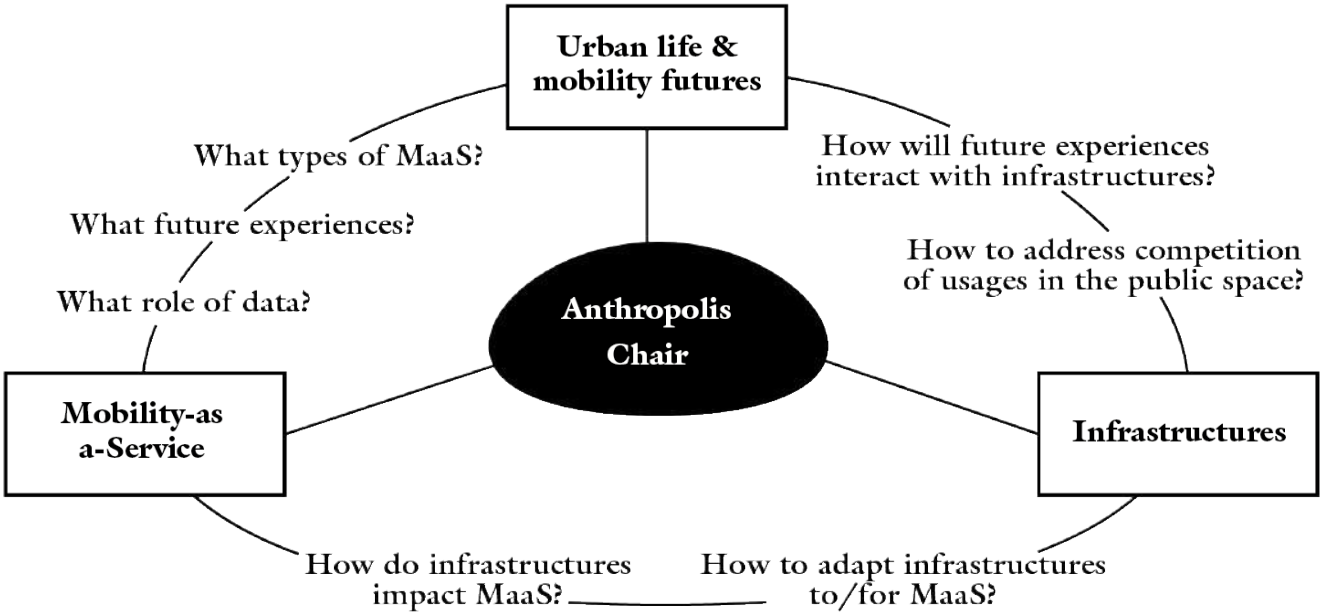
AnthroPOLIS
HUMAN CENTERED MOBILITY
2019-2023

Systemx

CentraleSupélec

BOOKLET OF DELIVERABLES

V2.0 | SEPTEMBER 2023



Presentation of interconnected themes of the Anthropolis Chair

BOOKLET OF DELIVERABLES

V.02 | September 2023

The research plan of the Chair is organised according to three interconnected themes based on Urban Mobility: Common Base (Task 1), Urban Mobility Futures (Task 2), Mobility-as-a-Service (Task 3), and Infrastructures (Task 4). An additional transversal topic is addressing Sustainability Challenges for urban mobility. The second season of the Anthropolis Chair (2019-2023) was co-constructed with the partners (EDF, Engie, Nokia, Renault, Communauté Paris-Saclay) and is co-hosted by IRT SystemX and CentraleSupélec.

This document outlines the main contributions of the Chair research plan separated into 15 deliverables. Each deliverable is introduced by a summary, a short list of highlights, and a representative graphical outcome allowing the reader to capture the essence of each research piece. Figure 1 (previous page) illustrates the Chair themes and their interconnections with a focus on initial cross-thematic questions. Some of the questions are answered in the deliverables and PhD theses while new questions arise as the research plan unfolds.

The originality of the Chair's work is to address major urban mobility challenges from different methodological perspectives, for different time frames, and with multiple modal options. The approaches and frameworks we use encompass:

- Scenario planning and transition design,
- Multi-agent simulation,
- Operations research,
- Business model design,
- Sustainable design, eco-design and life cycle assessment,
- Mixed social and IT models on urban mobility infrastructures.

Contact us for more information:

Flore Vallet	flore.vallet@irt-systemx.fr
Yann Briand	yann.briand@irt-systemx.fr
Tjark Gall	tjark.gall@irt-systemx.fr
Mariana Reyes	mariana.reyes@irt-systemx.fr
Tarek Chouaki	tarek.chouaki@irt-systemx.fr

Website: www.chaire-anthropolis.fr

Partners of the Chair

EDF ENGIE GROUPE RENAULT PARIS SACLAY Communauté d'agglomération NOKIA BELL LABS

LIST OF ACRONYMS

CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CPS	Agglomeration Community of Paris-Saclay (FR: Communauté d'agglomération Paris-Saclay)
GTFS	General Transit Feed Specification
HCM	Human-centred Mobility
IDF	Île-de-France
MAAS	Mobility as a Service
MATSIM	Multi-Agent Transport Simulation
PESTEL	Political, Economic, Social, Technological, Legal, and Environmental

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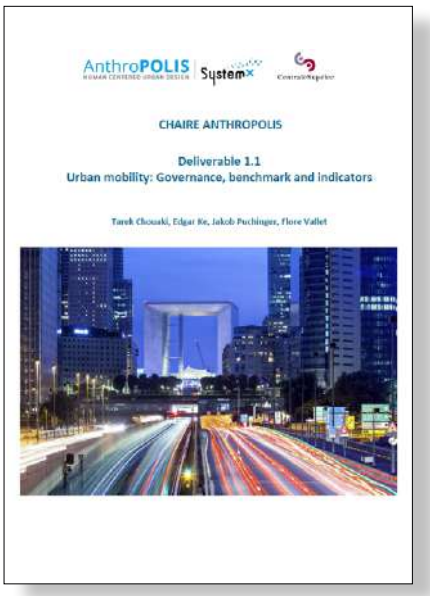
D1.1 | URBAN MOBILITY: GOVERNANCE, BENCHMARK AND INDICATORS

By Tarek Chouaki, Edgar Ke, Jakob Puchinger, Flore Vallet



This deliverable aims at introducing the main **concepts, models and challenges** currently discussed in scientific and grey literature, in the objective of providing guiding principles and key investigations for our main research themes.

By following a funnel model, we first dwell upon mobility governance – notably how it can lead to innovation – as well as how it translates effectively and concretely on different territories. We then look at various large-scale initiatives, and how patterns are emerging in terms of technological, social economic and environmental solutions. Finally, we introduce a systemic thinking around infrastructures and their increasing versatility, stating the need for new design principles in response to hard to solve urban mobility questions.

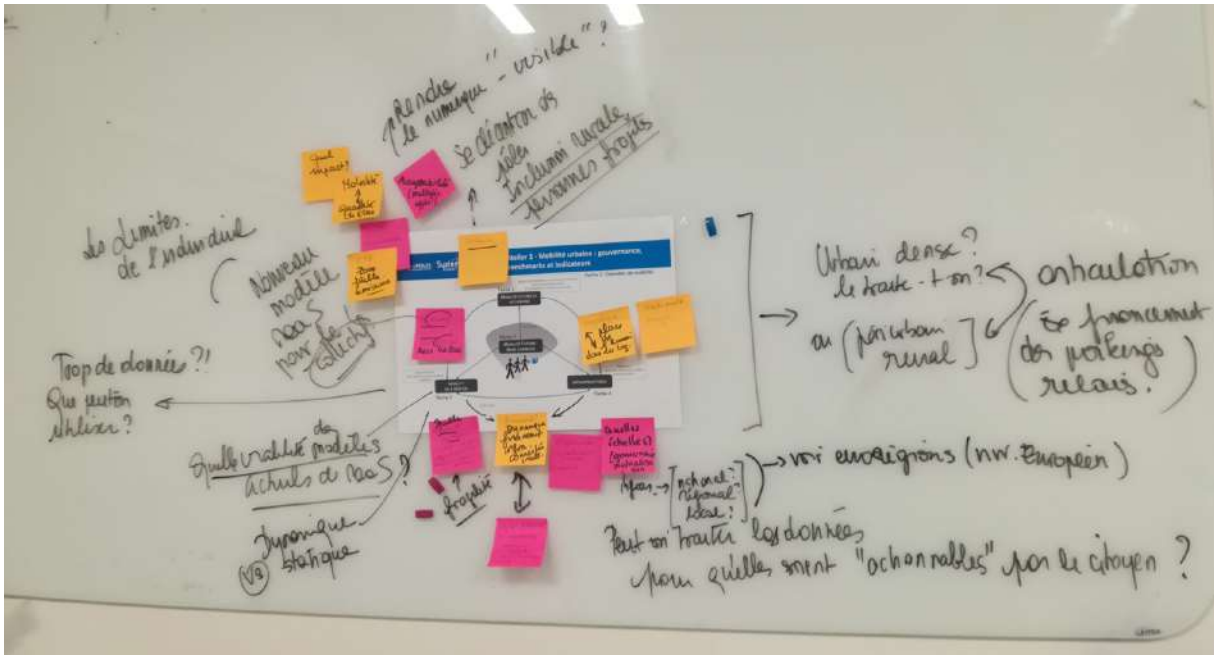
First, we focus on **mobility governance**, citing the rising needs for cities to provide a reliable framework of collaboration between private service providers and public authorities. Such a framework shall provide two key notions of enforcement and enablement: enforcement in providing rules that satisfy the collective interest beyond the interest of individual solutions, and enablement in setting up foundations (e.g data, connectivity technologies, fertile testing ground) that could benefit overall mobility patterns on a territory. The question of mobility governance and regulation is central for any new enterprise, such as servitised mobility (e.g., Mobility as a Service).

When looking at some of the **key initiatives that pave the way for new mobility**, Paris-Saclay and its cluster is a unique spot given its dynamism. Solutions are various and it is commonly known that no single 'killer solution' will emerge but rather a few ones will have to be combined. A patchwork of technological solutions, driven by concepts of automation (also autonomy), connectivity or big

data, combined with social foundations, around inclusivity, data-rights compliancy or sustainability, and powered by new economic and cooperative models, will emerge as a network of solutions.

The characteristics of the **infrastructures paving the way** for a new urban mobility are well known, they range from sustainability to resilience or human friendliness, but solutions are still lacking. Challenges still reside in their dynamism and their lack of optimisation notably. In response to that, systemic approaches are interesting in their ability to exhaustively map elements to be considered. Whether they translate into PESTEL matrixes or user journey maps, both acknowledge exhaustivity of elements and permit reflection about how parameter changes might affect the others. As such, capabilities of simulation, digital twinning, and remote operations are key in transforming obsolete infrastructures into ones that would lead to better resource allocation/utilisation and be more dynamic and hence more sustainable.

We propose an overview of **sustainability challenges** associated with the quality of travel experience, the development of Mobility as a Service, infrastructures and visions of future mobility. In order to evaluate future solutions, our recommendation is to set sustainability indicators not only considering potential greenhouse gas emissions but also envisaging other environmental indicators (for instance land use) and cost estimations.

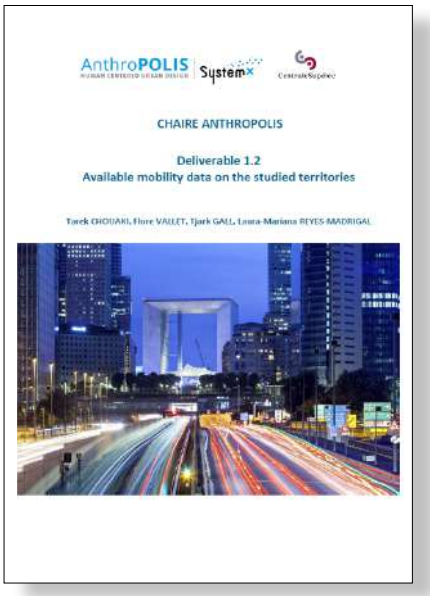


Workshop outcomes: Identification of urban mobility challenges

Outcomes of the first workshop of the chair conducted in February 2020 are also reported. A first list of relevant sustainability indicators for decision makers, service providers and citizens was collectively produced and will be further investigated in future work. The workshop also conducted groups to reflect upon a strategy to apply when dealing with mobility data; to raise additional questions and challenges (for instance mutualisation, inclusiveness, mobility at the interface of rural and urban areas). In the end, crucial points of our research acknowledge that the urban mobility system of the future is yet to be built. New models, new players, and new value flows will arise, but we have yet to see how they all interrelate and what will be the requirements to build a sustainable urban mobility ecosystem, i.e. one that stands the test of time and monetisation.

D1.2 | AVAILABLE MOBILITY DATA ON THE STUDIED TERRITORIES

By Tarek Chouaki, Flore Vallet, Tjark Gall, Laura Mariana Reyes Madrigal



This deliverable aims at offering an overview of mobility related data. These are the data that can be used as a basis for the different research topics addressed in the Anthropolis Chair.

We first present different layers for grouping the data used in mobility studies: **geographical, socio-demographical, traffic and transportation and economic data**. We also summarise the discussion that was conducted with the project's partners in December 2020 regarding the territories that we will be interested in for our studies besides the Île-de-France: **Helsinki, Rouen Metropolis, Madrid, Vienna, Casablanca, São Paulo and Beijing**. These territories have been chosen to have a variety in terms of scale, population and economic indicators while ensuring the availability of data regarding them either in open access or through the partners.

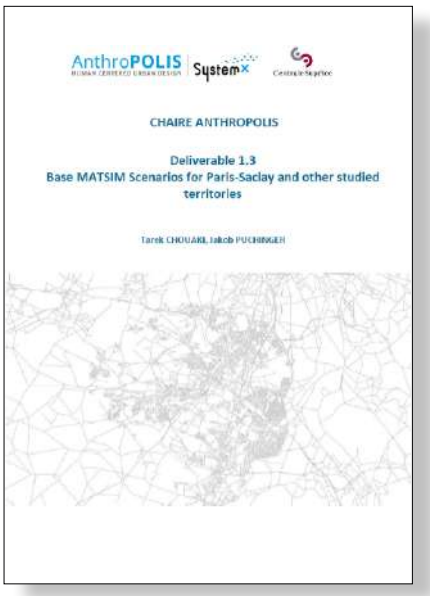
We then detail each identified layer by giving at least one example of data that can be used in a study on mobility. First with the geographical layer and the example of OpenStreetMaps, the socio-demographical layer with the example of population censuses in France, followed by the traffic and transportation layer in which we describe the GTFS standard.

This first version of the deliverable is centred on data that can be used in agent-based simulations to accurately reproduce realistic mobility scenarios. An emphasis is put on the area of Ile-de-France and Paris-Saclay in particular given that we have access, thanks to our partners, to forecast data that can be used to build future contextual mobility scenarios. Other openly available MATSim scenarios are used as they are in the scope of PhD task 4 to test various operation strategies for on-demand systems.

A view of Saclay plateau from Openstreetmaps.org

D1.3 | MATSIM BASE SCENARIOS FOR PARIS-SACLAY AND OTHER STUDIED TERRITORIES

By Tarek Chouaki, Jakob Puchinger



This deliverable documents the MATSim simulation scenarios that are or will be available to the Anthropolis Chair and that will be used for simulation-based studies. Agent-based simulation of mobility in MATSim will be mainly used in the PhD thesis on 'Stochastic Optimisation and Reinforcement Learning for the Design of On-Demand Mobility Systems by Simulation' under task 4 but other tasks will also use simulations to provide additional analysis.

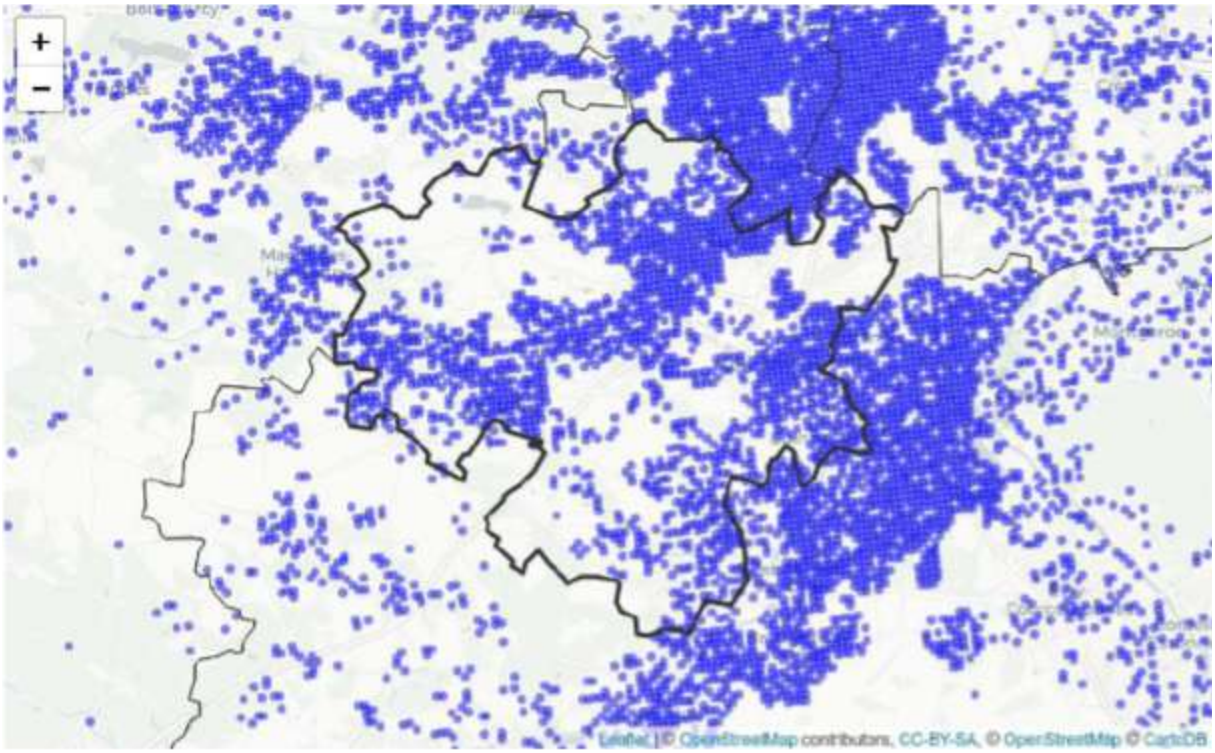
We introduce MATSim and give an overview on its underlying working principles. We also present the main components that are necessary to build a MATSim scenario (**road network, agent population and mobility services**).

We then detail the two scenarios that are already available to use for the Anthropolis team: the **Paris-Saclay** scenario and the **Rouen-Metropolis** scenario. We describe for each scenario the data that have been used in the elaboration process. We then outline the scenario regarding the city of **Casablanca** that is being constructed and provide a perspective on future scenarios for one or more territories among the ones chosen by the Anthropolis and the partners. We also detail the development that has been done on an existing MATSim tool to provide more ease of usage.

We finally conclude by a perspective on how existing and future MATSim scenarios will be used in the Anthropolis Chair.

The highlights are:

- We emphasise the MATSim scenario related to the Paris-Saclay area.
- The presented MATSim scenarios will be mainly used in the scope of the PhD subject 'Reinforcement learning and stochastic optimisation for the design of on-demand mobility systems'.
- Being of particular interest to our partners, the Paris-Saclay scenario will be extensively studied to explore the future of mobility in the area. Various contextual scenarios for the mobility demand will be contributed from the work on task 2 thesis and will be studied in MATSim.



Repartition of the places of residence for agents in Paris-Saclay scenario

D2.1 | OVERVIEW OF TRENDS AND CONCEPTS OF URBAN DEVELOPMENT AND FUTURES STUDIES

By Tjark Gall, Flore Vallet

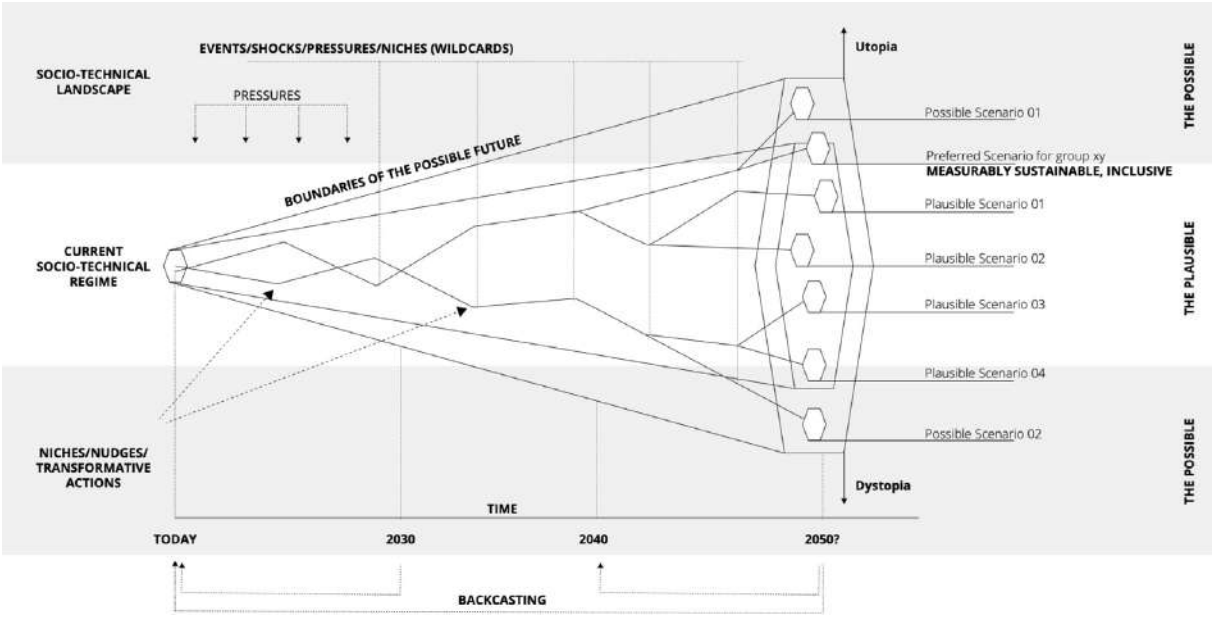
The Deliverable 2.1 'Urban Mobility Futures: Overview of Trends and Concepts of Urban Development and Future Studies' is the first outcome of Task 2 'Future Mobility' of the Anthropolis Chair. The deliverable aims to provide the foundation for the research on urban mobility futures through an overview of concepts and methods of future studies, as well as potentially impacting global and local trends. It sets out to address this by asking five key questions: (1) Which relevant concepts and methods for **futures studies** exist? (2) Which **methodological elements** of future studies are relevant? (3) Which **global trends** impact future urban mobility? (4) Which **local trends** exist in Île-de-France and Communauté d'agglomération Paris-Saclay (CPS) in the context of urbanisation and mobility? (5) Which initial **boundaries of possible futures** can be identified?

D2.1 constitutes the basis for Task 2 which continues the future methods' research and Personanarrative approach of the first cycle of the Chair. It aims at responding to the question of how the future of urban mobility may look like and how we can prepare, plan, or impact its materialisation. This deliverable is structured in three sections. First, it provides a brief overview over the field of future studies, followed by different foresight methodologies. Second, it describes global and local trends which span socio-economic, demographic, spatial, and technological dimensions, among others. The latter part zooms in on the current status of the Île-de-France, as well as CPS. Lastly, the deliverable attempts to provide an initial overview of boundaries of possible futures. These include, for example, the population growth and spatial expansion. The primary outcomes of this deliverable are the overview of what is there and an outlook to what might come next. While it does neither provide a comprehensive picture of societal and technological, nor of urbanisation or mobility trends, it shows major forces and developments and points towards existing and relevant reports and data. Some of the identified trends will be ex-

amined further and might lead to an extended, revised version of this deliverable.

The highlights are:

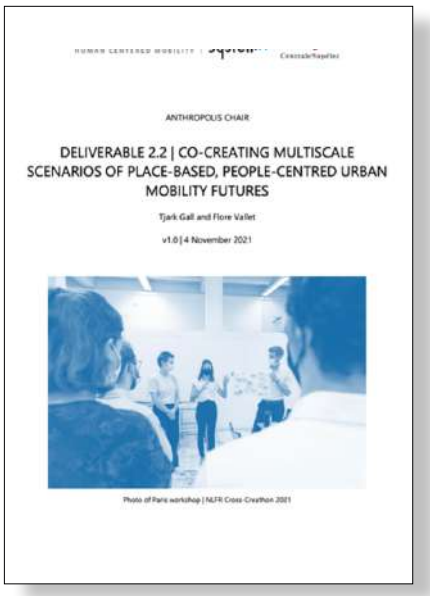
- Overview of theories and methods used to strategically work with futures with a focus on exploratory scenarios.
- Global trends in the context of sustainable development, urbanisation, mobility, and digitalisation.
- Trends in local context of the Chair, focusing on the historical, spatial, demographic, and socio-economic dimensions.



Futures Cone with multiple scenario pathways (synthesised by author)

D2.2 | CO-CREATING MULTISCALE SCENARIOS OF PLACE-BASED, PEOPLE-CENTRED URBAN MOBILITY FUTURES

By Tjark Gall, Flore Vallet



The deliverable extends the future studies and methodology approach of D2.1 and describes the application in the field of urban mobility. It provides a description of existing concepts and models, extends them, and guides the participatory research and co-creation process of urban mobility futures. In doing so, it attempts to respond to the main research question below, as well as three complementary research questions: How can human-centred urban mobility futures be co-created? How can we **model urban mobility futures?** How can we **co-create urban mobility futures**? How can we **assess urban mobility futures?** To answer these questions, the document is structured in four main chapters. The first chapter 'Why co-create urban futures?' looks at the motivation behind the co-creation of urban mobility futures, specifically in the French and local Chair context. This contains an overview of different policy documents, their scales and timeframes, and outcomes of scoping interviews conducted within the Chair. The chapter concludes with the findings that a broad variety of policy documents and plans already exist, but a mismatch between long-term visions and short-term plans, as well as between international/national and local scales is apparent. Further, the notion of local and place-based urban mobility futures is under-developed but appear promising.

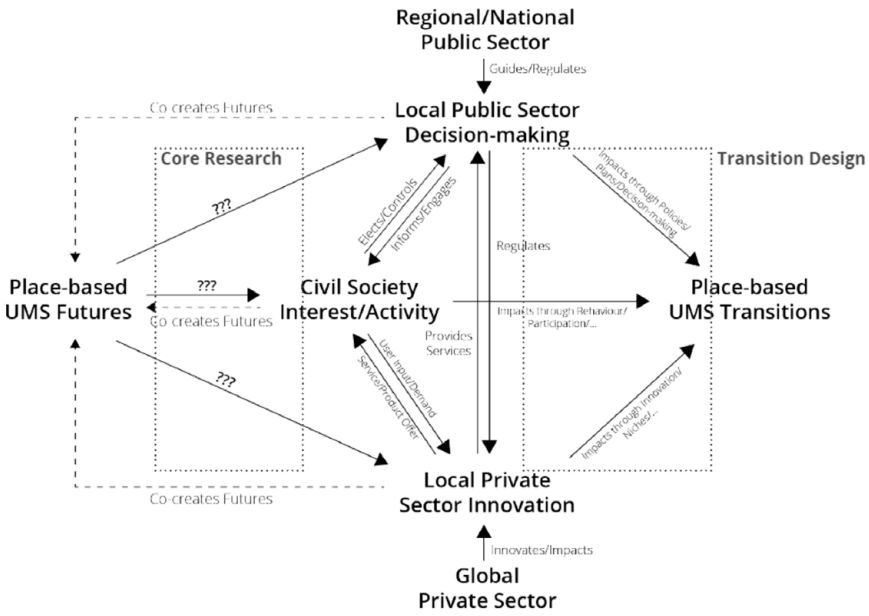
The second chapter, titled 'How to model urban mobility futures?' focuses on the modelling and definition of urban mobility futures, and the urban mobility systems that are at the core of such futures. A special attention is given to theories around socio-technical systems and complex adaptive systems. In addition, the focus lies on transition theories to conceptualise the change of urban mobility systems from today until the future in a strategic manner. The chapter provides the foundation for the systemic understanding of urban mobility, and the modelling and analysis of transitions.

The third chapter 'How to co-create urban mobility futures?' shifts the attention to the process of co-creation. Therefore, co-creation, and the sub-processes of co-ideation, co-design, and co-production are defined and described, followed by an initial framework and taxonomy. Additionally, a range of specific practices for the co-creation of urban (mobility) futures is presented. The chapter provides the conceptual framing for upcoming studies of co-creation processes, as well as the basis for a possible co-creation toolbox.

The fourth chapter, titled 'How to assess urban mobility futures?' intends to contribute to the question how we can ensure (1) that developed scenarios are sound, and (2) that one or several scenarios are more sustainable, people-centred, or otherwise preferred over other ones. The chapter provides some initial insights and lays the foundation for work in the upcoming months, in particular through a student project at the Laboratoire Génie Industriel, CentraleSupélec.

Finally, the deliverable zooms out again and explores what parts of co-creating urban mobility futures have already been studied extensively, which have been addressed so far in the work of the Chair and on which fields the focus should lie for the upcoming two years of the task's work.

Through the deliverable, it became evident that a **potential lies in localised urban mobility futures** in the context of planning and designing urban mobility systems as they can bridge the gap between the long-term national and global guidelines and policies with the local actions and plans. Due to the ambition of bridging between global and local scales, the notion of **place-based urban mobility futures** is understood as crucial to ensure that instead of generic scenarios or visions, place-responsive and context-specific approaches localise and root the futures in a relatable and clearly defined socio-spatial context. While gaps have been identified in the application of place-based futures in the design of urban mobility systems, a vast number of approaches, methods, and tools exist in the field of futures and foresight. Thus, no attempt is made to create novel approaches as such, but instead use, adapt, and combine existing approaches adequately. The **notion of co-creation** has gained a significant role in this area, as its application across phases is promising in the sense that it can enable a higher degree of **people-centred urban mobility futures** as outcome, while contributing further to the localisation. Further, first insights of different ways for the **assessment of urban**



Model of connections between futures, local actors, and place-based transitions

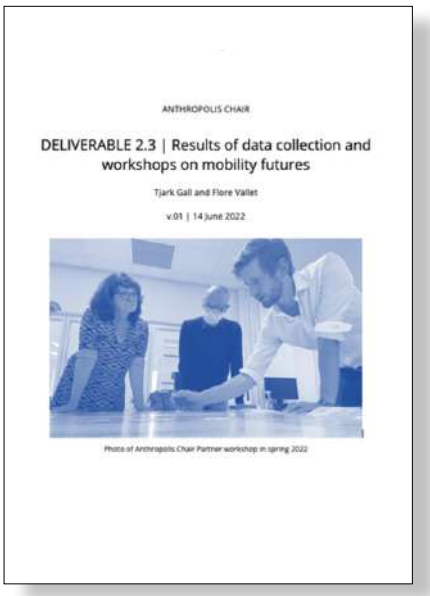
mobility futures build the foundation for upcoming work. Finally, to translate scenarios into actions, existing yet merged **transition theories** guide the **transition design process** from current urban mobility systems to future systems.

The resulting identified gaps are (1) the **validation and quantification of the positive impact of using place-based futures** in the process of designing urban mobility systems, (2) the further examination of the **role of stakeholders across stages of co-creation**, and (3) the **assessment of scenarios**, both regarding methodology and outcome. The first two will be the focus of the upcoming data collection and field work, while the latter is currently worked on within the context of the Laboratoire Génie Industriel. Regarding the broader task and Chair's work, this deliverable builds on D2.1, 'Urban Mobility Futures: Overview of Trends and Concepts of Urban Development and Futures Studies' and is the second deliverable of four within Task 2 'Futures of Urban Life and Mobility'. It builds the conceptual basis for the data collection and experimentation reported on in D2.3. The highlights are:

- Localised urban mobility futures can bridge between (inter)national strategies and local challenges.
- Strategic and adapted co-creation with various stakeholders and across process stages can enable people-centred urban mobility.
- Modelling sustainability transitions of urban mobility systems allows to identify transitions levers and areas of interventions.

D2.3 | RESULTS OF DATA COLLECTION AND WORKSHOPS ON MOBILITY FUTURES

By Tjark Gall, Flore Vallet



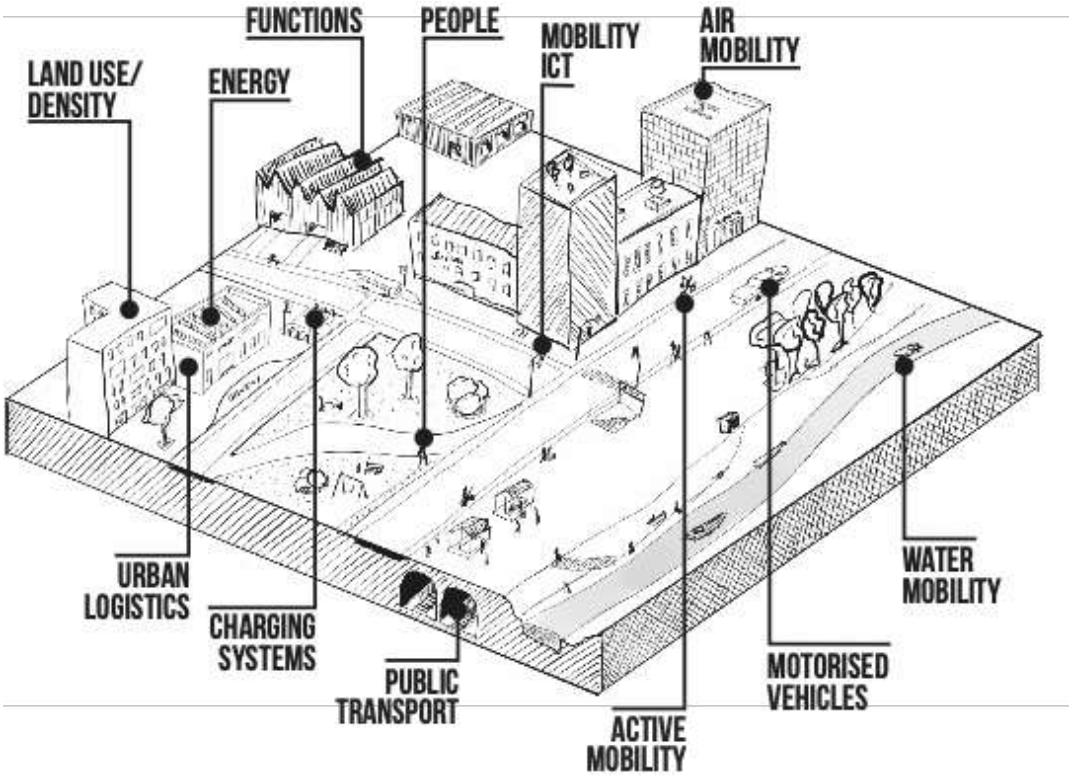
The third deliverable of task 2 describes the concept, approach, and outcomes of all participatory and interactive formats related to the development of future personas and scenarios of task 2. It addresses the gaps identified in deliverable 2.1 and 2.1. The reported-on activities include research seminars, expert workshops, interviews, as well as exchanges with the broader scientific and practitioners' society.

The guiding questions the activities of task aim to respond to are:

- What are the gaps and **key needs in the context of the Chair** for the work on futures?
- How can different urban mobility system **stakeholders work effectively with scenarios?**
    - How can we **communicate scenario concepts**?
    - How can we **translate futures into different types of scenarios**?
- How can we **ensure the suitability of scenarios** to respond to the identified needs?
- How can **model urban mobility systems** (UMS) be modelled across stakeholder' fields of expertise (e.g., simulation/transport engineering/economists/urban planners/mobility solution designer?)
    - What are the **key components** of UMS?
    - How do UMS **evolve over time**?
- What are **key trends and uncertainties** that affect the UMS?

The deliverable addresses the question in four chapters. The first chapter introduces the context and the underlying motivation, building on the preceding deliverables. The second chapter describes the methodology behind the data collection and analysis. This includes the conducted expert interviews, as well as the workshops. The third chapter describes each of the activities that contributed to responding to the guiding questions. Finally, the last chapter discusses the activities in their entirety, structured by the underlying questions. Additionally, an outlook on remaining workshops is given, as well as the works to which the deliverable contributes. The highlights are:

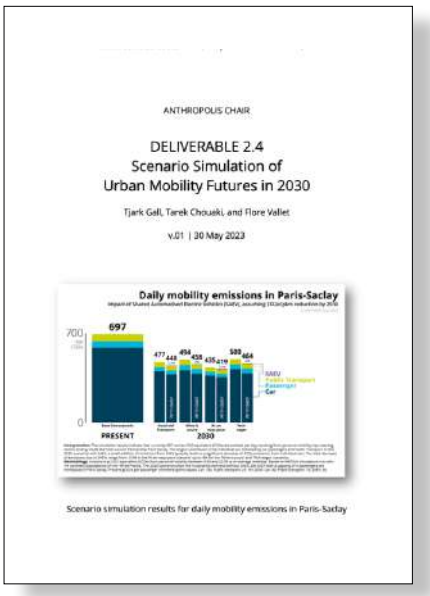
- There is a potential for an **uncertainty-integrating design method** that combines **qualitative and quantitative** dimensions and facilitates the **co-creation of multi-dimensional urban mobility futures.**
- Tools such as the **futures cone, archetypes**, and methods to **assess and evaluate impacts** and **assure the quality of scenarios** allow a resource-efficient and context-specific work with future scenarios.
- An interdisciplinary and spatially contextualised **Urban Mobility System model** builds the foundation for the strategic work targeting **transitions to sustainable and people-centred urban futures**.



Visualisation of an interdisciplinary urban mobility system model

D2.4 | SCENARIO SIMULATION OF URBAN MOBILITY FUTURES IN 2030

By Tjark Gall, Tarek Chouaki, and Flore Vallet



Scenario simulation results for daily mobility emissions in Paris-Saclay

The previously developed scenario-based approach to work strategically with futures of urban mobility systems is applied to the work on agent-based simulation also conducted at the Chair. This deliverable describes the methodological foundation for the reuse and creation of local scenarios of urban mobility systems, the adaptation via personas and synthetic population to integrate trends and uncertainties in the simulations, followed by the agent-based simulation of a set of four contextual scenarios for 2030 as well as the same set of scenarios including a Shared Automatised Electric Vehicles solution in the inter-council partnership Paris-Saclay.

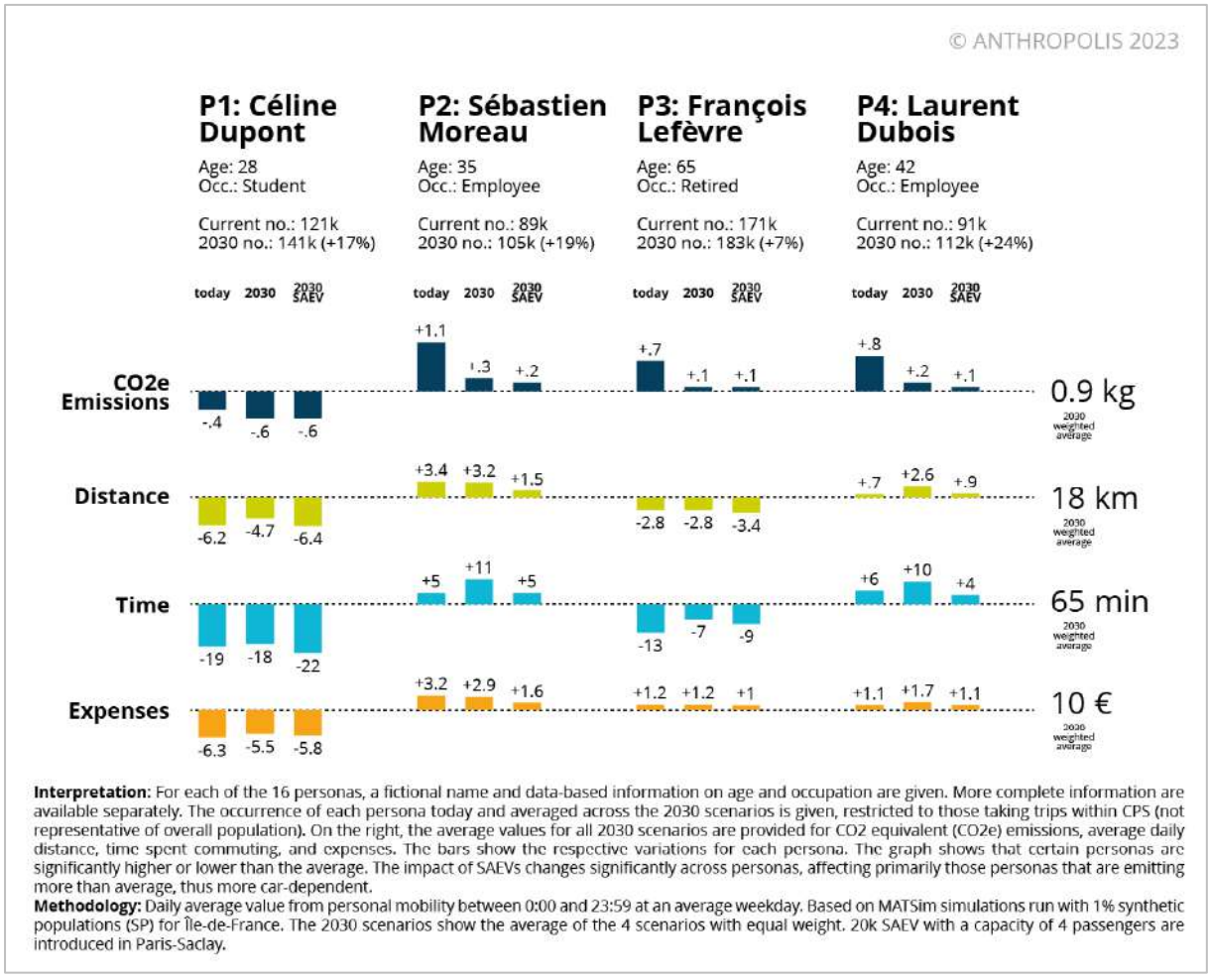
The guiding research question is **'How can we integrate strategic foresight in the simulation of urban mobility systems of tomorrow to better inform design and decision making today?'**

The proposed method allows comparing the socio-economic and environmental impacts of planned mobility solutions across varying future socio-demographic and urban mobility developments. Compared to other approaches, it permits to look at the change of behaviours and choices for individuals – aggregated into personas – by using agent-based modelling while extending the method by integrating future trends and uncertainties via qualitative exploratory scenarios.

The deliverable describes the following **contributions**:

1. A checklist-based approach to **evaluate the quality** and suitability of existing sets of scenarios.
2. A **scenario-localisation** process applied to the context of Paris-Saclay.
3. A method to **integrate future personas and synthetic populations**.
4. A set of **agent-based simulations of Paris-Saclay 2030** with and without shared autonomous electric vehicles.
5. An **impact assessment** of simulation outputs across scenarios.

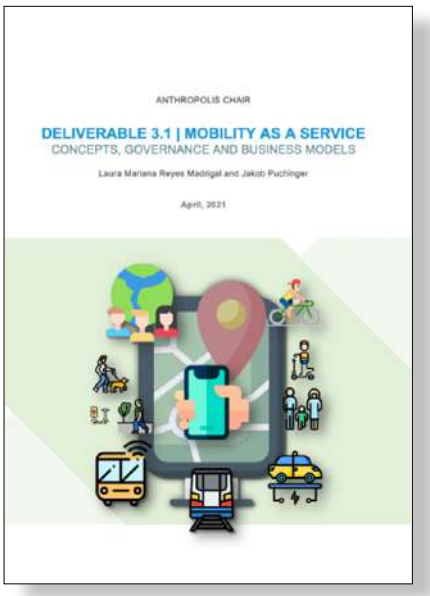
We argue that the approach has significant potential in conducting more robust impact assessments of future urban mobility solutions, ultimately contributing to more robust design and decision-making processes. This deliverable builds on four publications and contains two sections to be published.



Excerpt of persona-based comparative impact assessment

D3.1 | MOBILITY AS A SERVICE: CONCEPTS, GOVERNANCE AND BUSINESS MODELS

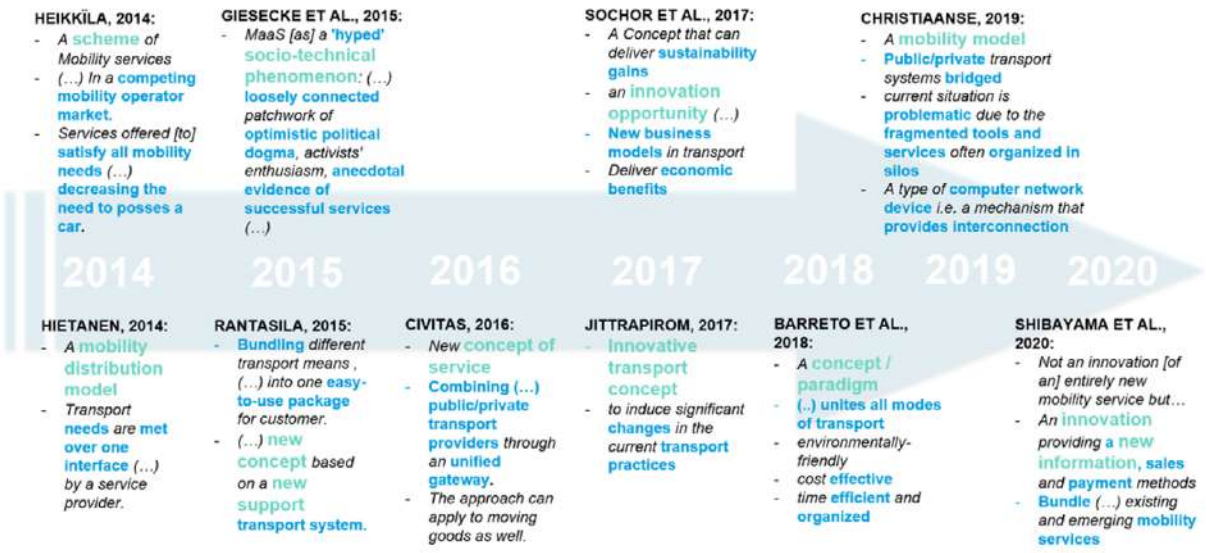
By Laura Mariana Reyes Madrigal and Jakob Puchinger



The deliverable 3.1 'MaaS Concepts, Governance and Business Models' represents the starting point of the Anthropolis research on Mobility as a Service (MaaS). In this document, we aim to provide a steady knowledge base that facilitates further analysis and understanding of organisational configurations in MaaS ecosystems as well as value creation dynamics. The deliverable 3.1 is structured in seven chapters, covering the genesis and evolution of the MaaS concept through scientific literature, the challenges in the processes of structuring sustainable business models and the possible angles for approaching governance complexities.

In the first chapter we introduce the transformations that took place or that are taking place and that have enabled the development of new mobility solutions and the current transition from the all automobile – all infrastructure paradigm towards new forms of imagining and conceiving mobility.

In the second chapter, we describe the genesis of the MaaS concept, and we identify some of the scientific knowledge foundations of MaaS that have emerged from the beginning of the new century. We take a look at some indicators that have guided the development of MaaS solutions so far. In the third chapter we give an overview of the main stakeholders' roles and global governance dynamics in MaaS ecosystems. The governance structures of specific MaaS solutions are presented with the case studies in chapter five. Chapter four presents the core of our research objectives. Matters regarding value creation, capture and redistribution and the reconfiguration of the value chain are identified in order to –in a more advanced stage of the research – propose the optimisation of business models towards more sustainable outcomes of MaaS. Chapter five presents the highlights of the case studies in the cities of Helsinki, Finland and Vienna, Austria. The studied context of MaaS in these European cities goes from the different



Evolution of the terms utilised to define MaaS. Source: Literature review by the author, 2021.

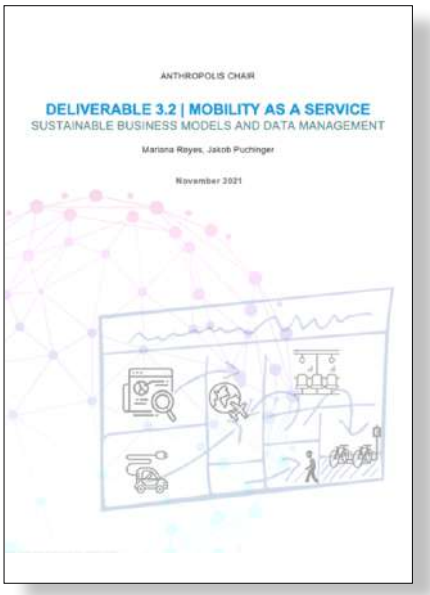
mobility offers between the MaaS solutions to their governance details. Finally, chapter six and seven share the Anthropolis vision on Mobility as a Service, as well as the conclusions of this first stage of the Anthropolis research on the subject of MaaS. The highlights of this deliverable are:

- The existing tension present when defining MaaS is ongoing. Defining MaaS is not just an exercise of scientific interest, in order to fully grasp its best outcomes, defining its components will facilitate decision making through the understanding for involved actors. We keep trying to move forward and to revolutionise the innovation that MaaS is, but basic aspects of MaaS remain to be clarified, approached and evaluated.
- MaaS continues to integrate innovations and is becoming a more tangible solution today, however, more work is still needed to **evaluate the outcomes** and to help shape regulation. The engagement of public authorities in the creation of directives and policy could help enable the development of MaaS.
- There are new market and governance dynamics present among a complex ecosystemic network of multiple actors. A first step of the analysis is to map their roles, interactions and business relationships to further identify the added value they bring to each other and to the ecosystem. **Mobility as a Service complex stakeholder's interactions** remain a key element to be studied, in part due to the importance of identifying the roles of each actor involved to better understand and evaluate the business dynamics between these actors in the MaaS ecosystems.

- **Data is a key element in MaaS** that requires the creation of special legal frameworks to build on trust among users, providers and public authorities. The sharing and the aggregation of data through technological tools mark a new step towards collaboration between stakeholders. Open data is a goal towards improving interoperability between services and users and at the same time, to better understand the usage of mobility services offered and improve them as a result.
- **Active modes** should be incorporated and incentivised in MaaS platforms. Giving non-monetisable modes such as walking a place in ecosystems at these early stages of MaaS development is going to be key to the creation and further implementation of truly sustainable MaaS solutions. In this case, policy and regulation will play an important role in the achievement of MaaS sustainable goals.

D3.2 | MOBILITY AS A SERVICE: SUSTAINABLE BUSINESS MODELS AND DATA MANAGEMENT

By Laura Mariana Reyes Madrigal, Jakob Puchinger



The research carried out for this deliverable aims at tracing the path of sustainable business models in the organisational, managerial, and institutional panoramas. The concept of sustainability joined the concept of mobility around the second half of the XX century when city dwellers and authorities started realising and undergoing the negative externalities of industrial activity and tailpipe emissions. Emissions linked to transportation had increased drastically due to the democratisation of cars, the stabilisation of economy and the wild expansion of the urban areas.

In the first chapter of this deliverable, we study the concept of sustainable mobility. We identify the components of sustainable transportation and bring to light the elements to build sustainable business models. All of this, from different angles, as approached by various authors in literature (Bocken, 2013, 2014, 2018, 2021; Cohen and Kietzman, 2014; WCSBD, 2015; Schaltegger et al., 2016; Aagaard et al.,

2019; Bellini et al., 2019; Nosratabadi et al., 2019; Ribeiro de Souza et al., 2019; Sochor, 2021; Alonso-Martinez et al., 2021). In this first stage of our analysis, we identify the main indicators and strategies necessary for the creation of sustainable business models.

In a second stage of the analysis of existing literature, we analyse the concept of sustainable business models placed in the context of urban mobility. We characterise the objectives of sustainable mobility and the key components for the construction of sustainable business models based on these objectives.

In a third phase, we delve into MaaS business and operational models, identifying the existing or missing sustainability system components and their roles. We focus on 2 elements for sustainable value creation in MaaS: 1) Data management for enhanced intermodality and 2) Sustainable behavior change for modal shifts. The analysis of these elements is carried out through a comparative case study. The case study focuses on MaaS deployments in the Paris capital region (Île de France). The MaaS solutions retained for the analysis are 1) Bonjour RATP, 2) IDFM App, and the other two are transnational navigation solutions that are equally present in the IDF territory: 3) Google Maps, and 4) Citymapper. These last two have evolved from being itinerary calculators and navigation tools, towards becoming a high-level MaaS solution (level 1 to 2 depending on the territory). Google maps and Citymapper currently provide users not only with information in real time for public transport networks and other mobility services in cities, but they have also integrated the possibility to buy tickets and pay for trips directly from the app. Nevertheless, these payment features are only available for the moment in some US and UK cities.

Finally, we propose a series of insights for the construction of sustainable business models for MaaS and its potential assessment based on existing frameworks developed in the literature (Karlsson et al., 2017, 2019, 2020; Karjalainen et al., 2021; Zhao, Andruetto, Vaddadi and Pernestal, 2021) and a list of research perspectives to further explore into the subject.This study will serve the members of the Chair, giving them perspectives for the construction of sustainable business models, specifically for MaaS solutions.

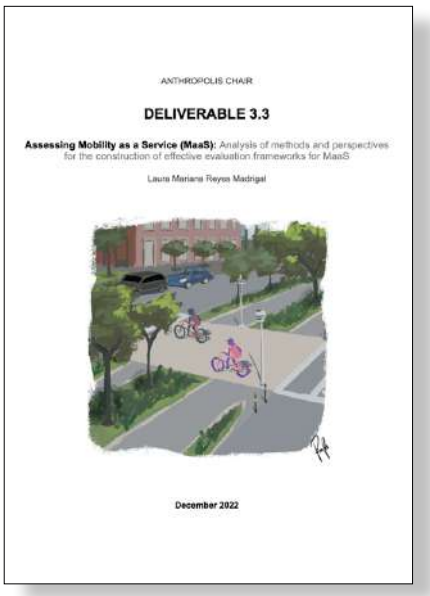
The highlights of this deliverable are:

- MaaS sustainable business models should incorporate strategies for behavior change, having an impact in mode choice, green modes, relying on technological innovations. Intermodality and behavior change are two key elements for value creation in MaaS.
- MaaS models should incorporate the smart use of motorised modes for rebalancing the spatial structure and use of public space. All of this should be reinforced and enabled by public policy and should give users access to intermodal journeys.
- Some strategies to facilitate intermodal journeys are advanced data capture, management, and distribution, as well as clear data opening standards and contractual arrangements that enable data sharing.
- Data is an asset for sustainable MaaS business models, nevertheless, big efforts are required to standardise data formats and syntax across services and platforms. Privacy remains a concern when it comes to gathering data, sharing it, and monetising it. Significant added value to be given to data producers (i.e. users).
- Measuring sustainability in MaaS business models is still a challenge and interesting projects are ongoing to achieve this (KOMPIS, 2018).

Overview of Main Roles of Data for Sustainable Urban Mobility. Source: Based on content from ITF, 2020; Icons from thenounproject.com, various authors.

D3.3 | ASSESSING MAAS: ANALYSIS OF METHODS AND PERSPECTIVES EVALUATION FRAMEWORKS

By Laura Mariana Reyes Madrigal



The research shaping this deliverable comes from two different work collaboration experiences. These experiences lead us to identify the limitations and opportunities of MaaS' impact evaluation frameworks through a series of empirical tasks and from literature. Some of the barriers for the effective evaluation of MaaS impacts are linked to the lack of fully deployed MaaS solutions and the narrow usage of existing MaaS, and, thus, lack of data to perform consequential impact assessments.

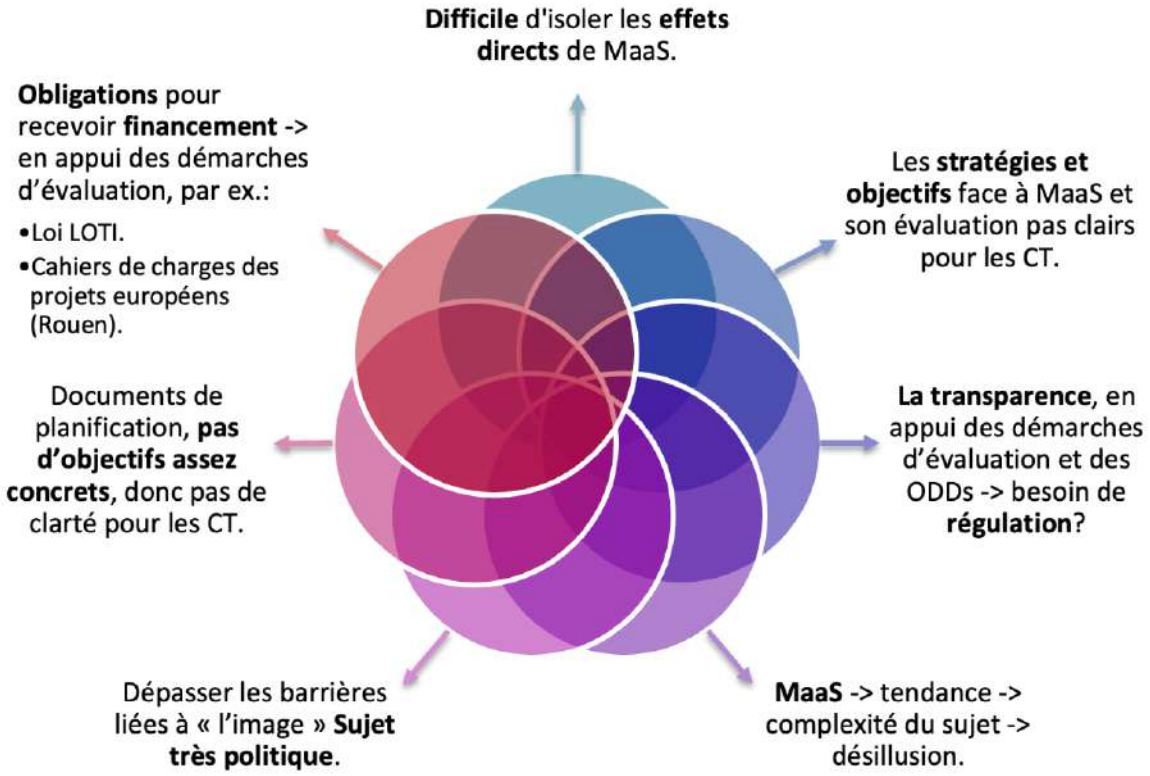
The lessons from these works show evidence of the barriers for evaluating MaaS from a system-level and individual and organisational perspectives. The identification of these barriers is particularly relevant for local authorities who require tangible, practical methods to measure the achievement of policy objectives while building and deploying MaaS solutions.

Two significant gaps were identified when exploring assessment models in the literature. The first one is the evaluation of impacts on the quality of life. This is seemingly due to the complexity and subjectivity of evaluating what individuals 'pursue' for well-being based on different 'values and priorities'. Nevertheless, through the included work, this indicator was found to be critical for the system-level assessment and to validate MaaS as a human-centered innovation facilitating access for people to opportunities, activities, and locations. The second gap is the indicator for measuring impacts on policy and regulation. The multisectoral nature of certain policies makes it difficult to point out if it is MaaS that is enabling them or if it is the effect of other policies in place.

When zooming in on the French local authorities' experience on the assessment of MaaS impacts, we face a topic with vast room for action. The main barriers identi-

fied from this case study involve the difficulty of isolating the effects directly linked to MaaS and separate them from other policies and strategies in place. Also, separate impact indicators from performance indicators is something that needs to be addressed. Further, the complexity of measuring macro-level and system-level impacts leads to perceive evaluation as an arduous process. Starting with measuring objective goals related to the behavior change and the visibility of MaaS mobility offers could be an action pathway to balance this perception.

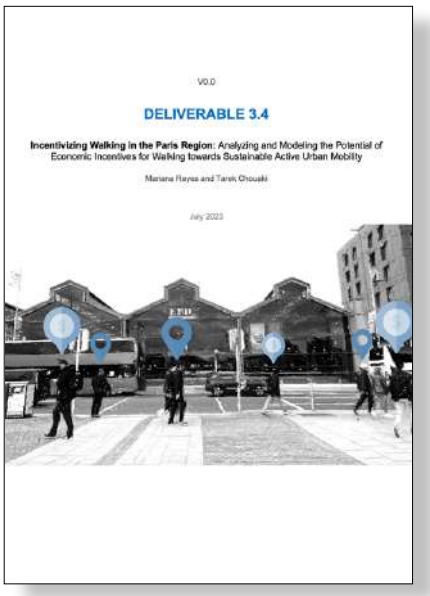
Lastly, the question if MaaS will ever come to be is posed. The pathway toward Gartner's plateau of productivity has taken more time than expected. MaaS has been on the discussion tables for the past eight years, but more needs to be evidenced about the actual changes MaaS can bring to everyday mobility. The buzz from the early years is vanishing, and at the same time, researchers keep looking for business models that sustain this innovation and the potential benefits it is supposed to bring. We only have one certainty, even though deploying and stabilising MaaS remains a challenge, we need to keep working to build the frameworks that will enable measuring its systemic and punctual impacts on society, the environment, and the economy.



Some key points of MaaS evaluation perspectives in France
(source: CEREMA, 2022, and interviews with representatives of CEREMA and SYSTRA)

D3.4 | WALKING IN THE PARIS REGION: THE POTENTIAL OF ECONOMIC INCENTIVES

By Laura Mariana Reyes Madrigal and Tarek Chouaki



We explore the different approaches to facilitate behaviour change towards the adoption of more sustainable mobility practices. Our research builds on the field of transportation, mobility, and behavior change. We test the impacts that monetary incentives for walking could have on mobility in Paris by responding to the following research question: How can walking be incentivised to enable behaviour change towards more sustainable mobility? We delve into the potential of two different financing schemes to incentivise three types of pedestrian mobility trips. We observe the global effects, modal shift, CO2 emissions, and distances traveled.

Sustainable and active urban mobility options, such as walking, represent a significant opportunity for achieving environmentally friendly and healthier transportation in the Paris Region. Despite the well-known benefits of walking on mental and physical health, there is yet a need to substantiate the potential gains that could be brought by supporting the development of walking as a transport mode in the eyes of public authorities at different governmental levels. Our research aims to analyse and model the potential impacts of economic incentives on walking behaviour in the Paris Region. We do so by addressing the research problem of how these strategies could effectively encourage individuals to choose walking as a mode of transportation, how the modal shift would affect the use of Public Transport (PT) and private cars, thereby promoting sustainable urban mobility.

We propose to tackle the topic through a quantitative modeling exercise where the impact of financial incentives for walking is assessed in detail by using agent-based modeling and simulations of 36 different incentive scenarios. In our simulations, traveller behaviour is modelled and considered individually, and a mode choice model is used to approximate real-life user decision-making. Such a model takes into account different components of a trip such as duration and cost.

In this work, a representative simulation of the Île-de-France area, as well as the underlying mode choice model, are extended to test the incentive policies for walking. Various incentive scenarios are studied and, by integrating the incentives in the mode choice model, we are able to assess the impact of each scenario on user decisions. This study sheds light on potential strategies that decision-makers and other stakeholders in the region's ecosystem could take to achieve multisectoral sustainable goals using economic incentives for walking.

This deliverable presents different behaviour change approaches with the potential to encourage sustainable mobility practices and assesses – through the lens of pedestrian mobility – the impacts that economic incentives for walking could have if applied in the Paris region. We cover three main themes in this deliverable:

1. The importance of encouraging a shift in urban mobility practices:
Addressing the relevance and urgency of the topic, the current walking context in the region, and the main characteristics and profiles of individuals, as well as the main barriers.

2. Behaviour change strategies for sustainable mobility:
Approaching different theoretical methods and concepts to tackle behavior change.

3. Modelling economic incentives for walking in the Paris region:
Presenting our framework, modeling choices, the KPIs used to measure impacts and the results.

The main results indicate that when applying monetary incentives on walking to reach public transport, the cost of these incentives is not compensated by the monetary value of the CO2eq (value per ton of CO2e of the European markets) emissions that are prevented thanks to the modal shift to walk.

D4.1 | SOCIO-TECHNICAL MODELLING OF URBAN MOBILITY INFRASTRUCTURES

By Sylvie Douzou, Edgar Ke, Jakob Puchinger, Laura Mariana Reyes Madrigal, Flore Vallet

This deliverable aims at providing a general framework to clarify the key concepts of urban mobility infrastructures that will be used in the subsequent work of the Anthropolis Chair. More specifically, it proposes an overview of the body of knowledge for the third research topic: 'Future infrastructures'.

Our objective with this deliverable is to make statements and **unify the various concepts defining contemporary urban mobility infrastructures**.

We first provide a semantic framework to define the following concepts: urban infrastructure and urban mobility infrastructure. This framework is driven by the idea that the city, seen as a social and technical space, makes the important connections between infrastructure components. It points out to different meaningful images of urban mobility infrastructures. We emphasise three main representations: (1) One definition of urban infrastructure in three interrelated blocks driven by territorial, social and technological components; (2) One representation of urban mobility infrastructure as a mobility practice system composed of competencies, meanings and materials; (3) One technical representation of delivered services based on physical, digital, cooperation and operational layers.

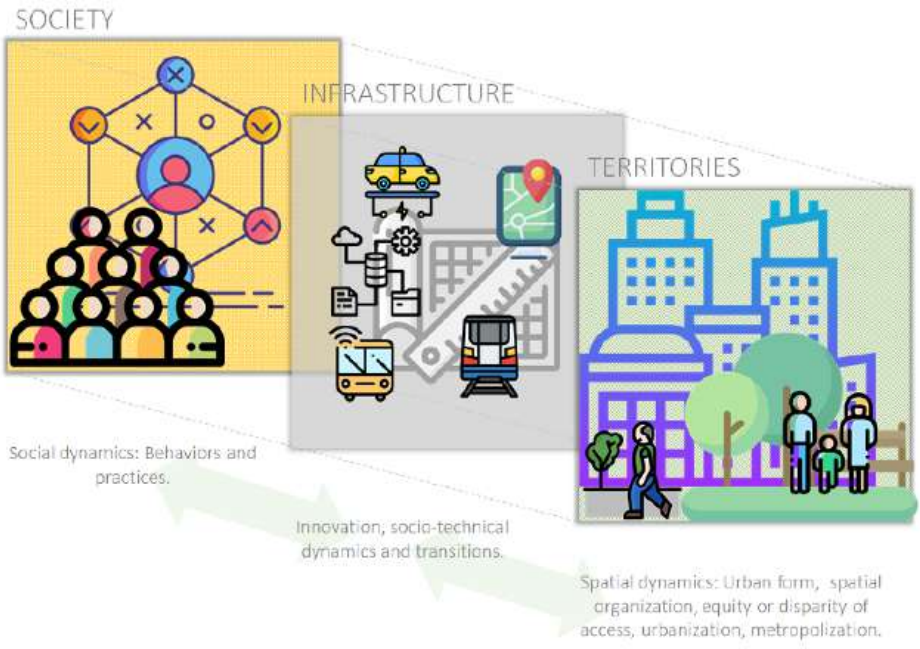
We show that mobility can be considered as **a system of social practices** (composed of competences, material and meaning) where infrastructures play an important role. In this context the perception of time and speed becomes a relative notion which can lead to unintuitive analyses. We are also witnessing the fact that physical parts of infrastructures **create friction zones and conflicting usages in a shared public space**. These are issues to consider when investigating the future of mobility infrastructures.

We then focus on the **technical layer of mobility infrastructures**, which are central to the simulation tasks of the chair. We propose a taxonomy that models the stacking of different types of infrastructures: physical, digital, coordination, and operation. The objective of such a categorisation is to display a set of tools that allow for traditional infrastructure to be augmented, leading to better management of the roads and its vehicles in accordance to policies. We further advocate for a deeper analysis of the complementariness of these viewpoints avoiding the pitfall of a simple opposition. As a matter of illustration, the technical elements of urban infrastructures are not only considered at the service of citizens but are infused by the humanity of users.

We finally provide concrete examples, explicative and illustrative, of the types of urban infrastructure in the frame of our study: **sidewalk and curb management; charging stations for battery electric vehicles.**

The highlights are:

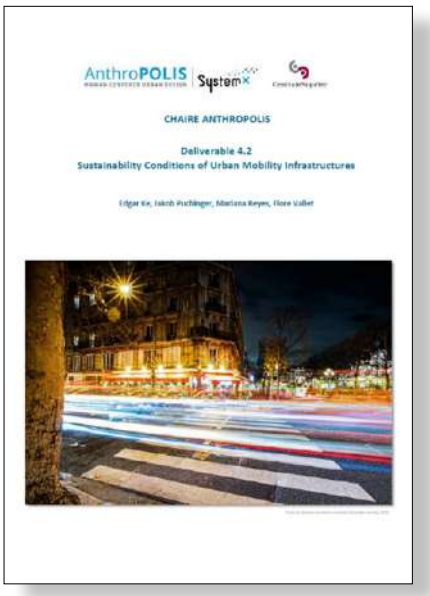
- The need to unify the concept of contemporary urban mobility infrastructures by means of three representations (territorial; influenced by social practices and technology)
- Mobility infrastructures generate specific issues, which are friction zones and conflicting usages in a shared public space



Infrastructure as a link between society and territories

D4.2 | SUSTAINABILITY CONDITIONS OF URBAN MOBILITY INFRASTRUCTURES

By Edgar Ke, Jakob Puchinger, Laura Mariana Reyes Madrigal, Flore Vallet



In this deliverable, we intend to address a selection of underexplored topics crossing urban mobility and sustainability challenges. According to D4.1, we argued that mobility infrastructures are indeed connected to public spaces: they constitute a spatial resource, shared, dynamically managed and (potentially) flexible. We conducted a structured analysis of various strategies to make mobility infrastructures as sustainable as possible, considering technological opportunities, but also organisational and behavioural ones. Considered as systems, mobility infrastructures ultimately appear to be a combination of elements with different technological contents, a balanced mix between simple and complex technologies.

The first outcome of the deliverable is the formulation of **13 interdependent guiding questions** to challenge the sustainability of mobility infrastructures, from the usage, data, and material intensity, to the artificialisation of soils, the resilience, or the promotion of safety for users amongst others.

The second outcome is the exemplification and sustainability-related analysis of **eight case studies of mobility infrastructures** as well as **innovations**: infrastructures dedicated to active modes; interactions between power grid and shared autonomous vehicles; solutions for road and vehicle management; and examples of several road-related innovations.

Lastly, we suggest the possibility to use a method linking prospective scenarios and life cycle assessment (i.e. **prospective Life Cycle Assessment**) to further explore the techno-environmental performances of future mobility infrastructures based on emerging technologies.

The highlights are :

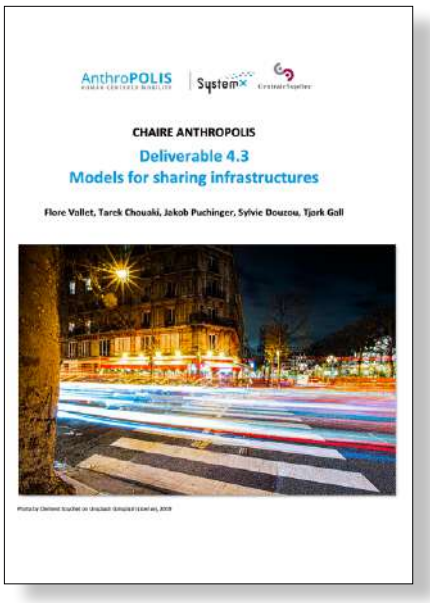
- The identification of a set of 13 questions to challenge the sustainability of mobility infrastructures.
- Developing a sample of eight case studies of innovative mobility infrastructures.

1. Does it allow a high usage intensity?
2. Does it preserve biodiversity, contribute to a restoration of ecosystems?
3. Does it allow users to shift behavior towards more sustainable mobility?
4. Does it limit carbon emissions?
5. Does it favor an equal access to mobility (inclusive and socially fair)?
6. Is it resilient to the occurrence of extreme events?
7. Is it sober in data consumption?
8. Does it favor a change in usages (flexibility, adaptability)?
9. Is it sober in renewable and non-renewable resource consumption? Does it allow to make the most of existing local resources?
10. Does it promote safety of users by managing friction zones?
11. Does it limit the artificialisation of soil and land use?
12. Does it limit the infrastructure investments (production and maintenance)?
13. Does it create socially responsible employment?

Guiding questions to challenge the sustainability of mobility infrastructures

D4.3 | MODELS FOR SHARING INFRASTRUCTURES

Flore Vallet, Tarek Chouaki, Jakob Puchinger, Sylvie Douzou, Tjark Gall



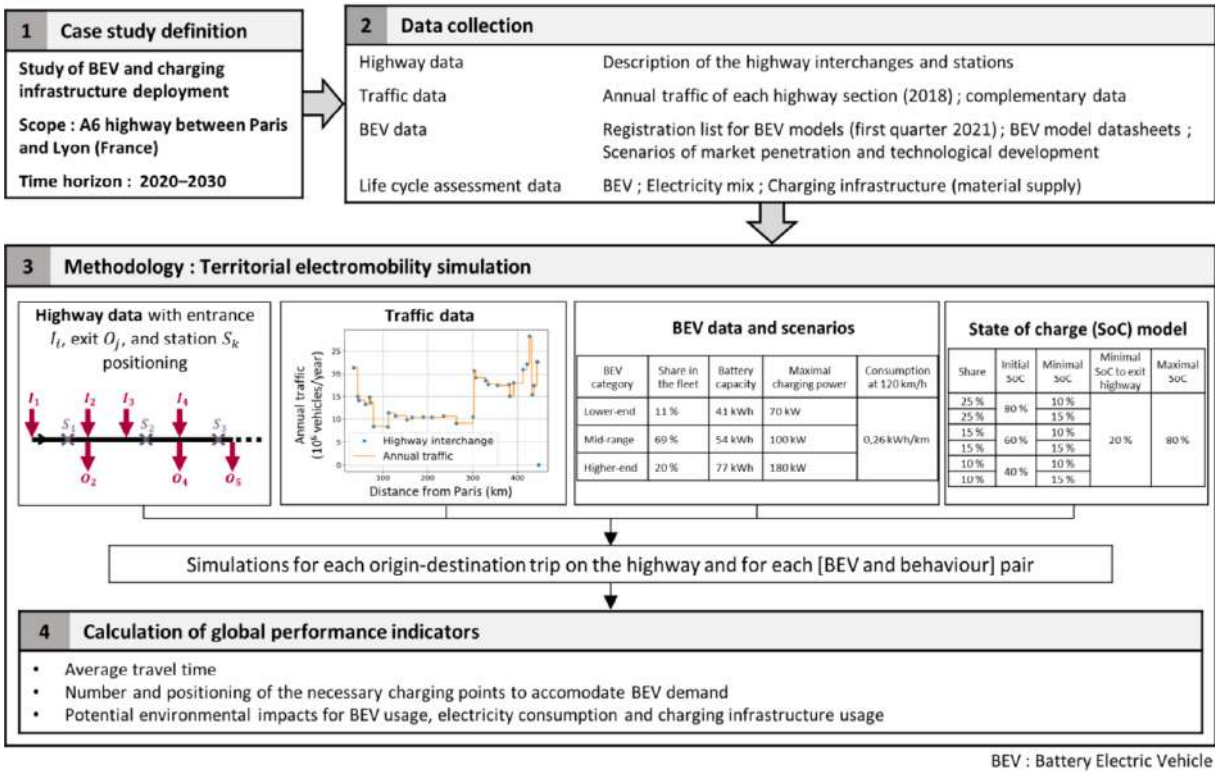
The aim of this deliverable is to provide a collection of tangible models involving shared mobility infrastructures in the continuity of deliverables 4.1 and 4.2.

In the introduction, we recall the current background of sharing economy and unfold the concept of shared infrastructures which can relate to diverse aspects such as: share vehicles, rides, EV charging stations, or roads between buses and cars.

More broadly speaking, developing urban mobility implies heading towards a peaceful sharing of public space and sharing investments between public and local authorities. We present four different models for sharing infrastructures and related objectives thereof: A) path-based optimisation (Electric Vehicles on a highway); B) dynamic discrete choice model in multi-agent simulation (Mobility on Demand & buses), C) dynamic optimisation (shared Automated Vehicles & grid), D) stochastic discrete choice model (future modal shares). We provide synthesised results of the four models developed in the Chair.

Whereas models A to C work with past or current mobility data, the last model allows thinking about and making estimations for 2030. Models B and D share the same background principles and can be associated: D for co-creation in multi-disciplinary groups and goal definitions in the longer term (here 2030), B for further simulations of mobility interventions. Finally, we underline that model D's impact assessment tool is the only one which includes future projections by means of future scenarios.

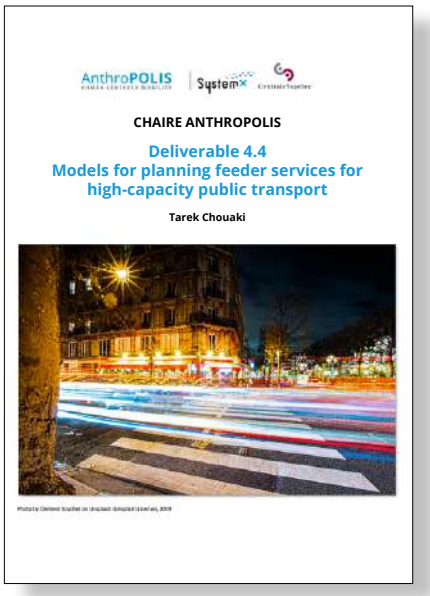
We more specifically present a methodology for assessing and comparing the impact of different policies to a sustainable urban mobility transition in a local context, exemplified by the increase of the active mobility share in the overall modal mobility mix. While a set of assumptions are underlying, the method has been co-created by a number of mobility experts and contains promising elements to support decision making or design processes towards sustainable urban mobility for all.



Overview of path-based model A (Baltazar, Vallet, Garcia, 2022)

D4.4 | MODELS FOR PLANNING FEEDER SERVICES FOR HIGH-CAPACITY PUBLIC TRANSPORT

Tarek Chouaki

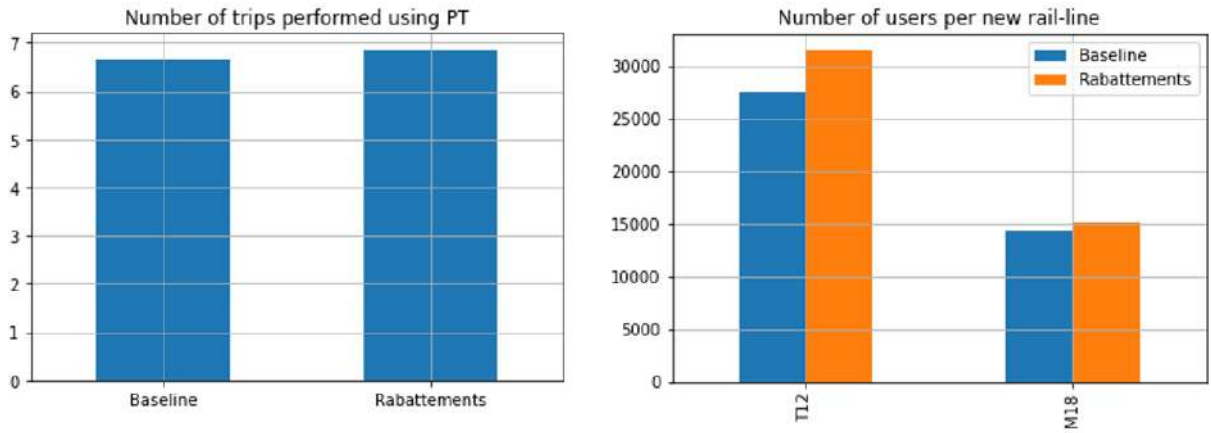


The area of Île-de-France is currently undergoing several development projects for the public transport infrastructure. An example is the Grand Paris Express, a project of major subway development, with the creation of four brand new lines and the extension of two existing ones. The availability of data regarding the new lines and their operational details have allowed previous studies in the scope of the Anthropolis Chair to investigate the impacts that the new offer could have on mobility in the area. However, stakeholders do not have yet a clear vision of how lighter public transports (i.e. buses) will evolve around the new lines. Many of the planned future subway stations are disconnected from the bus network, preventing travellers from efficiently feeding them. The usage predicted in the previous studies is then an underestimation. The current context provides an interesting opportunity for optimising bus services around new subway lines.

In this deliverable, we propose a two-stage method for the **design of bus services around future high-capacity rail lines.** The first stage consists of estimating the demand that a new bus service would have if certain criteria of service quality are met. Our focus here lies in the bus lines that are used as feeder systems to rail-based lines. This also allows to assess the attractiveness of future rail-based lines if accessing them is made easier. The demand assessment is performed using an agent-based simulation of Île-de-France equipped with a mode choice model. This allows to finely consider the relationship between the service quality and the demand. Moreover, using agent-based models, we are able to assess the demand on a highly detailed level, with the exact departure times and origin and destination locations for each trip.

The second stage consists in the optimisation of the bus network in order to satisfy the estimated demand while matching the service quality criteria assumed in the first stage, all while minimizing the operational cost (in this case, the distance).

This novel method presents the interest of allowing to manipulate user centric concepts in the first stage service quality and operator centric concepts in the second one. Moreover, its application on the localised setting of Île-de-France under the planned developments a first research insight on the potential future bus lines in the area.



Impact of feeder bus services on the demand for public transports in general and new rail-based lines in particular

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PHD THESES

Ouidad Benhlima (ongoing, started 11/2021) Data analysis and urban mobility in Casablanca: Spatial accessibility analysis. Doctoral dissertation, University Paris-Saclay.

Julien Baltazar (ongoing, started 10/2021) Help local authorities move towards more sustainable mobility: enhancing the planning process to better integrate environmental issues. Doctoral dissertation, University Paris-Saclay.

Mariana Reyes (ongoing, started 11/2020) Walking in Mobility as a Service (MaaS): Action Levers to Support Walking via MaaS from an Ecosystemic Stakeholder Perspective. Doctoral dissertation, University Paris-Saclay.

Tjark Gall (pending, defence 24 Nov. 2023) Scenario-based design of people-centred mobility solutions for urban systems. Doctoral dissertation, University Paris-Saclay.

Yue Su (2023) Heuristic and exact algorithms for solving the electric autonomous dial-a-ride problem. Doctoral dissertation, University Paris-Saclay.

Tarek Chouaki (2023) Agent-based simulations of intermodal Mobility-on-Demand systems operated by Reinforcement Learning. Doctoral dissertation, University Paris-Saclay.

TEAM OF THE CHAIR

Flore Vallet
Anthropolis Chair Holder at IRT SystemX and CentraleSupélec

Researcher on Human Centred Design at IRT SystemX and Assistant Professor at CentraleSupélec, Flore took over the Anthropolis Chair in September 2022.

Jakob Puchinger
Scientific Advisor,
Anthropolis Chair
Professor, EM Normandie

Jakob was Chair holder of the Anthropolis Chair from 2015 until August 2022. Now, he is professor at the EM Normandie and remains as scientific advisor for the Anthropolis Chair at IRT SystemX.

Edgar Ke
M.A.D. Anthropolis Chair
2020 to mid-2022

Edgar was the Mobility Innovation & Startup Manager at Nokia Bell Labs in France and lead the technological & market watch activities in mobility, staying up to date on new developments & trends in urban mobility. He supported the Chair until mid-2022.

Mariana Reyes
PhD Candidate,
Anthropolis Chair

Mariana is doing her PhD on 'Mobility as a Service: Concepts, governance and business models.' She joined the Chair in November 2020, after completing a MSc in Urban Planning, Transportation and Mobility at the Ecole d'Urbanisme de Paris (UGE-ENPC).

Yann Briand
Innovation and R&D manager,
Mobility Sector Leader at IRT SystemX

Manager at IRT SystemX, Yann is responsible for the mobility domain. Since September 2022, Yann supports the management of the Anthropolis Chair.

Sylvie Douzou
Senior Researcher,
EDF's R&D
M.A.D. Anthropolis Chair

Sylvie is social scientist at the Research & Development department, EDF, and supporting the Chair since 2020.

Tarek Chouaki
PhD Candidate at Anthropolis Chair – IRT SystemX and LGI, CentraleSupélec

Tarek Chouaki is working on Stochastic Optimisation and Reinforcement Learning for the design of an on-demand mobility service by simulation since 2019.

Tjark Gall
PhD Candidate, Anthropolis Chair

Tjark is since October 2020 pursuing a PhD on the topic of developing people-centred scenarios of urban mobility futures for Paris-Saclay and New Cairo.

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The Anthropolis Chair, operated by IRT SystemX and CentraleSupélec, brings together the partners EDF, Engie, Groupe Renault, Communauté d'Agglomération Paris-Saclay, and Nokia Bell-Labs to work towards human-centred mobility. To get to know more about ongoing activities, visit the Chair's website.

Website www.chaire-anthropolis.fr