Towards the design of sustainable mobility systems: objectives and barriers from the French local authorities' perspective

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Abstract

Within the on-going ecological transition, mobility systems are considered as sociotechnical systems that raise several challenges for local authorities due to the different levels of decision, a complex stakeholder network and the numerous objectives to be dealt with. Designers are therefore seeking to develop new frameworks to support local authorities moving towards more sustainable mobility systems. Based on the French context, this study relies on an analysis of the regulation and an interview-based survey that depict the mobility design from the local authorities' perspective. First, it investigates the objectives defined in the law and the difficulties met by local authorities. Then, it highlights the main political, organisational, and knowledge barriers for sustainable mobility. Finally, it proposes a set of recommendations to create a framework to better define and prioritise the objectives, ensure efficient planning and monitoring, clarify the interactions between actors, and enhance mobility plans.

Keywords

Mobility, Sustainability, Local authorities, Decision making, Organisational processes

1 Introduction

The transport sector is a major contributor to several adverse effects. Mitigation efforts performed during the last decades through the modification of mobility practices and technological improvements have been insufficient to address the environmental issues, notably related to oil consumption, air quality, and climate change. The barriers to move towards a more sustainable passenger mobility can be sorted in four categories (Bigo, 2020; Bardal et al., 2020):

- Mobility demand is growing. The number of kilometres travelled by French citizens increased by 19 % between 2008 and 2019, which means about +12% per capita (SDES, 2018; SDES, 2021).
- Modal shares of car and plane usages are dominant. In France, in 2019, about 65% and 20% of the kilometres were travelled during trips with respectively the car or the plane as the main transport modes (SDES, 2021).
- Occupancy rates are stable. For passenger cars in France, the average number of occupants was 1.6 in 2008 and remained the same in 2017 (Foussard and Riedinger, 2019).
- The life cycle environmental impacts of transport modes have not been significantly reduced and, during the use phase, the average real-world CO_2/km emissions of German vehicles only decreased by about 10 % between 2001 and 2017 (Tietge et al., 2019).

To significantly reduce environmental impacts, societies may engage a profound transformation of mobility technologies and practices. The electrification of vehicle fleets and the use of alternative fuels could contribute to a significant reduction of some environmental impacts. Yet, moving from one technology to another imply risks of burden shifting between impact categories, e.g. from climate change to metal depletion potential, and lifecycle stages, e.g. from use phase to energy supply. It is therefore fundamental to investigate the sustainability of emergent transportation technologies by adopting a lifecycle perspective and by covering the three sustainability dimensions (Bouillass, 2021). Relying on technological solutions is insufficient to achieve the transition to sustainable mobility. Therefore, addressing mobility demand, modal shift, and occupancy rates is a complementary solution to mitigate environmental impacts and improve quality of life. It implies an involvement of various mobility stakeholders, notably users as they may change their behaviour and public authorities because they can enhance their sustainable mobility strategies and actions.

In this context, the objective is to determine how local authorities can improve the design of mobility systems to move towards more sustainability. This article proposes a first contribution that aims to answer the following research question: *Which barriers are met by the French local authorities to design sustainable mobility systems?* The paper investigates this question in three parts. Section **Erreur ! Source du renvoi introuvable.** explains how mobility systems can be considered as a complex sociotechnical system and the role of local authorities to move towards more sustainable mobility. Section **Erreur ! Source du renvoi introuvable.** proposes an analysis based on the French context including a description of the territorial mobility organisation, an identification of the public authorities' objectives related to mobility, and the barriers local authorities are facing. Section **Erreur ! Source du renvoi introuvable.** summarises the paper and provides some recommendations to improve the mobility system design.

2 Design for sustainable mobility systems

Design is related to systems through different decision-making processes happening at different levels. Joore and Brezet (2015) distinguish the design of a product (e.g. a new vehicle), the design of a transport service (e.g. a carsharing service), and the design of a transport system, which is about organising mobility multimodal offer and demand. Even if these designs may involve the same products, the stakeholders, boundaries and objectives are totally different. For example, whereas vehicle design is mostly managed by car makers, transport system design is the role of local authorities because they oversee their organisation.

2.1 Mobility as a complex sociotechnical system

The literature covers several examples of complex sociotechnical systems which share some common characteristics. On the one hand, complex systems induce major issues in terms of modelling, prediction, or configuration (Cluzel, 2012). On the other hand, sociotechnical systems are clusters of elements including technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks, and supply networks, which fulfil societal functions such as transport, communication, housing, energy supply, or food (Geels, 2005).

Therefore, a mobility system can be defined as a complex sociotechnical system. Its perimeter goes beyond a technical system by encompassing the social, economic, political, legal, and environmental dimensions (Auvinen and Tuominen, 2014), by considering its different components, e.g. vehicles, infrastructures, fuel supply, user behaviours, policies, production, distribution, and maintenance networks (Geels, 2005), and by implying various stakeholders (Freudendal et al., 2020). Together, these elements fulfil the societal function of allowing people to move and their interactions give the mobility system its complex nature (Al Maghraoui et al., 2017).

2.2 Mobility design from the local authorities' perspective

Manufacturing planning and control (MPC) organise the decisions for manufacturing systems in three levels (Hans et al., 2012). The operational level is about the execution of processes and short-term adaptation [A]. The tactical level addresses the changes in the organisation of the processes [B]. The strategic level refers to the definition of the system orientations within a long-term horizon [C].

Similarly, local authorities can design mobility systems at three levels, which are characterised by three different time-horizons. First, they can change the ways the current system is operated, notably during periods of operational disfunctions. Then, they perform various actions and projects to modify the system. Based on the four barriers to sustainable mobility mentioned in the introduction, the approaches can be sorted in four categories: reducing travel needs (e.g. by linking land-use planning to mobility planning), shifting to more sustainable transport modes (e.g. by creating infrastructures to develop cycling), increasing transport mode effectiveness (e.g. by increasing occupancy rates or optimising bus routing), and reducing the life cycle impacts of transport modes (e.g. by renewing fleets with low emission vehicles) (Bigo, 2020; Bardal et al., 2020). Finally, they define plans to shape their long-term strategy, which then leads to the choice, the prioritisation, the scheduling, the coordination, and the monitoring of different actions. Mobility planning has notably been developed to promote the practices that do not favour car ownership and conventional car use (Freudendal et al., 2020). It has been the case in France notably, with the first mobility plans defined in the law in 1982 (French Government, 1982).

2.3 Sustainability objectives for mobility systems

As a sociotechnical system, the design of sustainable mobility implies considering its technical, social, economic, political, legal, and environmental dimensions (Auvinen and Tuominen, 2014). It is notably the role of local authorities to identify the interests of each stakeholder, weight up competing priorities, and accommodate the diverse objectives. Yannis et al. (2020) highlight some objectives for three sustainability dimensions:

- Economic: economic efficiency (e.g. minimising costs, maximising rate of return), contribution to economic growth (e.g. maximize regional development, positive effects on tourism, or positive effect on local employment).

- Social: mobility system efficiency (e.g. minimising travel time or congestion, maximising reliability or comfort), equity and social inclusion (e.g. maximise territorial accessibility, notably for people without car or with impaired mobility, minimise household displacement), safety (e.g. minimise fatalities or the number of accidents).
- Environmental: protection of the environment (e.g. minimising air pollution, fuel and energy consumption, or noise and vibration).

2.4 Research gap

The scope of design can be widened from the study of product or product-service systems to sociotechnical systems (Joore and Brezet, 2015). As transport-related environmental impacts are still insufficiently addressed, a new framework could be proposed to help local authorities designing their mobility system by addressing the different dimensions of sustainability. However, some barriers to do so are identified in the literature. Næss et al. (2011) described the challenges for sustainable mobility in Copenhagen and Oslo and highlighted the lack of coordination between sectors, levels, and administrative territories. Bardal et al. (2020) studied sustainable mobility policy design and implementation in three Norwegian cities and notably found political barriers (conflicting objectives, difficult collaborations between land-use planning and mobility planning), organisational barriers (about the division of responsibilities, and the too long-lasting and closed planning process), knowledge barriers (lack of evaluation of policy measures).

To determine how local authorities can better address sustainability aspects within the design of mobility systems, a first contribution based on the French context is proposed. It aims to describe the organisation of mobility from the public authorities' perspective, identify their objectives for sustainable mobility design, determine the barriers they deal with, and give some recommendations to address them.

3 Sustainable mobility design for local authorities

To answer the research question, the present paper suggests a two-step methodology. First, it relies on an analysis of the French law. Then, interviews of representatives from six local authorities, detailed in Table 1, have been conducted. These interviews took place between August and October 2022 and lasted 1h25 in average. Diagrams of this article were validated by one of the representatives.

Table 1: Summary of the interviews carried out, which precises the main characteristics of the local authorities and specifies the duration of the interviews

Perimeter of the interviewed local mobility organising authorities	Number of inhabitants	Number of municipalities	Interview duration
Communauté d'agglomération (CA) d'Haguenau	97k	36	1h30
Mulhouse Alsace Agglomération (M2A)	274k	39	0h50
Communauté urbaine du Grand Reims	296k	143	1h25
Angers Loire Métropole (ALM)	302k	29	2h05
Communauté d'agglomération (CA) de Paris-Saclay	314k	27	1h40
Métropole Aix-Marseille-Provence (AMP)	1,9M	92	0h55

In section **Erreur ! Source du renvoi introuvable.**, a five-level description of mobility design is proposed. It distinguishes product, product-service, and mobility system levels (Joore and Brezet, 2015). To account for the local authorities' design levels, the mobility system level is sub-divided into the operational, tactical, and strategic levels (Hans et al., 2012). In section **Erreur ! Source du renvoi introuvable.**, the objectives for sustainable mobility are structured along the dimensions identified by Auvinen and Tuominen (2014). In section **Erreur ! Source du renvoi introuvable.**, the barriers faced by local authorities are identified and grouped according to the classification of Bardal et al. (2020). Among them, political, organisational, and knowledge barriers have appeared to be the most relevant from the local authorities' perspective.

3.1 Modelling the organisation of mobility systems in France

As mentioned before, different levels for mobility design can be distinguished. Table 2 proposes a five-level scale and presents these levels from the largest to the smallest perimeter. The object of decision are national laws, territorial strategic plans, projects and actions, operational management, infrastructures, mobility services, and products. A local authority is in charge of the organisation of a territorial mobility system, corresponding to the following three levels of design: defining the strategic plans, conducting projects and actions, and operating the mobility system.

The design of a territorial mobility system can then be distinguished according to the kind of local authority which is considered. In France, the competences are shared between several administrative divisions, namely regions, departments, public establishments for intermunicipal cooperation (EPCI, in French), and municipalities. Regarding mobility, the most important authorities are regions and mobility organising authorities (AOM, in French) which are the mobility department of an EPCI.

The main competences of local authorities are defined by the French Government (2010). On the one hand, regions organise transport services of regional interest (art. L1231-3), define regional transport infrastructure planning (multi-modal hub, rail transport) and regional multimodality planning (services, schedules, pricing, ticketing) (L1213-1 and L1213-3), supervise a social mobility plan (access to mobility for everyone) (L1215-3), and coordinate local organising authorities, notably through a contract with AOMs (L1215-2). On the other hand, AOMs organise local transport services (L1231-1-1), define local mobility planning (services, schedules, pricing, ticketing, information, parking, charging infrastructures for electric vehicles) (L1214-1 and L1214-2), and help companies and schools to define their own mobility strategy (L1214-2 and L1214-8-2).

Table 2: A five-level description of design for passenger mobility

Design levels	Object of decision	Examples of objects
Strategic	National laws	Mobility laws defined by the Government. They can make compulsory the purchase of some low-emission vehicles when renewing a fleet, the installation of charging infrastructures in new buildings, the part-repayment of the public transit subscription by employers, etc. They can also be about mobility governance, e.g. defining the content of mobility plans, specifying their monitoring process, or defining the competences of each territorial actor.
	Territorial strategic plans [C]	Mobility plans or, more broadly, planning documents of local authorities
Tactical	**Projects and actions [B]**	Projects and actions defined and conducted by the local authorities, e.g. creating a low-emission zone, reworking a transport network, changing the pricing or the billing system for public transport, buying low emission vehicles, developing a given transport service, etc.

Operational	**Operational management [A]**	Processes for the management of the territorial mobility system and the short-term adaptation, notably during periods of operational disfunctions
Product-service systems	Infrastructures	Road infrastructures, charging stations, multimodal hubs, mobility as a service, etc.
	Mobility services	Carsharing, ridesharing, bike rentals, on-demand transport, etc.
Products	Vehicles	Cars, bikes, buses, etc.

Based on the description of the design levels and the local authorities, Figure 1 presents how mobility is organised in France from the regions' and AOMs' perspective. The interactions between the different actors can be summarised in a four-step description:

- Public authorities organise mobility by involving the users, notably through a coordination committee which is composed of representatives from companies and user associations and some inhabitants randomly chosen (French Government, 2010, L1231-5).
- The local authorities can influence the operational management of their mobility systems [A]. This system is composed by users (e.g. private cars or bikes), companies (e.g. vehicle fleets, home-to-work shuttles), and public or private mobility service operators (e.g. buses, carsharing service).
- Local authorities such as regions and AOMs conduct various actions and projects to change their mobility systems [B]. Also, they define their local mobility strategy by determining objectives and planning actions for a given period [C]. These strategies are defined in a broad set of documents such as regional transport infrastructure plans or local mobility plans.
- Finally, the French Government and local authorities define the national transport policy. It influences every level previously described, e.g. by providing incentives for electric vehicles [A], by making compulsory the creation of low emission zones [B], or by defining general orientations of mobility plans [C].

3.2 Eliciting local authorities' objectives for sustainable mobility design

Public authorities declare numerous objectives for mobility. This section presents an analysis of the French law performed to identify these various objectives. Then, it presents the results of the interviews, which highlight the barriers faced by local authorities regarding these objectives.

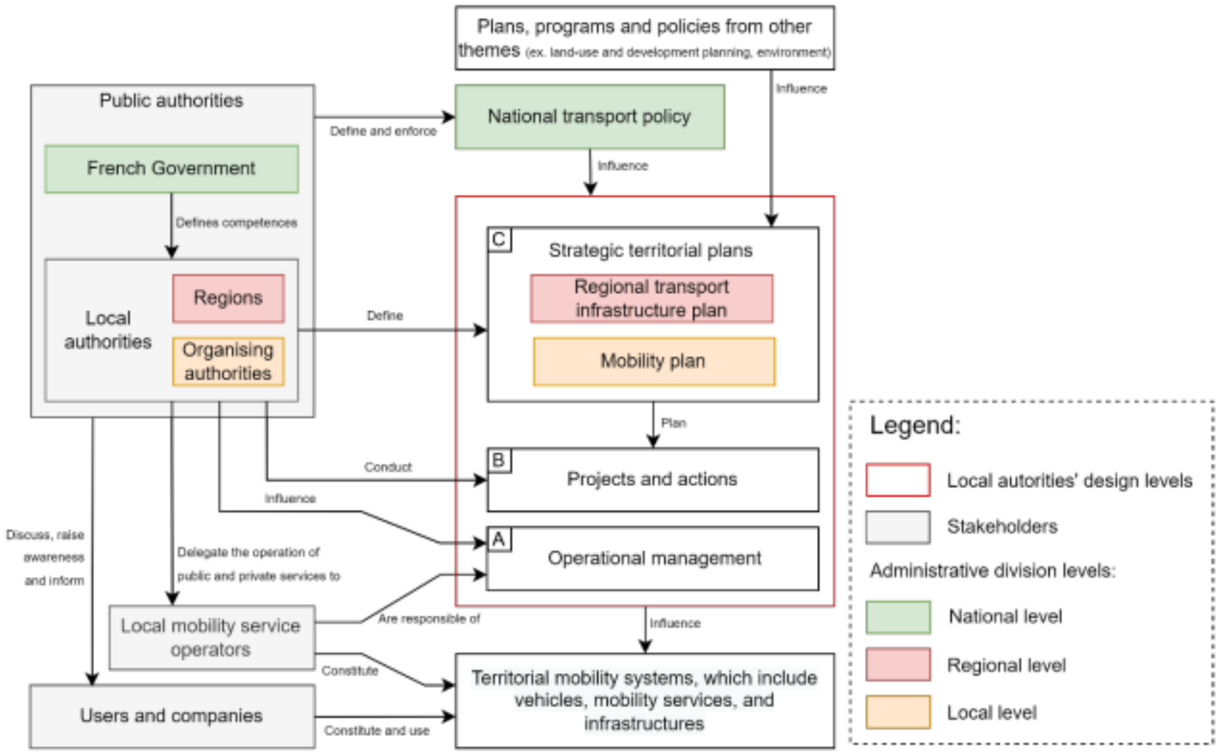

Figure 1: High level mapping of the French mobility organisation from the local authorities' point of view

3.2.1 Analysis of the French regulatory context

National objectives regarding mobility are defined in the law. They can be sorted according to four sustainable mobility dimensions. First, there is the objective of satisfying users' needs in the best **economic** conditions for the community (French Government, 2010, L1111-1).

Then, there are **technical** objectives. There is a challenge to reduce car traffic and combat urban congestion (French Government, 2010, L1214-2; French Government, 2019, art. 1). Several laws also aim to facilitate low-emission vehicle deployment, notably by making compulsory to get low emission vehicles when renewing a fleet (French Government, 2000, L224-8, L224-8-2, and L224-10), accelerating charging infrastructure deployment (French Government, 2010, L1214-2; French Government, 1977, L113-12), developing low-emission zones (French Government, 1996, L2213-4-1; French Government, 2000, L229-26), and ending the sales of fossil-fuel-powered light vehicles by 2040 (French Government, 2019, art. 73).

Moreover, there are **social** objectives. It means ensuring the "right to mobility" (French Government, 2010, L1111-2), notably by helping mobility of disabled or disadvantaged people (French Government, 2010, L1111-5, L1113-1, and L1215-3), opening up rural areas, increasing territorial attractiveness, and reducing territorial inequalities (French Government, 2010, L1111-3, L1214-2, and L1212-3-2; French Government, 2019, art. 1). It also implies well-being objectives, such as combating sedentary behaviour, notably by improving active modes attractivity (French Government, 2010, L1111-1), increasing transport safety and reducing accidents (French Government, 2010, L1111-1, and L1214-2; French Government, 2019, art. 1), or improving the quality of service of transport (French Government, 2010, L1111-2; French Government, 2019, art. 1).

Finally, there are **environmental** objectives. They imply limiting energy consumption (French Government, 2010, L1211-3), pollutant emissions, and damages to biodiversity (French Government, 2010, L1111-1 and L1111-3; French Government, 2019, art. 1). There is a recent will to reduce air travel impacts, whereas there were unaddressed by laws before 2021 (French Government, 2021, art. 142 and 144; French Government, 2010, L6412-3; French Government, 2000, L229-57). Regulation also aims to limit urban sprawl and land use (French Government, 2010, L1214-2 and L1211-3; French Government, 2019, art. 1) and protect people from noise (French Government, 2010, L1111-1).

3.2.2 Difficulties met by local authorities

Local authorities must deal with the various objectives described previously. However, they meet some difficulties, according to the information gathered during the interviews and detailed below. First, the **economic** dimension is a very important topic for local authorities. The economic difficulties in EPCIs have increased with the covid crisis, e.g. M2A representative reported a 10% income reduction since then. The 2022 energy crisis also led to higher operating cost, e.g. the estimation of the annual electricity cost of the new tramway network of ALM increased from 1,2 M€ to 3,5 M€. These events reduced the capacity to invest in the transport network and low emission vehicles.

There are also **technological** uncertainties, enhanced by difficult forecast of the future costs and AOM incomes (CA d'Haguenau, ALM). For example, the relevant powertrains and energy mixes for buses, i.e. gas, electricity, or hydrogen, need to be further investigated. Different AOMs used to partly rely on gas-powered buses (Grand Reims, AMP, M2A, ALM), notably because battery electric vehicles require high investments (CA d'Haguenau, AMP) and an evolution of the staff skills, e.g. drivers' or maintenance technicians' skills (AMP). However, in the densest areas of the EPCIs of more than 250k inhabitants, only full-electric and hydrogen buses are considered as very low emission vehicles (French Government, 2000, D224-15-4 and D224-15-2). AOMs are required to have in service or to buy in case of fleet renewal at least 25 % very low emission buses since late 2021 and this rate will increase to 50 % from 2025 onwards (French Government, 2000, L224-8-2 and D224-15-5-1). Between these two technologies, battery electric vehicles are considered the most reliable and cost-efficient, yet hydrogen-based energy is increasingly taking part of some territorial strategies as several government incentives are attributed to develop further local value chains for hydrogen (Grand Reims, AMP).

The importance of the **social** dimension and the role of mobility users have also been highlighted, notably regarding their needs and the acceptance of the actions. First, the difficulties about energy and investment costs for low-emission vehicles mentioned before are an issue for inhabitants' passenger cars, especially since the 2022 crisis. It causes major risks of social division, notably in poor or rural areas (CA d'Haguenau, Grand Reims). Indeed, satisfying the national "right to mobility", accessibility, and servicing for everyone is a challenge for AOMs, especially in territories with density gaps (CA d'Haguenau, Grand Reims, AMP, CA de Paris-Saclay, M2A). It requires to address mobility everywhere in the AOM perimeter (AMP) and to create an agile multimodal mobility system to satisfy mobility needs, including occasional trips (CA de Paris-Saclay). To develop social inclusion and participative democracy, public consultation has been made an important part of the decision-making process. However, performing consultation requires resources, which then cannot be used to perform other actions (ALM). Public consultation is also a way to increase acceptancy, which conditions the will of political representatives to carry out some unpopular measures, such as reducing parking offer, increasing its cost, or creating a low emission zone (ALM, M2A, Grand Reims).

AOMs also face numerous **environmental** objectives, but they struggle to address them. AOMs lack tools to evaluate the environmental consequences of their choices (ALM, Grand Reims) because it requires resources and a specific knowledge regarding modelling, ecology, technologies, etc. They also face numerous objectives and difficulties to manage trade-offs between criteria, e.g. reducing soil artificialisation, greenhouse gas emissions, and air quality issues while increasing demographic and economic growth, territorial accessibility, and inhabitants' acceptance (CA de Paris-Saclay, M2A, AMP, ALM). The strong links between the environmental dimension and the other objectives often lead to conflict, e.g. when limiting car use or financing public transport or new technologies.

3.3 Identification of barriers to sustainable mobility design

Numerous objectives are identified for the different sustainability dimensions of mobility system design. However, there are several political, organisational, and knowledge barriers linked to these objectives.

3.3.1 Political barriers

As presented in Section **Erreur ! Source du renvoi introuvable.**, the regulation has pushed the inclusion of economic, social, technological, and environmental dimensions within the design of mobility systems. So, there are numerous and conflicting objectives and difficulties to manage trade-offs. Therefore, AOM struggle addressing them because of the limited human and financial resources of local authorities (AMP, ALM, CA de Paris-Saclay, M2A). They also lack guidance to prioritise the short- and long-term objectives (ALM, AMP).

Another political barrier is the lack of collaborations and interactions between public authorities' actors. In some EPCIs, the siloed organisation of the different departments can lead to sub-efficient planning and actions (Grand Reims, ALM). In ALM, some construction projects used to be launched despite inconvenient locations in regard to the transport network. So, during the urban land-use plan revision of 2010, ALM adopted an effective communication between urbanism and mobility departments and it led to significant land-use improvements since the late 2010s. In theory, the law demands these interactions: for example, a mobility plan must be designed “in coherence” with plans from land-use or environmental planning. The links ensuring the coherence between plans as required by the law are detailed in Figure 2. It is to note that the nature of the interactions between these plans is not specified so, in practice, they mostly depend on the willingness of the various actors to collaborate.

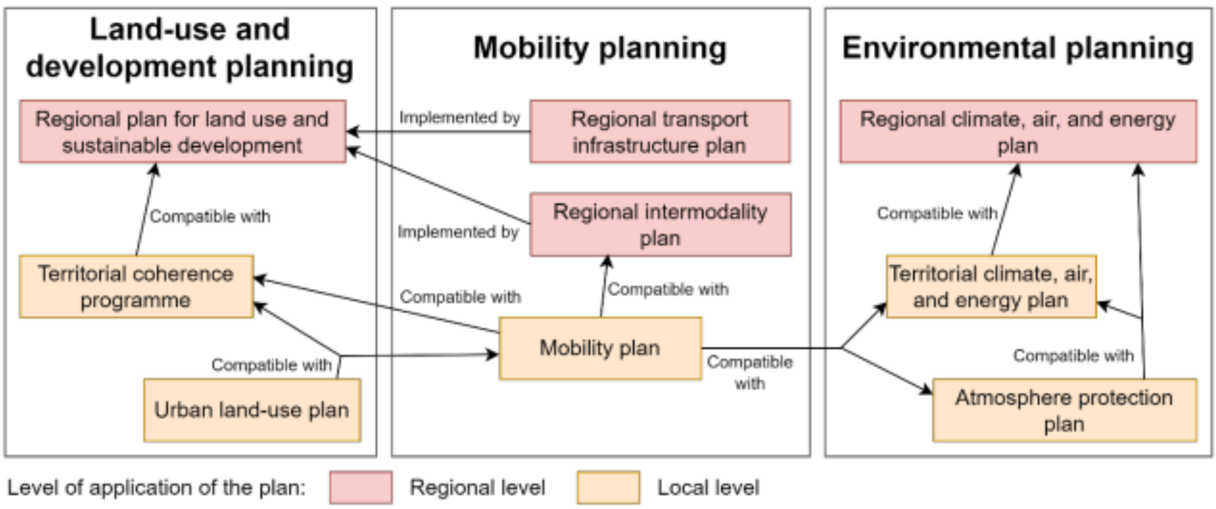

Figure 2: Overview of the different plans linked to mobility planning perimeter, specifying their normative interactions (based on the French laws, 2022)

Also, another barrier is the lack of political willingness to have ambitious mobility strategies. Often, ambitious long-term objectives are defined and targeted by local authorities instead of short-term quantitative objectives. This can be explained by the fact that the elected representatives might not want to constraint their actions during their mandate (Grand Reims). Therefore, mobility plans are not very prescriptive: the plan is only seen as an opportunity to make a diagnosis, to summarise the

AOM actions, and to sensitize the stakeholders (ALM, CA de Paris-Saclay, Grand-Reims). In the end of the process, the document will include general guidelines for decision-making, but it will probably not be very consulted and only few people will be aware of its content (Grand Reims, ALM).

3.3.2 Organisational barriers

Attribution of responsibilities between the different local authorities can raise some issues. Laws have often influenced mobility governance and competence attribution over the last three decades. It increased the complexity for the mobility organisation. The interview with Grand Reims highlighted that this could lead to frictions between actors, e.g. the AOM is bothered because road management is a competence of municipalities. Also, it makes mobility organisation confusing and some representatives have doubts about which parts of the transport network are theirs or not (CA Haguenau).

Mobility plans are too static and long-lasting, so they do not fit the territorial dynamics: therefore, plans are rapidly outdated. Mobility plans last between five and ten years, sometimes even more, although the context of the organisation of the mobility is always changing. Indeed, the EPCIs' perimeters are often extended to new municipalities. Also, there can be changes in citizen expectations or new political elections, and mobility practices are changing notably due to the covid and energy crises.

Long distance mobility is not sufficiently addressed by the current mobility organisation although 46 % of the kilometres were travelled during long distance trips (>80 km) in France in 2019 (SDES, 2021). The AOM mobility plans mostly cover local mobility, eventually targeting commuting trips or short trips done by car (CA d'Haguenau). Long distance mobility organisation is supposed to be a regional or national competence (AMP, ALM). However, there is no holistic approach to address it as regional mobility planning is limited to infrastructure planning.

3.3.3 Knowledge barriers

There is no methodology or tool to ensure the coherence between the different mobility design levels. Indeed, there is no estimate of the required conditions (i.e. actions, resources) to reach the plan objectives. Furthermore, there is no systematic monitoring protocol to control if the currently conducted actions are sufficient to reach the strategic objectives and to apply corrective measures if necessary (Grand Reims). These lacks are notably due to the fact that diagnoses, evaluations, and monitoring requires substantial resources and skills to be performed. For example, a normative territorial diagnosis of the mobility costs about 700k to 1M€ according to M2A who cannot afford it. The same reasons prevent Grand Reims to have a multimodal simulation tool paired with an environmental evaluation, which they would be willing to use for mobility system design.

4 Conclusion and recommendations

As a complex sociotechnical system, mobility is a cluster of elements that fulfil a societal function and induces major issues in terms of modelling, prediction, or configuration. Local authorities organise mobility, but there are barriers to move towards more sustainability. Based on the French case study, this paper identifies the local authorities' objectives and barriers.

The local mobility authorities, mainly regions and AOMs, organise mobility in their perimeters, taking into account the national policy and the influence of other sectors. The analysis of laws and interviews of AOM representatives identified diverse economic, social, technological, and environmental objectives for sustainable mobility design. Furthermore, political, organisational, and knowledge barriers related to mobility design have been discussed to help local authorities addressing them.

Highlighting these barriers leads to five recommendations to improve mobility design by local authorities. The first three are short-term measures and the two last depend on a revision of the law so they are longer term measures. 1) First, there should be a harmonised set of sustainability indicators for diagnosis and monitoring to clarify sustainability objectives and knowledge to prioritise objectives. Moreover, the planning stage where objectives are defined should be improved. 2) There should be methodologies and tools to determine the conditions (e.g. actions, resources) required to reach each objective and to propose corrective measures if the execution of the plan leads to insufficient results. 3) Furthermore, the nature of the collaborations between the actors of the local authorities and the interactions between plans should be characterised to improve the territorial organisation. Notably, the interaction between the mobility plan and the local environmental plan should be clarified. Finally, from the national perspective, mobility plans should be reworked as their static and long-lasting nature is not compatible with the territorial dynamic. 4) A more continuous process that would effectively help the mobility decision-making and monitoring should be elaborated. 5) Also, regional plans should be revised to go beyond infrastructure planning and tackle long-distance mobility issues.

Studying a complex sociotechnical system from the local authorities' perspective led to insights about theorising a territorial organisation and identifying local authorities' objectives and the difficulties they face. Based on these findings, some theoretical recommendations are given, but they have not been validated among local authorities, which is a limitation of the present work. To further investigate them, future validation studies could aim to define guidelines with local authorities to improve sustainable mobility design. Although similarities have been found between the different interviews, the quality of the study is limited by the low number of interviewees and the absence of evidence that the AOM representatives answered with transparency. Another last limit is that the case study is based on the French context. However, even though there are national specificities, the method, results and recommendations of the paper could be relevant to other countries dealing with the same objectives.

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References

Al Maghraoui, O., Vallet, F., Puchinger, J. and Yannou, B. (2017), "Framing key concepts to design a human centered urban mobility system", Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 3: Product, Services and Systems Design, Vancouver, Canada.

Auvinen, H. and Tuominen, A. (2014), "Future transport systems: long-term visions and socio-technical transitions", European Transport Research Review, Vol. 6 No. 3, pp. 343–354. https://doi.org/10.1007/s12544-014-0135-3.

Bardal, K.G., Gjertsen, A. and Reinar, M.B. (2020), "Sustainable mobility: Policy design and implementation in three Norwegian cities", Transportation Research Part D: Transport and Environment, Vol. 82, p. 102330. https://doi.org/10.1016/j.trd.2020.102330.

Bigo, A. (2020), Les transports face au défi de la transition énergétique. Explorations entre passé et avenir, technologie et sobriété, accélération et ralentissement, Économies et finances, Institut Polytechnique de Paris.

Bouillass, G. (2021), Sustainability assessment of electric mobility scenarios with the integration of a life cycle perspective, Engineering Sciences, MINES ParisTech - Université PSL.
Cluzel, F. (2012), Eco-design implementation for complex industrial system: from scenario-based LCA to the definition of an eco-innovative R&D projects portfolio, Industrial Engineering, École Centrale Paris.
Foussard, A. and Riedinger, N. (2019), Les émissions de CO2 liées à l'énergie en France de 1990 à 2017 - Facteurs d'évolution et éléments de comparaison internationale, Commissariat général au développement durable.
French Government (1977), Code de la construction et de l'habitation, version in effect on November 29, 2022.
French Government (1982), Loi n°82-1153 du 30 décembre 1982 d'orientation des transports intérieurs, version in effect on December 31, 1982.
French Government (1996), Code général des collectivités territoriales, version in effect on November 29, 2022.
French Government (2000), Code de l'environnement, version in effect on November 29, 2022.
French Government (2010), Code des transports, version in effect on November 29, 2022.
French Government (2019), Loi n°2019-1428 du 24 décembre 2019 d'orientation des mobilités, version in effect on November 29, 2022.
French Government (2021), Loi n° 2021-1104 du 22 août 2021 portant lutte contre le dérèglement climatique et renforcement de la résilience face à ses effets, version in effect on November 29, 2022.
Freudendal-Pedersen, M., Hartmann-Petersen, K., Friis, F., Rudolf Lindberg, M. and Grindsted, T.S. (2020), "Sustainable Mobility in the Mobile Risk Society—Designing Innovative Mobility Solutions in Copenhagen", Sustainability, Vol. 12 No. 17, p. 7218. https://doi.org/10.3390/su12177218.
Geels, F.W. (2005), "Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective", Technological Forecasting and Social Change, Vol. 72 No. 6, pp. 681–696. https://doi.org/10.1016/j.techfore.2004.08.014.
Hans, E.W., van Houdenhoven, M. and Hulshof, P.J.H. (2012), "A Framework for Healthcare Planning and Control", in Hall, R. (Ed.), Handbook of Healthcare System Scheduling, Vol. 168, Springer US, Boston, MA, pp. 303–320. https://doi.org/10.1007/978-1-4614-1734-7_12.
Joore, P. and Brezet, H. (2015), "A Multilevel Design Model: the mutual relationship between product-service system development and societal change processes", Journal of Cleaner Production, Vol. 97, pp. 92–105. https://doi.org/10.1016/j.jclepro.2014.06.043.
Næss, P., Strand, A., Næss, T. and Nicolaisen, M. (2011), "On their road to sustainability? The challenge of sustainable mobility in urban planning and development in two Scandinavian capital regions", Town Planning Review, Vol. 82 No. 3, pp. 285–316. https://doi.org/10.3828/tpr.2011.18.
SDES (2018), Enquête nationale transports et déplacements (ENTD) 2008. [online] Available at: https://www.statistiques.developpement-durable.gouv.fr/enquete-nationale-transports-et-deplacements-entd-2008 (accessed 25 April 2022)
SDES (2021), Résultats détaillés de l'enquête mobilité des personnes de 2019. [online]. Available at: https://www.statistiques.developpement-durable.gouv.fr/resultats-detailles-de-lenquete-mobilite-des-personnes-de-2019 (accessed 25 April 2022)
Tietge, U., Díaz, S., Mock, P., Bandivadekar, A., Dornoff, J. and Ligterink, N. (2019), From Laboratory to Road: A 2018 Update of Official and "Real-World" Fuel Consumption and CO2 Values for Passenger Cars in Europe, The International Council on Clean Transportation.
Yannis, G., Kopsacheili, A., Dragomanovits, A. and Petraki, V. (2020), "State-of-the-art review on multi-criteria decision-making in the transport sector", Journal of Traffic and Transportation Engineering (English Edition), Vol. 7 No. 4, pp. 413–431. https://doi.org/10.1016/j.jtte.2020.05.005.