traveling experience, as well as the opportunity to use the time while moving from one place to another is an emergent aspect. Users expect to be able to do other activities during the trip to enjoy the time spent in mobility, such as having breakfast, a reserved space for working, or similar personalized opportunities. The vision of a future of work characterized by a "work-from-everywhere" scenario has an impact on the motivation to move (#11) but also on the expectations related to the journey itself, that is envisioned to offer the user

a personalized, customizable and programmable experience. The different network of mobility goes in the direction to generate a fluid experience from one service to another, with the first aim to minimize the mental efforts traditionally required to commute with a public service. In this way, the choice to spend time moving around the city will no longer be dictated by what awaits at the destination, but it will be the journey itself that enriches the individual. The experience of the journey will give greater value to the day, whether it is a journey made with physical activity or by public transport.

Food for thought:

- *The multiresidentiality effect.* Driven by new work practices, people tend to easily live in different places as required. This could encourage the adoption of public services, as people will gradually tend to reduce physical assets and prefer flexible service that can meet their needs anywhere. Opening up thinking about how travel between two major cities may change.
- *Quality as the main driver.* Fast urban travel is no longer the real goal. Providing quality commuting time is much more impactful, with a comfortable experience (on-board or while riding on the roads). This gives a unique value to the trip, dedicating this time to your activities being no longer wasted time, changing how society considers the commute time (as working time or me-time).

3.3 Examples of key technologies and technological innovation

During the interviews and workshops, a rich set of technologies and technological innovations emerged as key elements for the future of mobility, independently of the alternative future scenarios that can possibly come true.

They have been clustered into three groups, namely Transportation system, Urban infrastructure, and Policies (Figure 9).

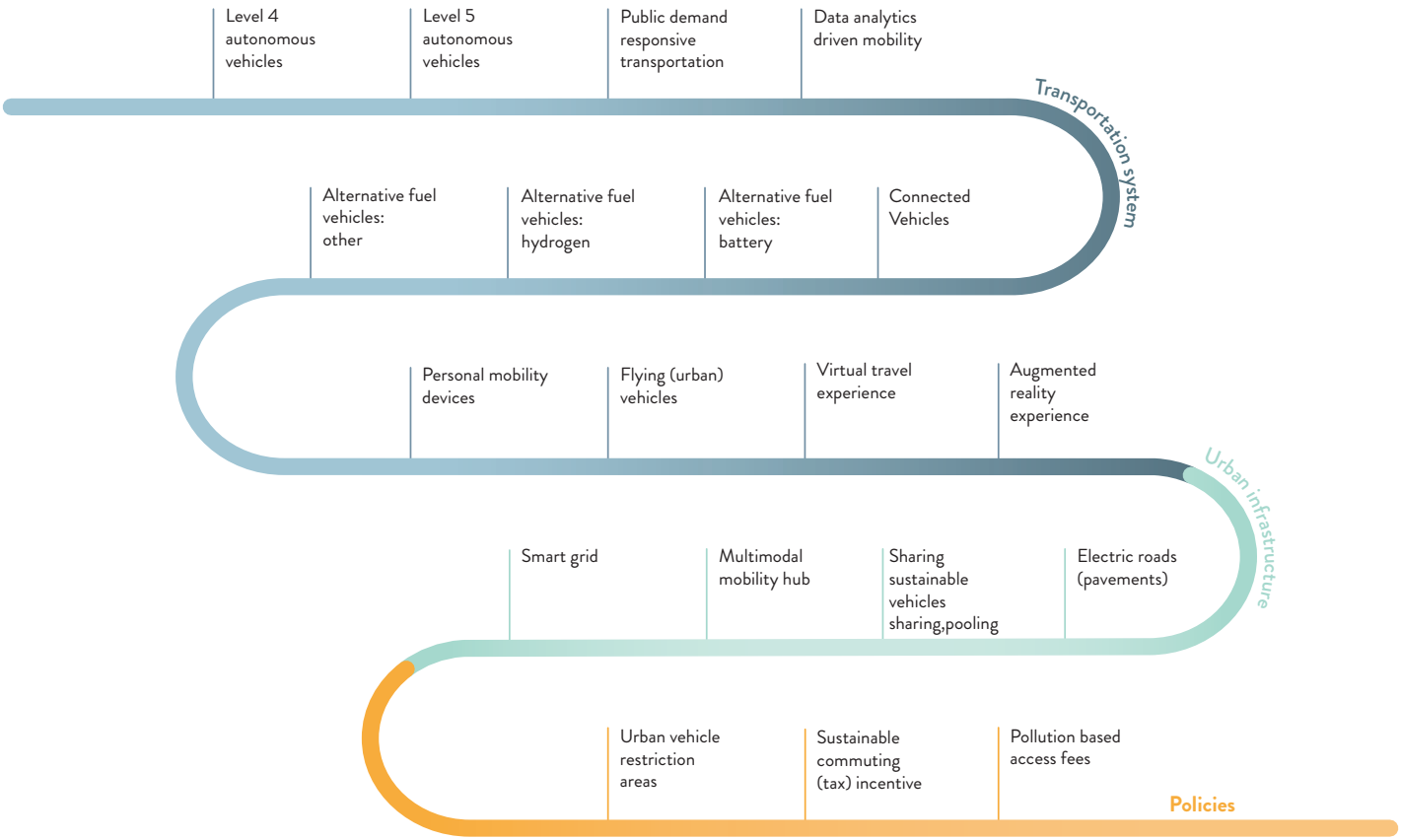
Transportation system

Level 4 autonomous vehicles

Level 4 autonomous vehicles are highly self-driving automated systems without human controls, within a well-defined operational design domain. Outside of these specific situations, the control of the car returns to the human-driven and it allows operational capability even if a human driver does not respond appropriately to a request to intervene.

These vehicles perceive their surroundings using technologies such as radar, LiDAR, and computer vision. The sensory information they gather is then processed to determine the appropriate routes for the vehicle, to avoid obstacles, and to adhere to traffic signs and rules. Theoretically, autonomous driving should be more reliable than human driving, leading to a reduction in accidents (e.g., drunk driving).

Figure 9.
Emerging key technologies.



The introduction of self-driving vehicles involves several aspects related to both passenger safety (preventing accidents and implementing safety procedures in case of malfunctioning) and cybersecurity. As these devices are connected to the network, it is necessary to take all the necessary countermeasures against hacker attacks and to protect the privacy of users. Low-latency telecommunications infrastructures, such as 5G and edge computers, are needed to process all this information quickly. Dedicated legislation is also required from governments to allow self-driving cars to run on public streets.

Supporting evidence:

- Level 4 autonomous cars allowed on German roads.
- Autonomous vehicle technology that understands spoken instructions, explores surroundings, and interacts with people.
- Humanizing autonomy envisions an ethical AI, by predicting pedestrian intent considering mostly elderly, children, and disabled.
- Fear of cyber attacks will reduce the penetration of autonomous vehicles.

Level 5 autonomous personal/public vehicles

Level 5 autonomous vehicles are fully self-driving systems without human controls in all driving environments and environmental conditions, including both privately-owned/shared cars and buses/shuttles for public transport. It is therefore not constrained by geofencing or affected by weather conditions and humans are transported comfortably and efficiently without requiring a driver. The only human involvement will be to set a destination.

Such possibility offers new scenarios both in terms of road safety improvements and urban mobility efficiency solving other technologies' problems (e.g., on-demand access to car-sharing). On the other hand, the full application of this technology will depend on national regulatory developments in the next few years.

Supporting evidence:

- Autonomous vehicles will potentially induce more urban sprawl, as more effortless travel becomes available to people.
- The first autonomous driverless robotaxi was developed and has been tested on public roads in Beijing.
- Reduction in 5G network latency to 10 milliseconds; it will support autonomous vehicles with fewer risks of glitches.
- Edge computers are increasing AVs computational power, making them more secure with the reduction of latency.
- The first Italian autonomous small bus, Olli, tested in a real city context.

Public demand-responsive transportation

It refers to an alternative to personal vehicles or taxis and it aims to supplement public transportation in areas with reduced access (for schools, senior citizens, employees), and to manage late night or off-peak hour trips. The objective is to provide streamlined transport solutions to efficiently match supply with demand based on gathered data.

One of the advantages of public demand-responsive transportation is that it enables the provision of transport services for underserved and rural areas, thus improving the capability of people to use essential services and take part in the active life. For elderly people who do not

own a private vehicle, public demand-responsive transportation provides a way to connect with medical, commercial, and other essential services.

Operators of the transport fleet have the advantage of being able to manage the on-board capacity of vehicles more precisely (e.g., in situations where social distancing and contact tracing have to be maintained). Demand-responsive transportation also allows operators to make quick data-driven decisions on fleet size if demand exceeds peak capacity.

To be effective, public demand-responsive transportation needs multi-channel reservation infrastructures and relies on sophisticated algorithms that coordinate passenger bookings, vehicle departures, and vehicle stops, optimizing the efficiency of the overall service.

Supporting evidence:

- The spread of smartphones and urban sprawl is pushing public and private actors to redesign the concept of a demand-responsive transportation system.
- Europe has developed guidelines to highlight the benefits of DRT and identified barriers to be overcome.

Data analytics driven mobility

Nowadays, transportation means generating a large amount of data. Just think of the fact that a car contains at least 150 different subsystems controlled by microprocessors that will progressively be integrated through a holistic approach. Gathering, understanding, and generating insights from this unstructured data is key to success in the frenetic mobility sector.

The analysis of these data will enable the development of real-time platforms for increased safety, reduced environmental impact, and improved efficiency.

These data are therefore of fundamental importance as they can provide an unprecedented opportunity for the transport industry to understand travel behavior and propose efficient management strategies. However, the ownership of this information is fragmented between

different entities (both public and private) who rarely communicate with each other and, as a result, the data is used and analyzed only partially and locally. It will therefore be of paramount importance to find ways of sharing, storing, and protecting them properly.

Supporting evidence:

- Connected cars could be turned into revenue-generating machines.
- Toyota's data-focused company aims to make cars smarter.
- Data brokers claim that "de-identified" data on millions of Americans is risk-free. Lawmakers need to know that "anonymity" is an abstraction.
- A data-driven approach could be used to boost the tourist experience in integrated mobility services.

Connected vehicles within the IoT ecosystem

It refers to a vehicle capable of connecting over wireless networks to nearby vehicles, infrastructure, and mobile devices. The cases of use range from vehicle-to-vehicle and vehicle-to-infrastructure communications (also known as vehicle-to-everything - V2X).

One of the sectors benefiting most from this technology is connected vehicle fleets. Vehicles already have sensors and enabling technology on-board (e.g., GPS and OBD for on-board diagnostics). Companies can leverage these technologies to extract data from their fleet vehicles. For example, they can learn details about the routes taken, assess whether vehicle maintenance is needed and what the driving conditions are, all in real-time. Thus, fleet managers can gain insight into fleet performance (e.g., by analyzing travel speed, fuel spent, engine diagnostics, etc.). That can be used to ensure driver safety and service satisfaction. With real-time data available, managers can make faster and more informed decisions.

Of uppermost importance are investments in the development of 5G communication technologies to ensure speed and reliability in data transfer between connected vehicles, while minimizing latency. Legislation is also needed to regulate connected vehicles and privacy aspects associated with the operation of these vehicles.

Supporting evidence:

- IHS Automotive claims that the number of actively connected cars roaming the global roads will hit 2 billion by 2025.
- Vodafone started to invest in the development of 6G systems for automation and connected agriculture application.
- In 2035 93% of all EU cars will be connected while their number is expected to surpass 305 million in 2035 in the USA.
- Nokia is investing in 5G roadside infrastructure to process data faster to support connected vehicles.

Alternative fuel vehicles: battery

A battery electric vehicle (BEV) is a type of electric vehicle (EV) that uses only chemical energy stored in rechargeable batteries, without any secondary source of propulsion, relying on electric motors and motor controllers. There are different types of BEVs: boats, forklifts, buses, trucks, cars, motorbikes, bicycles, scooters, and skateboards. Compared to internal combustion engine vehicles, electric cars are quieter and have much lower emissions. The battery charging stations can be installed in both houses and public areas. Thus, the use of these vehicles in an urban

context can reduce air and noise pollution and improve their impact both from an environmental point of view and in terms of urban comfort.

To make this possible, it will be necessary to produce batteries at a lower cost and with higher energy density, use fewer rare raw materials (e.g., lithium), increase their service life and define processes for recycling. It is also important to develop fast recharging systems.

Supporting evidence:

- Electric car batteries could feed power back into the grid.
- Sodium-ion Batteries are a Valid Alternative to Lithium-ion batteries.
- Fortum claims breakthrough in recycling lithium-ion batteries.
- Batteries capable of fully charging in five minutes have been produced in a factory for the first time.
- Ultra-low-cost batteries could be the lithium-free energy storage to power the renewable grid.
- Murata will deliver solid-state batteries to market.

Alternative fuel vehicles: hydrogen

It refers to a motor vehicle that runs on hydrogen. Once consumed in a fuel cell, only water is produced. Today, hydrogen can be produced through several methods: the most common are natural gas reforming (a thermal process) and electrolysis.

Hydrogen as an energy source has been suggested as a viable option to reach the needs required to meet the growing global energy demand. However, the successful implementation of a full-scale hydrogen economy requires large-scale hydrogen storage. As such, storing hydrogen in geological formations has been considered a potential option.

Hydrogen fuel cells are very attractive for vehicle propulsion and most big car companies are trying to adapt to this new technological solution. The production, storage, and transportation of hydrogen, as well as its use as a fuel, are important steps in the exploitation of this alternative source of energy.

Regarding public transportation (from the most local to the most extensive, whether by land, rail or air), there are already several successful examples of the use of hydrogen as an energy source: trains, buses (and even airplanes) are already able to operate using hydrogen as a fuel.

Supporting evidence:

- ZeroAvia, hydrogen flying vehicles completed an 8 min flight that resulted in lower CO_2 emission of intra-EU flights by 10%.
- European Union funded a project for H_2 fueled buses, towards sustainable public transportation.
- «Hydrogen Valley» in the north of Italy. No CO_2 emissions and local production of hydrogen for public transport.
- An extremely compact reactor has potential to reduce global CO_2 emissions significantly.

Alternative fuel vehicles: other

An alternative fuel vehicle is a vehicle that runs on a fuel other than petroleum-based one (petrol or diesel). This technology also refers to any engine powering solution that does not exclusively involve petroleum for a zero-emission in situ solutions: it can be a single fuel source or multiple

fuel sources. Among the best known are batteries and hydrogen, but other alternatives are being developed and have received investment such as air compressor engines, alternatives to battery electric stored energy (e.g., solar), biofuels and liquefied natural gas.

The development of cleaner alternatives has become a priority for many governments and vehicle manufacturers worldwide due to the environmental impact that traditional fuels have. On the other hand, it is important to understand what secondary or long-term impacts these alternative fuels could have. One example is biofuel, for which it has been estimated that indiscriminate production can lead to a high risk of deforestation with a consequent negative impact on climate.

An environmental analysis of the impacts must therefore be performed beyond mere operational efficiency and emissions, especially if a technology is used on a large scale, taking in consideration also production and post-use aspects.

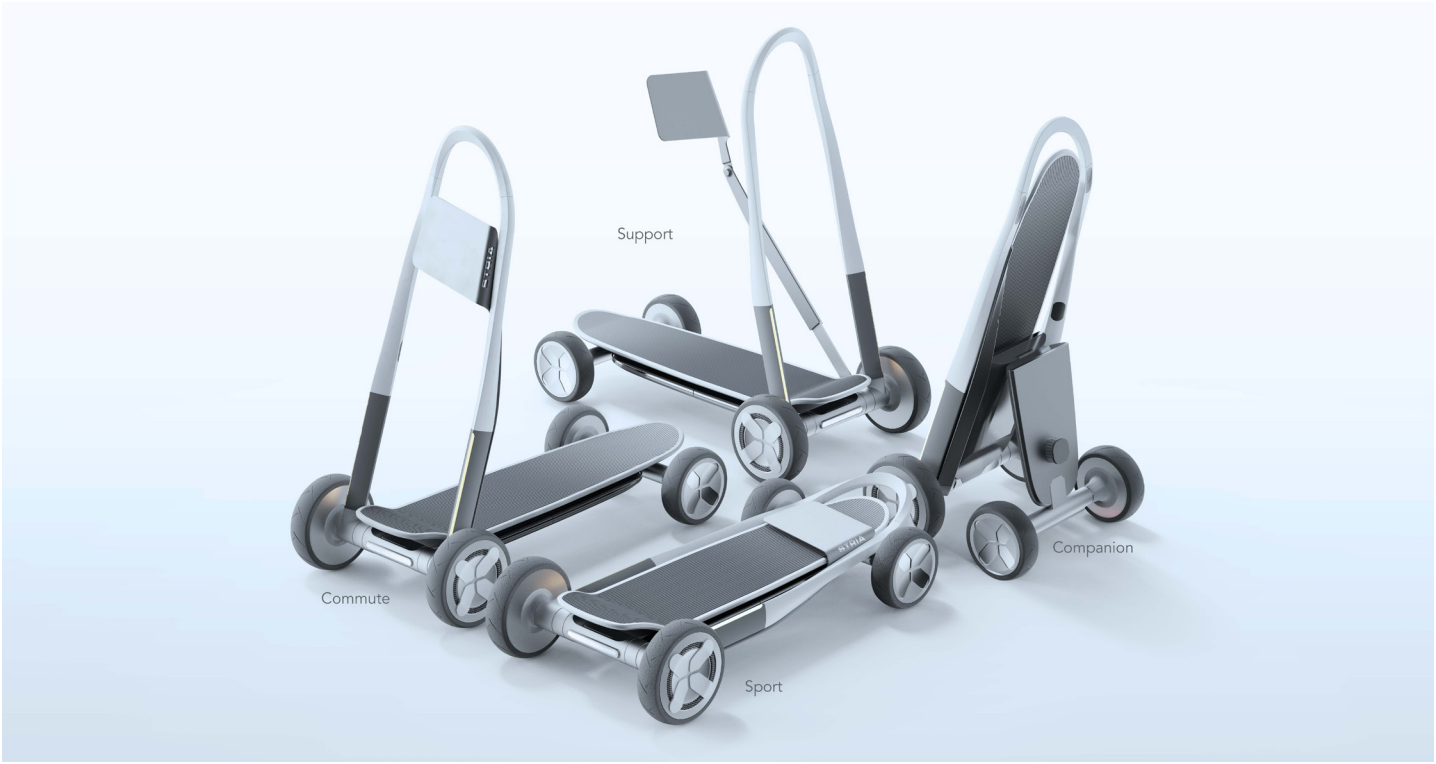
Supporting evidence:

- Increased demand for biofuels risks a massive increase in deforestation by 2030.
- France climate plan includes ending fossil fuel vehicle sales by 2040.
- Porsche is researching synthetic fuels to make gas-powered cars sustainable.

Personal mobility devices

These are compact, motorized micro-mobility vehicles that are aimed at transporting an individual. Personal mobility devices include electric scooters, electric unicycles, electric hoverboards, skateboards, roller skates, and similar devices. Technological research in the field of personal mobility devices is mainly focused on rechargeable batteries (often lithium-ion) and brushless motors, which allow high efficiency with low weight.

In recent years, with the spread of these devices also in the sharing mobility market, it has been shown that it is increasingly necessary to regulate the use of personal mobility devices. Many countries have already introduced a series of regulations to ensure the safety of users and of people around them.



Supporting evidence:

- Segway closes production after failing to fully transform transportation although having defined a new category of mobility.
- An alternative design solution for micro-mobility has been developed for a market worth $450 billion in the US and EU by 2030.
- Innovations in e-bikes allowed the implementation of stabilization system for senior users and sidewalk charging stations.
- Walk 21 council improves walkability of cities and micro-mobility rules.
- MIT designed a shared, on-demand autonomous bicycle with 3 wheels that fold itself when the user picks the bike up.

Flying (urban) vehicles

The idea of flying vehicles has been appealing to humans from the very early use of vehicles. As congestion became an issue, the dream of flying cars evolved. Today, advances in the miniaturization of sensors, power storage, electric motors, and artificial intelligence are seemingly aligning to finally bring the flying car close to reality even if the engineering challenges facing flying vehicles are manifold.

The most daunting obstacle to deployment is the limitations of current lithium-ion batteries. Battery-electric vertical take-off and landing are preferable to traditional combustion engines because they are quieter and release no emissions and excessive emissions and noise would result in massive community opposition. In fact, the prospect of bringing airport-level noise to dozens or even hundreds of rooftops would end up in short-circuiting in flying vehicles in the planning stage.

The flying vehicle prototypes that are under development try to combine the best features of airplanes and helicopters and are envisioned for the transportation of a limited number of people, e.g., flying taxis.

The outlined scenario will require dramatic upgrades to Air Traffic Control (ATC) systems and procedures as existing ATC systems were developed to handle scheduled commercial aviation traffic to and from airports along established air corridors. Even at a modest scale, the presence of flying cars in urban airspace will present significant operational challenges and the potential for routing errors that may lead to deadly collisions. In the very long term, commuting without a road infrastructure will decongest our metropolitan areas allowing for a freer and more dynamic use of land.

Supporting evidence:

- Flying taxis are about to take off thanks to better batteries and lightweight materials.
- Flying taxi startup Volocopter picks up another $241M.
- Airbus reveals a modular, self-piloting flying car concept.
- Joby Aviation raises $590 million to launch an electric air taxi service.

Virtual travel experience

Virtual travel experiences are travel experiences that take place in a virtual world, recreating real-life situations using immersive virtual reality (VR) and wearable devices.

The pandemic situation that began in 2020 has certainly led to an increase in the offer of virtual travel experiences: the closure of territorial borders has meant that it is impossible to physically

travel to countries other than one's own, and this has prompted many people to try a virtual experience.

Technological research focuses mainly on devices and sensors for virtual reality, such as VR visors that allow you to immerse yourself in a 360-degree environment. There are also audio devices for immersive sound, and tactile/motor interfaces for pressure haptic feedback. The challenge is to create a virtual world that is as realistic as possible. This involves the use of low-latency infrastructures and the involvement of virtual content creators.

Supporting evidence:

- Taipei Tech LiquidMask VR: a headset that infuses liquid to avoid wet skin for a seamless virtual travel experience.
- Travel restrictions due to Covid-19 increased virtual reality experiences in 2020.

Augmented reality experience

It refers to digital tools that overlay reality with virtual enhancements to empower drivers and travelers during their commute.

Augmented Reality (AR) generally means overlaying computer-generated imagery (or even sound, movements, smells, etc.) on our perception of the real world. The goal of the currently competing technological solutions is to have an unobtrusive device that seamlessly overlays the virtual world on top of the user's natural senses.

AR technology can play an important role in the field of interaction between drivers/passengers and automated vehicles. As AR advances and becomes more available, the number of use cases in and around vehicles is growing. In the past, AR research has focused on increasing road safety and displaying navigation aids. More recent research introduces support for immersive activities not necessarily related to driving that enhance the driver and passenger experience. AR can also be used to facilitate the acceptance of autonomous vehicles, thus helping the transition from manual to automated driving.

Supporting evidence:

- Nissan created the Invisible-to-Visible (I2V) to see the hidden world, empowering the driving experience.
- Cybershoes enables users to track their physical activity and determine the distance of their virtual travels.
- The future will belong to AR because it improves both the efficiency of the activities performed and their quality, enhancing the user experience.

Urban infrastructure

Electric roads that charge the vehicle while moving

An electric road provides electrical power to vehicles traveling on it. Common implementations are ground-level power supply through conductive rails or inductive coils embedded in the road, but also overhead power lines above the road. The efficiency of electric roads is highest in the case of conductive charging technology.

Electric roads also have several disadvantages: we currently do not have enough real-life data to support their reliability (excluding the pantograph, invented over a century ago).

Charging infrastructure entails a considerable cost in road construction, installation, and maintenance. While the infrastructure is being upgraded, there is obviously a disruption in the road network. One way to limit this is to coincide the implementation of the electric road with planned maintenance work.

Regulating electric roads requires full cooperation between many actors such as governments, municipalities, energy suppliers, and transport companies. Standards for charging are still under development.

Supporting evidence:

- Tel Aviv set to become the first city with electric roads that charge public transportation while they are moving.
- Sweden and Germany are leading the development for electric roads.
- Electric Roads: a niche solution for confined areas?

Sustainable vehicles sharing/pooling systems (micro-mobility, cars, ...) beyond the city boundaries

A membership based service that enables the usage of shared vehicles within a dispersed network, available 24-hours a day. The adoption of this technology refers to both four wheels vehicles and micro-mobility ones. Specifically, the areas of analysis are medium-size towns, small cities, and a context different from the metropolitan area.

The perceived convenience of ownership has decreased in denser urban areas, mainly due to better access to public transportation and the emergence of multiple shared mobility services (cars, bicycles, scooters, etc.). When analyzing the use of owned cars, as an example, cars that remain parked for 95% of their lifetime emerged. The main reasons to believe that shared mobility services will continue their growth are the reduced congestion and environmental impact, and the increased availability of resources for the community. Yet, one of the main challenges to overcome is to ensure fast access to on-demand ride-hailing and car-sharing services.

Supporting evidence:

- People own cars just to know they are there when needed.
- GM will provide all-in rental cars to Lyft drivers creating a short-term rental program.
- The developments of Bird's e-mobility solutions provoked a reduction in carbon emissions reaching 10,000 tons in 2021.
- Spin's e-scooter designs sustainable micro-journeys with fewer carbon emissions than single-occupancy vehicles on the road.

Multimodal mobility hub (at city boundaries)

It is a mobility service infrastructure, positioned in a crucial access point of the city center, to switch seamlessly between two different transportation means. Potentially, this facility addresses the diverse needs of commuters while shaping a car-free city center.

The multimodal mobility hub advantage is that it combines various public and private modes, facilitates connections, and changes, and improves access to sustainable transit by combining and structuring networks to meet the needs of more users than existing linear routes.

Although very similar to multimodal mobility hubs, existing transport interchanges are not yet fully multi-modal, and there is often a lack of coordination between the offered services.

For example, there are railway stations with integrated metro, bus, and taxis stations, but often these services do not have coordinated timetables, or the appropriate signage to switch between modes of transport is lacking together with integrated journey planning and real-time information systems.

In provincial and rural areas, a multimodal mobility hub can be implemented around existing train or bus stations. In this case, it is even more crucial to also provide first/last mile coverage, one of the main reasons why many people depend on private vehicles. One possibility is to invest in minibuses or vans for demand-responsive transportation because they can represent a solution of lower cost than classic fixed timetable lines.

Grouping several transport modes in a mobility hub is an opportunity to provide more flexible and comprehensive transit services and can be a viable alternative to private cars in the future.

Supporting evidence:

- The Norwegian solution to avoid private cars in cities could be MaaS.
- A fuel station could be transformed into a mobility hub, by adding a wide range of sharing and micro-mobility services.
- Mobility hubs can accelerate post-pandemic recovery.

Smart grid

Smart grid refers to an electricity network enabling a two-way flow of electricity and data allowing detection, reaction, and pro-action to enable self-healing capabilities and electricity customers to become active participants.

Building a smart grid means creating an ICT infrastructure in parallel to the electricity grid. The grid infrastructure connects self-generating power plants in the distribution network (e.g., those using renewable energies) and with large power plants. The communication channel makes it possible to exchange information on the electrical energy produced to regulate the energy dispatching.

The ICT infrastructure can exploit the power grid itself (e.g., powerline technology) or can be built ad hoc. The management of the grid is computerized and automated through intelligent monitoring software that keeps track of the entire electrical flow in the system. Smart meters are also used to detect consumption habits and adjust electricity costs accordingly.

Several governments are encouraging the construction of smart grids with the aim of energy independence and of winning the battle against global warming. In 2006, Italy became the first nation in the world to have a nationwide smart grid.

Supporting evidence:

- Vehicle-to-grid technology is seen as the future towards more electrification of transport and a smart grid.
- Smart grids will dominate smart city spending through 2026.
- Re-imagining the United States power grid could save consumers $50 billion a year.

Policies

Urban vehicle restriction areas (w.r.t. modality and/or fuel)

It refers to the implementation of car and parking restrictions in certain areas of a city. These solutions are typically applied in the city center to improve the flow of public transport vehicles, and increase the public space's attractiveness.

To successfully implement these policies, the city has to provide a public transport offer adapted to the demand, sharing mobility offers, and the presence of dedicated routes for alternative and non-polluting means of transport, such as bicycle lanes. Moreover, it is necessary to monitor the restricted areas (e.g., with camera systems) and to establish a system of sanctions.

Urban vehicle restriction areas also have an economic impact on commercial activities in the concerned areas, both for on-site and delivery-based activities.

Supporting evidence:

- An increasing number of European cities introduced the 30 Km/h speed limit for a quieter and safer city center.
- Culdesac Tempe, Arizona, will be the first purpose-built car-free neighborhood in the U.S.
- 21 streets in Barcelona's is an example district that will become a car-free superblock (allowing only residents essential services or deliveries) and full of green spaces.
- Singapore realized "a truly fair" fee collection system based on next-generation ERP.
- Curb management policies: charging fees for curb usage from delivery or sharing services, to improve urban traffic and living, moving deliveries to off-peak periods.

Sustainable commuting incentive

Sustainable Commuting Incentives are typically introduced to encourage the adoption of more sustainable transport choices i.e., the use of public transport and the transition to more sustainable and less polluting means of transportation. Many alternatives are currently implemented around the world, such as incentives for traveling during off peak demand, commuting with public transport from decentralized locations, adjusting public transport prices, adopting tax fees, or direct economic support to purchase transportation means.

The goal of encouraging sustainable commuting is reached by making these options more convenient or by making the alternatives less convenient. One example is the availability of parking spaces: studies show that more spaces lead to more car use. If fewer parking spaces are available, more people opt for public transport.

Supporting evidence:

- Cork, Limerick and Waterford to get people back on bikes are investing in dense networks of bike lanes and partnering with the private sector to provide ad hoc incentives to support cycling.
- Leicester has donated £250 worth of vouchers (shopping, school book, etc.) for those who travel more sustainably and to incentivize more people to do the same.
- Companies can reduce a considerable portion of their transportation-related emissions by encouraging sustainable commutes.

Pollution-based access fees

Pollution-based access fees are payments based on the amount of pollutants discharged into the environment (e.g., air, wastewater emissions, or solid waste). Parties can choose to emit pollution and pay the tax or install systems to prevent or reduce pollution and avoid taxes.

To implement this kind of policy, infrastructures are needed to check access. Image processing techniques can be used on video streams from the cameras at access points to recognize the plate number of vehicles entering the area, register their entry and exit and then charge an access fee if the vehicle does not meet the area criteria. More pervasive mechanisms based on radio antennas, such as Telepass, can be used to register vehicle access and regulate payment. Adequate road signs at and near access points should also be put in place to warn vehicle drivers. Of course, public transport and sharing mobility must be able to support the movement of people who do not access the city with their own vehicles. This kind of policy is often challenged as being equivalent to a "license to pollute".

However, if a sufficiently high price is charged, then the average vehicle owner is encouraged to consider not traveling on that road. Pollution-based access fees have triggered a discussion on privacy aspects since vehicle accesses to the city are being registered. An access restriction policy also has an impact on the home delivery economy. This leads shipping companies to consider adapting their fleets.

Supporting evidence:

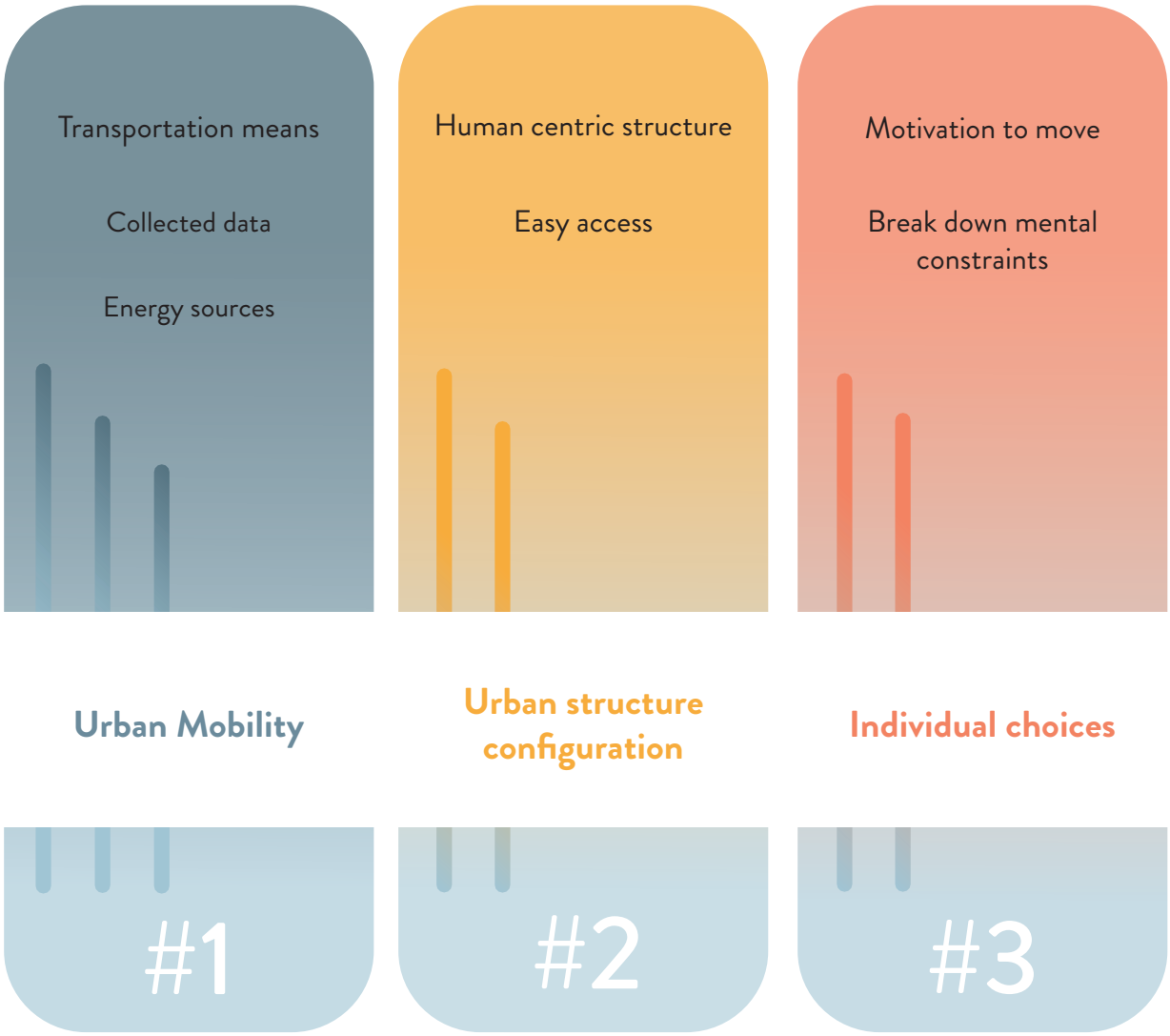
- The city of Rome is planning to introduce a congestion charge.
- London is exploring scrapping the charge for motor vehicles driving in the city center, replacing it instead with a fee for all car journeys across the entire city.
- Milan congestion charge allowed a reduction of car pollution and traffic, promoting investments in the replacement of vehicles with low environmental impact ones.

Insights

4

We here report the main elements, the insights, that emerged from the workshops and interviews with the experts, as well as the outcomes of the interviews to outside experts, drawing a map of the overall landscape of the mobility in 2035.

Figure 10.
Key insights.



4.1 Pillars: means, infrastructures and behaviors

The foresight phase built around the alternative futures generated fruitful conversations that led to uncovering relevant insights, to better reflect on how to prepare for the possible futures that may come true. Three are the pillars around which the discussions and considerations of the related to the transportation means, the infrastructures and the behaviors, respectively. For each one of them a few key insights emerged.

Pillar #1 - Urban mobility

Key insight #1 - Transportation means

People don't compromise their independence. The infinite possibilities of destinations and time of travel guaranteed by a private will remain, but it is paramount to integrate it with a sustainability requirement, both in commuter's life and in environmental terms. The growth of micro-mobility to move within the city center goes in this direction. E-bikes are now compared to private cars guaranteeing ease and freedom also in medium-long urban movements. The ownership of such vehicles is not requested, leveraging on the capillarity of sharing services.

Supporting evidence:

- Boom in popularity of all forms of micro-mobility that allow, despite their age, to move around the city without restrictions. Commuting with these vehicles allows a healthy lifestyle and also strengthens one's public image.
- Sharing services are a way to ditch the private car and rely on public transportation. Ensuring their availability even in small and medium-sized cities is one way to get used to their powerful effect.
- In recent years the sales of e-bikes in the European market increased by 23% compared to 2019. The freedom e-bikes also supports multiple usages, which is beneficial for both leisure and work duties.

Key insight #2 – Collected data

Data are the new engine for public transportation. They require administration policies and capabilities to be orchestrated in an optimal way to lead people to commute with public transportations, without feeling the need for an owned vehicle. Urban mobility becomes a service, integrated in one interface that orchestrates and customizes the offer based on user's needs and movements. The key point is to provide on-demand solutions that adjust frequency, availability and the typology of vehicles offered according to the individual request.

Supporting evidence:

- Rise of central boards (with local footprint) to integrate the data ecosystem leveraging on data collected from various sources and organize demand-responsive mobility solutions.
- Public transportation has always been designed to accept a large number of passengers. However, this feature does not always meet the individual need to reach the destination due to an infrastructure that is not widespread. Modular EVs could be the alternative, being reorganized according to capacity needs, and be separated to reach different destinations, orchestrated using collected data.

- The competitiveness of rail services could increase by meeting demands for efficiency, reliability, and adaptability, by investing in advanced traffic management and control systems, based on data collected and processed in real-time. In addition, the definition of new signals and control systems can improve the overall environmental sustainability by decreasing energy consumption and carbon emissions.

Key insight #3 – Energy sources

The abandonment of fuel-burning engines, in favor of electric ones is a fairly definite path. However, ensuring fair and equitable access to electricity requires action in two areas. First, the source of energy. Renewable sources play a crucial role in ensuring the sustainability of motor mobility; unfortunately, their output is unlikely to exceed 50% of the required energy. For this reason, fossil fuels and other sources of energy production still play a role, that will (maybe negatively) impact the level of sustainability of electric vehicles. In addition, other forms of fuels are needed such as e-fuels or hydrogen (which will necessarily be adopted in trains and buses) to reduce pressure on the energy grid. Second, the energy storage and smart grid infrastructures. The latter are used to address increased demands for electricity, they enable ubiquity and efficiency in energy transport, allowing citizens to proactively move unused energy to where it is most needed. Commuters take on the role of prosumers, being both passive consumers of energy and active producers. Critical point becomes also the definition of new types of batteries with better efficiency and built without critical raw materials (e.g., lithium) improving their sustainability also in the production process.

Supporting evidence:

- The use of Vehicle-to-Grid (V2G) solutions transforms electric cars from simple means of transportation to energy carriers, capable of exchanging electricity with the grid, storing energy in excess and returning it when needed. This allows a more efficient accumulation, especially for renewables sources.
- Decarbonization of public transportation systems relying only on hydrogen as fuel, to balance the request of electricity in public transportation, such as in Valle Camonica (Italy) the “hydrogen valley”. Efforts to create an ecosystem to exploit “green hydrogen” to be sustainable also in the production process.
- E-fuels and biofuels are spreading as alternative solutions to support climate-neutral energy fuels. Applicable not only to public transport but also to freight.
- In Europe, rise of energy communities where people want to be participative, with an active role in managing energy consumption and production. The collaboration and cooperation among administrative entities and local communities is the cornerstone of energy transition and realization of climate and sustainable development goals.

Pillar #2 - Urban structure configuration

Key insight #1 – Human centric structure

The configuration of the city will no longer be structured to allow private vehicles to move freely, focusing on improving the lives of individuals, based on a human centric approach, where spaces are organized to support people’s needs. The urban mobility of 2035 is based on active mobility (with bicycles, e-scooters, skateboards), so the city structure should support it with lanes that ensure safe commuting, while enhancing the beauty of the city.

Supporting evidence:

- The construction of dedicated areas for micro-mobility lanes is designed not only for securing safer commute of citizen; new bicycles or pedestrian areas could be designed as "green lanes", so streets full of flowering trees and lawns, to affect also the beautification of city, reducing the city climate impact and temperature generating a better quality of life.

Key insight #2 – Easy access

The vast heterogeneity of transportation means requires urban spaces dedicated to easily decouple the different solutions. City will be equipped with multimodal stations in city's critical zones to enable commuters (mainly arriving from the outside) to switch from one transportation solution to another one. However, if people choose to adopt the 20-minute neighborhood concept, the urban infrastructure in each neighborhood should be structured to support short movements within it and enhance a life of proximity. The desire to move with more sustainable means of transportation and the on-demand management of mobility, allows to realize a city structure according to different layouts, without having to embrace conflicting lifestyles. In fact, the definition of a city on a more human scale allows to support both a proximity life and commuters who need to reach further destinations, even outside the urban area.

Supporting evidence:

- 20 minute neighborhood is a new way of reconfiguring the city center that promotes an inclusive city model with human-based distribution of spaces. Supporting a healthier lifestyle encouraging active mobility and easily integrating with multimodal solutions.
- Introduction of "30 zone" and rise of area banned for private cars. To reduce the risk of incidents and supporting pedestrian safety. Also, these measures enhance the quality of urban life with less noise and pollution.

Pillar #3 - Individual choices

Key insight #1 – Motivation to move

Urban commuting becomes an act of interest and care. Virtual mobility and digital tools have enabled people to do almost anything they imagine from home, with sometimes even greater efficiency than before. Although the number of daily journeys per capita may decline of 20% or more, the value of physical interaction increases in its uniqueness. People will continue to move because the added value of in presence activities will have no equals, also positively affecting mental well-being. The same will hold for active mobility. As a consequence, interest and care towards oneself and others will motivate journeys, and a power and efficient transportation system will be of utmost importance.

Supporting evidence:

- Using commuting as a ritual to support individual well-being and show care to others. Although before Covid-19 daily commuting often meant the nightmare of being stuck in city traffic, yet the daily ritual somehow provides stability and confidence in daily life. In the future it should be possible to recreate that same positive feeling, without the negative facets.
- Urban commuting in the post Covid-19 pandemic has reduced of about 20%.

Key insight #2 – Break down mental constraints

Public institutions, schools, research centers and firms should all collaborate to enable the transition towards a new sustainable mobility. Despite joint efforts to bring to market the innovations that are in line with people's needs, these key players should work together to convey the benefits of moving with public transportation as opposed to private car. Such information is key to overcoming any reluctance and puzzlement in people's minds, to give them a gentle push to embrace sustainable mobility. A collaboration between public and private institutions can succeed in changing habits and behaviors.

Supporting evidence:

- People are capable of radical changes in behaviors; however they should be guided by bold political actions and especially participative processes could be the key. As community and policymakers collaborate on the definition on Sustainable Urban Mobility Plans.

4.2 Expected impact

The set of technologies and technological innovations that emerged from individual and group activities have been analyzed through a survey from the readiness and impact points of view. Experts had to critically analyze the role of technology in the future of mobility with respect to three aspects, and then evaluate how each technology impacts on the United Nations SDGs.

More specifically, the survey questions are the following ones:

Role of the technology/innovation in the future of mobility:

- Possibility to respond to future demands.
- Possibility to develop and have the technology available in Italy in 2035.
- Priority - necessity to promptly develop the technology with respect to others.

The adopted scale is: none, very low, low, high, and very high.

Possible impacts or implications on SDG areas:

For the impact and implications on SDGs, we adopted the same thematic areas used in our previous activity, shown in Figure 11, borrowed from the "The World in 2050" project.

Figure 11.
Six thematic areas grouping SDGs as proposed in "The World in 2050" project. (http://www.TWI2050.org)

We asked the Experts how the technology/innovation would:

- Contribute to improve quality of life and promote well-being (*Essential needs for the person).*
- Contribute to promoting inclusive and sustainable economic growth (*Socio-economic growth*).
- Contribute to lead to the adoption of sustainable consumption and production of energy sources (*Sustainable resources usage).*
- Contribute to ensuring equitable access (*Universal values protection).*
- Contribute to preserve a sustainable use of resources (*Planet preservation*).
- Require a joint effort and policies to make the technology/innovation impactful (*Governance - enablers).*

The adopted scale is highly negative, limited negative, none, limited positive, and highly positive.

Responses to the role of technologies in the future of mobility are shown in Figure 12, and the following considerations can be drawn.

Possibility to respond to future demands

The general opinion is that all technologies/innovations will have a medium/high possibility to respond to future sustainable mobility needs, with few negative and positive exceptions. More precisely, virtual travel and augmented reality experiences seem not to be impactful, while public demand-responsive transportation and data analytics driven mobility are expected to have a high possibility to fulfill future needs.

Possibility to develop and have the technology available in Italy in 2035

Overall, all technologies/innovations will have a medium to high possibility to be developed and be ready in Italy by 2035, except for level 5 autonomous vehicles and flying urban vehicles, evaluated to require more years. Public demand-responsive transportation, sustainable vehicle sharing/pooling systems, and urban vehicle restriction areas have been evaluated as possibly ready with a high/very high probability.

Priority - necessity to promptly develop one technology with respect to the others

A few of the technologies have been considered not prioritized in the overall panorama, namely autonomous personal vehicles at level 5, virtual travel experiences, flying urban vehicles and augmented reality experiences. Public demand-responsive transportation emerged as a real priority, leaving the remaining technologies at an intermediate level.

As far as the possible impacts or implications on SDG areas are concerned, the following considerations can be drawn (Figure 13).

The strongest impact is expected to be on the Social-economic growth and Essential needs for the person areas, with dominance on the positive side, except for a few technologies where there are some negative due to the fact that these technologies are not relevant for mobility.

The perception is that these technologies and innovations will also work towards sustainable mobility, exhibiting a non-negative impact on Sustainable resource usage and Planet preservation. The opinions for the Governance area show that policies, visions, and strategies are necessary to move the future of mobility towards scenarios where the analyzed technologies and innovations

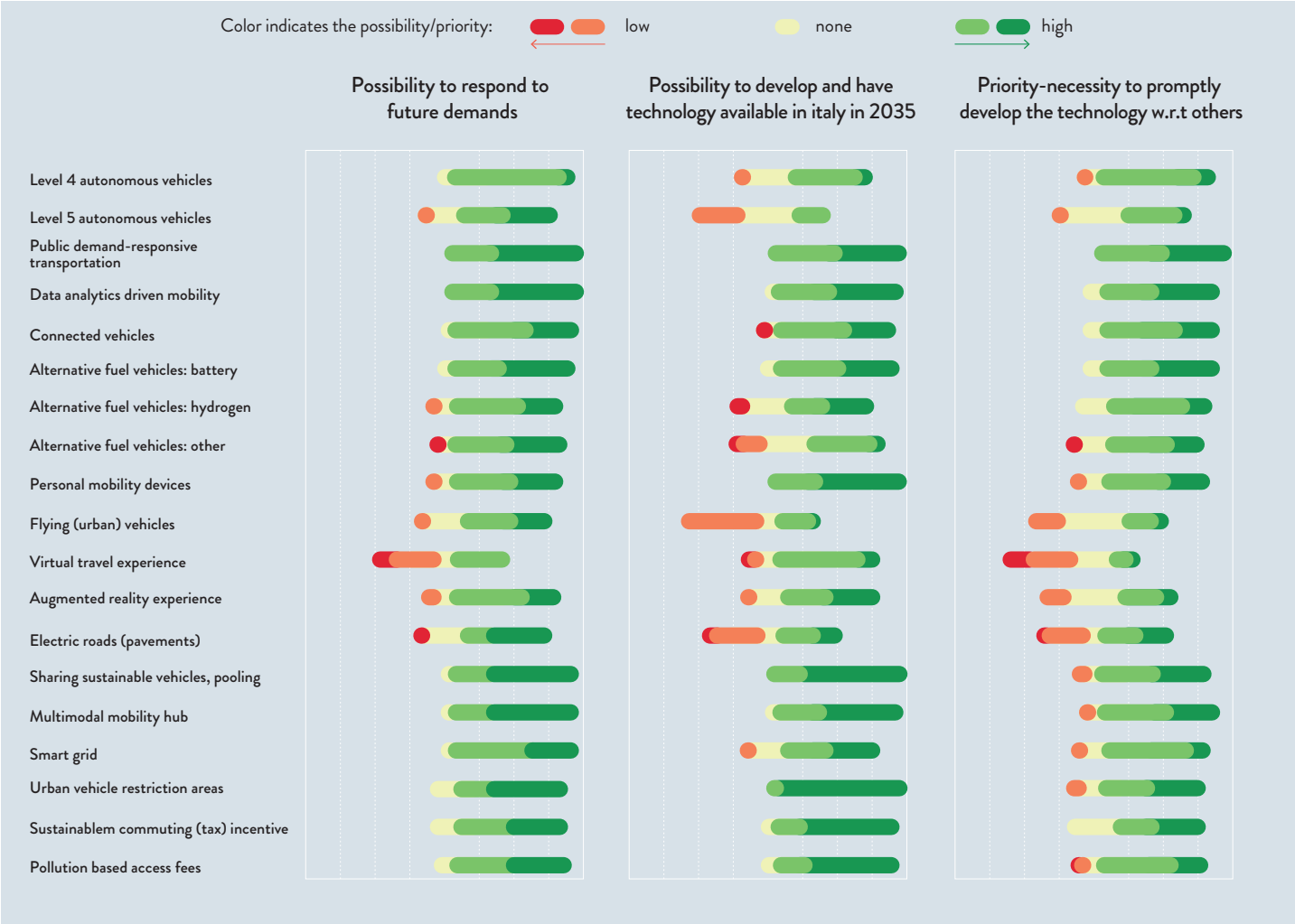
make a difference, as emerged during the complementary activities. The only SDG area that seems to be marginally affected by these technologies is the Universal values protection, where all technologies have been evaluated as having a predominantly neutral impact. Indeed, inclusivity emerged during the entire activity as a relevant driver of future mobility. Yet this aspect seems to be rather a goal to be pursued rather than something that is strictly related to technologies, innovations, and policies. When looking at the technologies and innovations, the one that exhibits no negative effect whatsoever is hydrogen, as an alternative source of energy. Public demand-responsive transportation is the innovation that is expected to have the greatest positive impact.

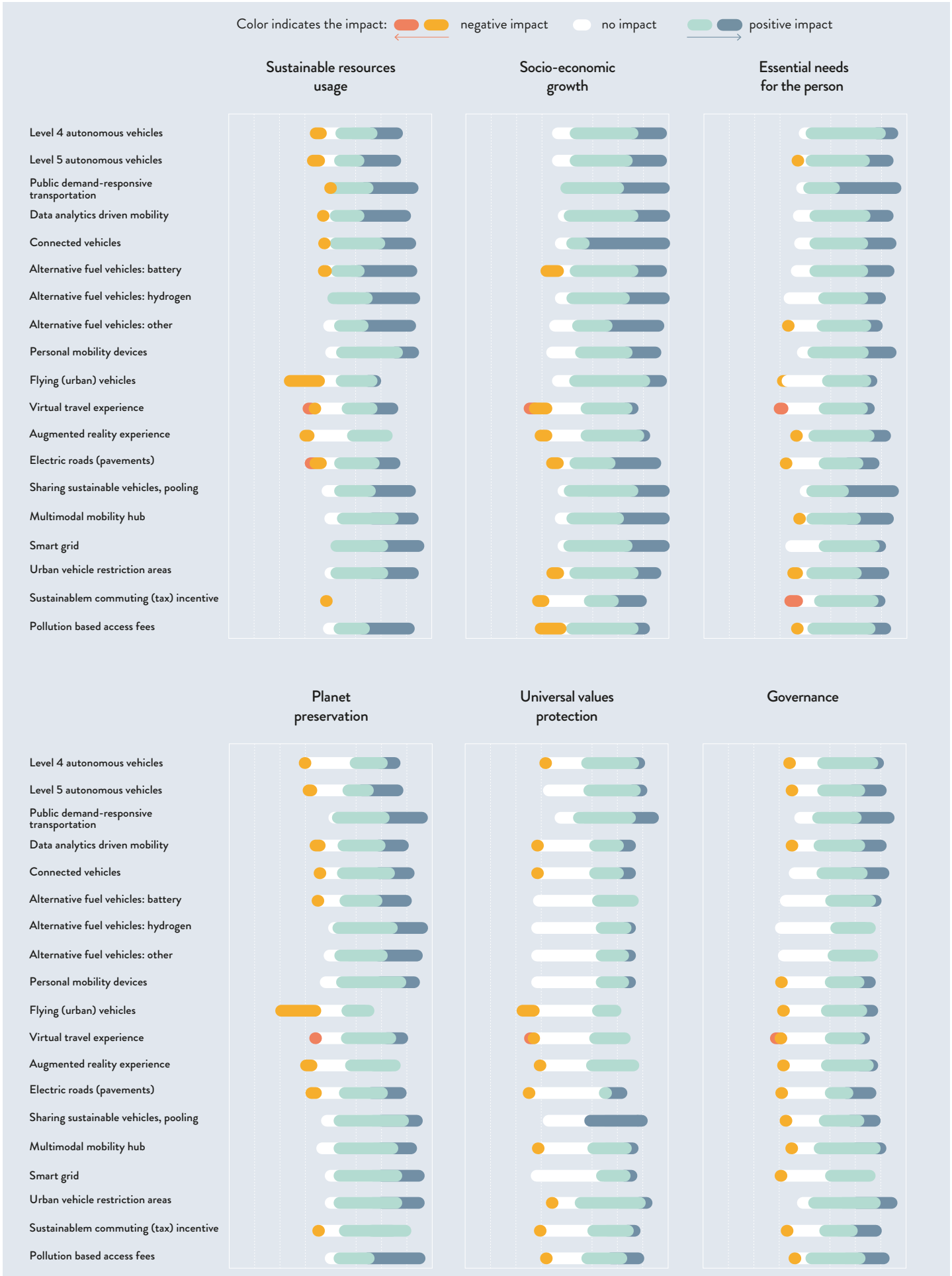
Possibility to develop and have the technology available in Italy in 2035

Overall, all technologies/innovations will have a medium to high possibility to be developed and be ready in Italy by 2035, except for level 5 autonomous vehicles and flying urban vehicles, evaluated to require more years. Public demand-responsive transportation, sustainable vehicle sharing/pooling systems, and urban vehicle restriction areas have been evaluated as possibly ready with a high/very high probability.

Figure 12.
Opinions on the effectiveness of the technologies.
(Image below)

Figure 13.
Expected impacts of technologies, innovations and policies related to the future of mobility on SDG areas.
(Image on the next page)




Color indicates the impact:
negative impact
no impact
positive impact
Sustainable resources usage
Socio-economic growth
Essential needs for the person
Level 4 autonomous vehicles
Level 5 autonomous vehicles
Public demand-responsive transportation
Data analytics driven mobility
Connected vehicles
Alternative fuel vehicles: battery
Alternative fuel vehicles: hydrogen
Alternative fuel vehicles: other
Personal mobility devices
Flying (urban) vehicles
Virtual travel experience
Augmented reality experience
Electric roads (pavements)
Sharing sustainable vehicles, pooling
Multimodal mobility hub
Smart grid
Urban vehicle restriction areas
Sustainablem commuting (tax) incentive
Pollution based access fees
Planet preservation
Universal values protection
Governance
Level 4 autonomous vehicles
Level 5 autonomous vehicles
Public demand-responsive transportation
Data analytics driven mobility
Connected vehicles
Alternative fuel vehicles: battery
Alternative fuel vehicles: hydrogen
Alternative fuel vehicles: other
Personal mobility devices
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Virtual travel experience
Augmented reality experience
Electric roads (pavements)
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Multimodal mobility hub
Smart grid
Urban vehicle restriction areas
Sustainablem commuting (tax) incentive
Pollution based access fees

Impacts, requirements and opportunities

5

The research and workshops examined the impacts, requirements and opportunities for 3 critical stakeholder groups: citizens, organizations and policy-makers.

Impact requirements of mobility futures

The results indicated that the stakeholder groups have some specificity, but much more shared requirements in managing the impacts of any future of mobility.

Funding local partnerships to mitigate economic impacts and build trust

Access to essential services like education and healthcare will be necessary in any future mobility. This will most likely require new models of local support, resources and initiatives. Policymakers can anticipate the need to invest to provide common and inclusive digital infrastructure and platforms for mobility services. Private and public sectors will need to form new partnerships and initiatives to create these digital environments as independent, and unregulated action might lead to inconsistency and inequality. Collaborative and transparent partnerships between policymakers, organizations and citizens will help contribute and build trust and engagement around the responsibilities the different actors play, and provide everyone with an active societal role.
In an ideal future, the digital divide will be reduced from these shared investments to provide mobility options to all segments of the population in Milan. However, decreased income from reduced foot traffic and tourism will also require new social and economic models and levers for local neighborhoods to survive. The reduction of mobility requires improved autonomous neighborhoods at a local scale, which means a need for increased investments in the local economy, activities and communities.

Mobility considerations:

- Designing for local conditions and digital infrastructure may include partnering and collaborating with emerging auto manufacturers, microfactories, etc.
- Similar to fashion, could sustainable custom mobility be a key export of Milan?

Securing the future of mobility

Since transportation is a basic human need, tech transparency is critical for trust and ethical use. Organizations and policymakers will have to manage data collections and the artificial intelligence algorithms to ensure a high level of cybersecurity across all sectors. Acceptable definitions of digital identity and verification processes will be essential requirements in providing a secure digital environment for the future of mobility. In the increasing likelihood of "metaverse" platforms, new regulations and policies will be required to ensure business models maintain the

required flexibility and openness to provide community access to a number of new mobility solutions. A concerted and coordinated effort will be required to increase social acceptance around restrictions imposed by policy and government bodies in building trust in more localized communities.

Mobility considerations:

- As cars become more connected, they may be capable of recording data and surveillance (e.g., facial recognition, biometrics, etc.). This might discourage use of the vehicles by those who are concerned about personal security and privacy.

Creating new markets, by design

Mobility policy making is really about urban economic organization, as the global economy gets disrupted. Specifically, the likelihood of distributed energy markets will be a critical enabler for supporting mobility across all population segments. To ensure public access in any future of mobility, new regulations will be required for energy-producing communities or individual citizens. These regulations will most likely need to be flexible to accommodate any moves into virtually gated communities reinforced by the impact of climate change. Similarly, mobility solutions and transportation infrastructure will necessitate mitigating personal or private ownership. This will require new business models with innovative public-private partnerships to create a healthy and sustainable mobility market. In these new markets, the innovation of mobility systems will be based on local, not global, conditions. A critical catalyst for creating an innovative market will be to shift the design of mobility technological and infrastructure solutions from vehicles to citizens.

Mobility considerations:

- Identify and support DIY energy-saving efforts.
- Design future-oriented mobility policies (e.g. the UK has mandated that new homes are built with electric vehicle charging capabilities).

Cultivating a shared sense of sustainability

Whether accessing essential public services via mass transportation or basic economic activities via pedestrian/cycling, all transportation will need to actively contribute and promote green solutions and regenerative designs, and behaviors to mitigate the impact on climate change. “Green and clean” energy will become the default with the introduction of new policies. This will require new business models for sharing goods and services within and between communities. The policy changes will require educating the population around a shared understanding for the role of sustainability in the development of mobility infrastructure.

Mobility considerations:

- Host mobility forums with experts and citizens to tackle emerging sustainability challenges.
- Consider local tourism and digital travel to offset tourism loss.

Impact opportunities of mobility futures

The research and workshops examined the opportunities for mobility to create a better future of mobility. The results indicated that the stakeholder groups have some specificity, but several

shared opportunities to accelerate the future of mobility:

Building new economies of mobility

Building New Economies of Mobility will open three types of opportunities: knowledge creation, knowledge sharing and knowledge transfer. Knowledge creation will be generated in the process of renovating new mobility systems and solutions. Knowledge sharing will be dependent on sharing and trust within the new mobility ecosystem. Knowledge transfer will enable knowledge transfer to build capacity for citizens to contribute to the new economies of mobility.

Mobility considerations:

- Research and disseminate emerging forms of mobility that could be beneficial to Milan and its residents.
- Connect to leaders in mobility (academic, private sector, etc.) to identify emerging business models.

Accelerating mobility solutions innovation

From planning, vision and design to implementation and infrastructure, innovation in transportation and mobility management will become exponential as vehicles become more connected, and people expect more sustainable solutions. Envisioning, designing, developing and deploying infomobility systems and green efficient sustainable infrastructure for micro-mobility and macro-mobility. The design of mobility software and hardware will increasingly focus on security and safety, with an emphasis on interoperability. Scaling solutions with better capture, communication and visualization of the climate impact of mobility systems to users and the public opens opportunities to introduce new city environmental metrics. New models to measure climate impact and footprint not only at a business or country scale but at the scale of an individual citizen.

Mobility considerations:

- Choice of mobility platforms and software may then dictate what hardware (e.g., cars, sensors, etc.) work within the city. Coordinating with other regions may be necessary.

Moving between communities

Mobility will be a key enabler for urban survival as we move towards smaller local communities. Localization will open up new spaces for opportunities at a community level, e.g. development of micro energy resources, DIY and custom made approaches for employment and micro community infrastructure and new definitions of community values as a local currency. The multimodality between neighboring communities will spark new car sharing systems, shared electrical bikes and societal flexibility in transportation systems.

Mobility considerations:

- Conduct mobility gap analysis to identify key infrastructure communities might be missing (factors that may prevent 15-minute neighborhoods from emerging).

Leveraging community-led innovation

With localization will come more local innovation. Sources of potentially beneficial innovation will come from grassroots, hyperlocal, improvised and unregulated activities, so exploring opportunities to support these initiatives will be important. Defining and implementing new

services and applications that will arise can significantly benefit from the knowledge and input from new generation students entering the university. Opportunities to experiment with citizens design solutions for improving livability of public spaces and accessibility by proximity. Leisure time will be spent more within closed communities thus opening up new spaces to explore more local events and cultural engagement opportunities. We'll have "more space and more time" as we'll move around more locally, which opens up for new opportunities to socialize and enjoy the local environment and community as well as newly found leisure time.

Mobility considerations:

- Foster creative mobility from DIY projects for local personal transportation.

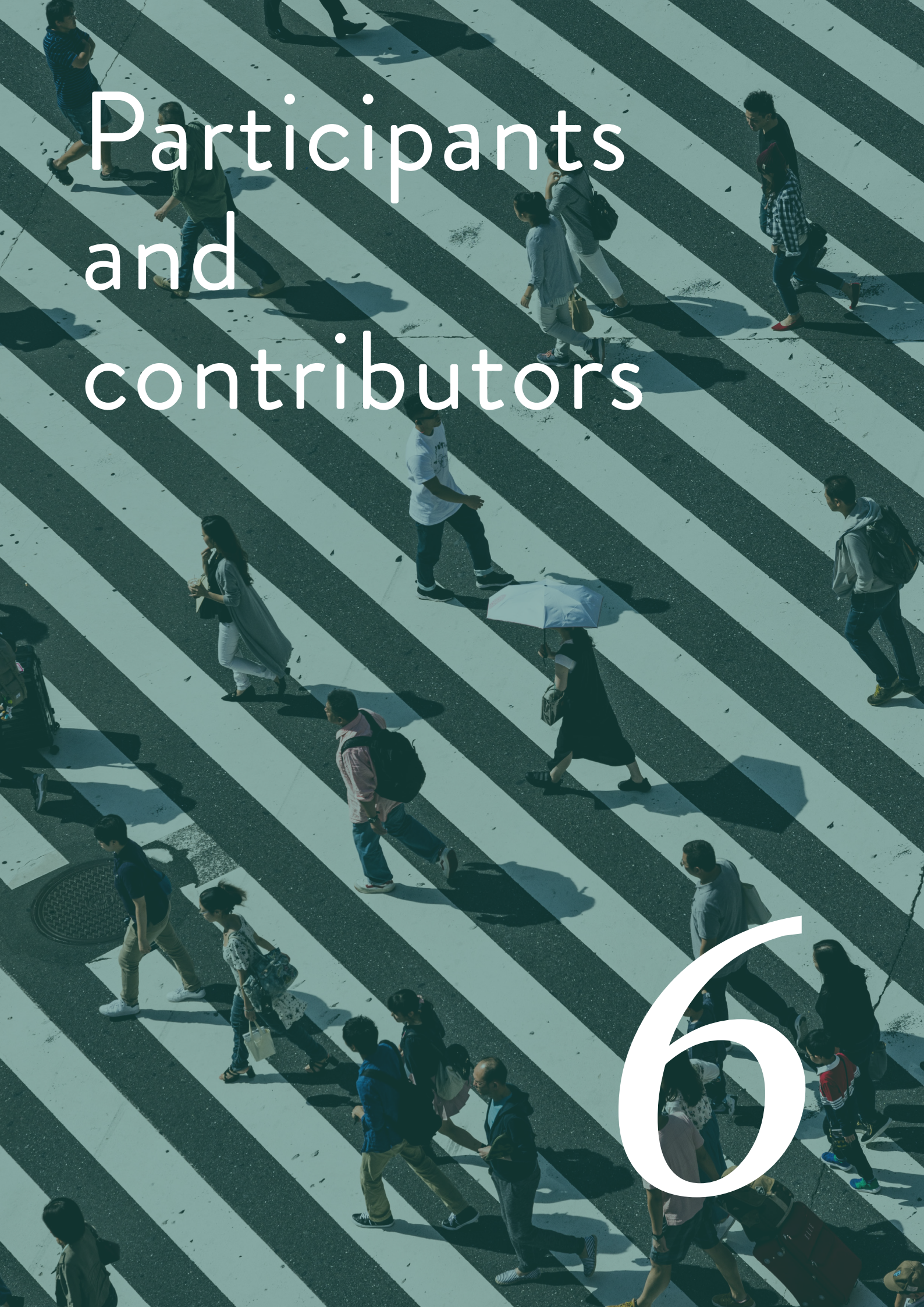
Co-creating mobility futures

Co-creation will be essential for building new mobility-based economies. Opportunities for business collaborations between e-commerce and local businesses will be important to ensure an integrated approach to mobility, and validate more sustainable economic models. Conducting urban pilot tests will demonstrate, convince, and educate policymakers and the public in what a sustainable mobility transformation would look like. Participation and economic incentives for citizens and organizations to transition into more sustainable households and businesses (e.g., by sharing resources) can help further the transformation. The need to create new types of partnerships between organizations, citizens and policymakers to come together to fight a common threat (e.g., climate change, pandemics etc) will open new opportunities, while taking into account who might resist these new partnerships, collaborations and initiatives.

Mobility considerations:

- Prepare and educate for a new sustainable mobility by creating living labs of what it could look and be like.

How will we move around the city in 2035?



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The activity has been carried out through a series of interviews with internal and outside experts, in presence workshops to have thought-provoking discussions, to imagine the future of local, urban mobility for people in 2035 in a metropolitan city such as Milan. We warmly thank them for their unvaluable contributions and insights.

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End notes

7

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