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HARMONY

Holistic Approach for Providing Spatial & Transport Planning Tools and Evidence to Metropolitan and Regional Authorities to Lead a Sustainable Transition to a New Mobility Era

D8.4 Harmony roadmaps for the transition period

Submission date: 28/02/2023

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SUMMARY SHEET

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ATC	Air Traffic Control
ATM	Air Traffic Management
AV	Autonomous Vehicle
B2B	Business-to-Business
B2C	Business-to-Consumer
BEB	Battery Electric Bus
C2C	Consumer-to-Consumer

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CAA	Civil Aviation Authority
CAV	Connected and Autonomous Vehicle
CDT	Comune Di Torino
CNG	Compressed Natural Gas
CPO	Charge Point operator
DRT	Demand Responsive Transit
EV	Electric Vehicle
GHG	Greenhouse Gas Emissions
GPS	Global Positioning System
ICT	Information and Communication Technology
IoT	Internet-of-Things
ITS	Information Technology Solutions
LDM	Land Development Model
LEVs	Light Electric Vehicles
LoS	Level of Service
LTP	Local Transport Plan
LUTI	Land Use and Transport Interaction
MaaS	Mobility-as-a-Service
MS	Modelling Suite
OASA	Athens Urban Transport Organisation
OCC	Oxfordshire County Council
PT	Public Transport
OEM	Original Equipment Manufacturer
PPE	Personal Protective Equipment
PT	Public Transport
R&D	Research and Development
REM	Regional Economic Model
RFID	Radio Frequency Identification

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SFM	Servizio Ferroviario Metropolitano (Turin Metropolitan Railway Service)
SME	Small and Medium Size Enterprises
SUMP	Sustainable Urban Mobility Plan
TCO	Total Cost of Ownership
TFS	Tactical Freight Simulator
TUD	Technical University of Delft
UAM	Urban Air Mobility
UAV	Unmanned Aerial Vehicle
UCC	Urban Consolidation Centre
UTM	Unmanned Traffic Management
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
ZE	Zero Emission
ZEZ	Zero Emission Zone

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EXECUTIVE SUMMARY

Deliverable 8.4 focuses on the HARMONY Roadmaps (task 8.5), aiming at building on the outcome of HARMONY modelling activities for preparing roadmaps to support authorities in the transition to the new mobility services' era. This task involves the final synthesis of the project outcome, reported in this deliverable.

The approach followed for the development of the roadmaps consists of five steps. First, the appropriate number of roadmaps, as well as their goal and timeline had to be defined. Next, the selection of the basic components was an essential step to formulate the building blocks of the roadmaps. These basic components were further classified and described into sub-components to fit the vision of the individual roadmaps. The pathway for every roadmap was further specified, focusing on further detailing the requirements needed for the sub-components to be fulfilled. This step included the definition of the stakeholders required to be involved in the process. Lastly, each roadmap was elaborated and visualized.

In total, 12 HARMONY roadmaps have been developed, each one focusing on specific components, which can all contribute to the specification of the pathway needed to be followed in order to achieve specific scenario goals. Selection was based on the most promising co-created scenarios, as these have been identified from the modelling activities of HARMONY, the different areas' co-creation labs and demonstrations and stakeholder engagement activities. Five roadmaps relate to city logistics' solutions and five relate to passenger mobility ones, all of them having as reference the HARMONY metropolitan areas. The last couple of ones constitute two composite roadmaps aiming at low carbon passenger mobility and city logistics respectively.

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1. Introduction

1.1 Aim of the project

Nowadays, new mobility services and technologies are presented as possible solutions to reduce greenhouse gas emissions and energy consumption in metropolitan areas. However, authorities face several challenges when it comes to harmoniously integrating these developments into spatial and transport plans to improve the citizens' wellbeing and achieve environmental targets. Given the rapid technological advances and the emergence of new mobility services, metropolitan authorities are often in need of expertise, knowledge, and tools for multiscale spatial and transport planning.

In view of this, HARMONY's vision is to enable different city or regional authorities to lead a sustainable transition towards a low-carbon new mobility era. This will be guided by its harmonised spatial and multimodal transport planning tools, which comprehensively model the behavioural and operational dynamics of the changing transport sector as well as metropolitan areas' spatial organisation.

HARMONY has set ambitious targets for the co-creation of metropolitan scenarios, informing updated spatial and transport planning tools. Therefore, a strict and stable planned coordination is mandatory to ensure the quality of the results and findings of each area and, also, to allow comparisons across the six different geographic areas. The consortium's intention is to ensure the best experience of the implementation of the HARMONY concept in each area and its exchange, not only across the HARMONY metropolitan areas, but also across other EU and international areas.

1.2 Objectives of the deliverable

Within HARMONY, WP8 is responsible for translating the results of the HARMONY integrated spatial and transport planning Model Suite into recommendations for updating spatial and transport strategies and the SUMP framework and for developing roadmaps for the transition to new mobility services. Specific objectives of WP8 are to:

- **Assess the HARMONY multiscale platform implementation** and the possibility to scale-up and transfer.
- Use the **findings of the electric van and drone demonstrations** and propose specific **recommendations.**
- **Propose recommendations for the preparation of SUMPs** in the form of Guidelines to deal with the new mobility concepts in metropolitan areas.
- Develop the **HARMONY roadmaps** to support authorities in the **transition to the new mobility services' era.**

In this framework, **task 8.5 HARMONY roadmaps** specifically focus on the last objective, by building on the outcome of modelling activities and preparing roadmaps to support authorities in the transition to the new mobility services' era. This task involves the final synthesis of the project outcome. The main objective of the current deliverable is to present the developed roadmaps, with different pathways on how to realize the new mobility services' era.

1.3 Structure of the deliverable

Deliverable 8.4 includes the following parts: first, the approach towards developing the roadmaps is described in detail in chapter 2. Next, the core chapter 3 presents 12 roadmaps, together with the specification of pathways and the identification of the business cases. The deliverable is completed with chapter 4 on summary and discussion.

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2. Approach

The final synthesis of the project outcome is done in Task 8.5 where HARMONY roadmaps **to support authorities in the transition to the new mobility services' era** are prepared, building on the outcome of the HARMONY modelling activities (WP2 to WP7). Below, we explain the steps of the approach followed and the final selection of the roadmaps that were developed. These steps slightly deviate from those initially proposed in the proposal. Figure 1 shows the approach, which is elaborated after the figure. The roadmaps are developed in five steps. For each step, the method and main input data are shown as well.

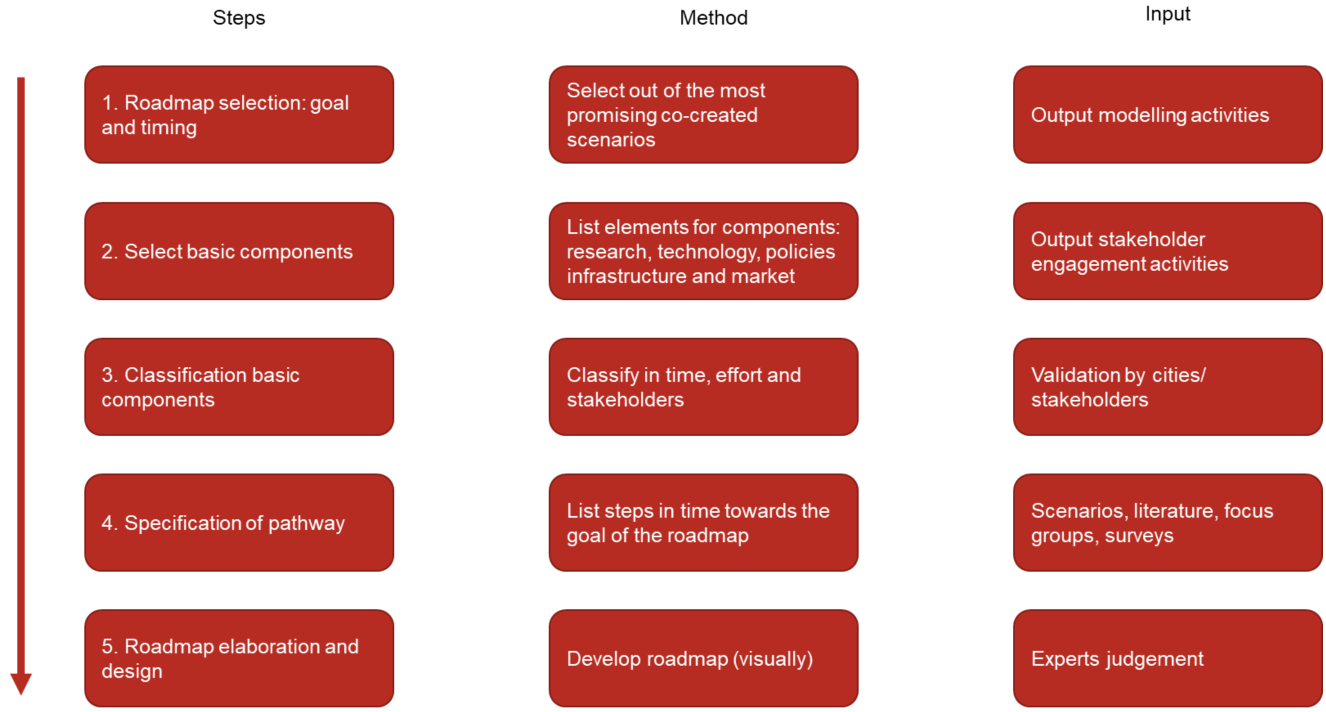

Figure 1 Approach to develop roadmaps

Step 1: Roadmap selection: goals and timing

Based on the modelling outcomes, the scope of 12 roadmaps is determined. The scope of each roadmap refers, in the first place, to the specific innovation, technology or policy measure. Second, the goal and target year of each roadmap is determined. This is based on an analysis of the most promising co-created scenarios that have been simulated using the HARMONY platform. Considering the variety in terms of goals and solutions for each roadmap, the time horizon must differ accordingly. The maturity level of each specific innovation, technology or policy measure proposed varies, while every city aiming at a specific roadmap, has set their own goals while being at a specific stage in terms of implementation. The HARMONY scenarios are reported in various HARMONY deliverables, specifically D1.4, D2.5, D6.4, D7.6, D9.2, D9.3, and D9.4. The roadmap provides directions for action towards a common goal for the specific roadmap. In this respect, the roadmaps that have been developed are as follows:

1. Zero emission zone for city logistics (2030). Based on Rotterdam.
2. Micro-hubs for city logistics (2030). Based on Rotterdam.
3. Autonomous vehicles for freight (2050). Based on Rotterdam.
4. Crowd-shipping (2030). Based on Rotterdam.
5. Drones for freight (2030). Based on Trikala, Oxfordshire, and Katowice.
6. Autonomous vehicles for passengers (2050). Based on Athens and Oxfordshire.
7. Public transport electrification (2028). Based on Athens.
8. Micro-mobility (2028). Based on Athens and Turin.
9. New housing development as part of the SUMP (2030). Based on Oxfordshire.
10. Urban vehicle regulation measures (2030). Based on Turin.

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11. Roadmap towards low carbon city logistics (2050)
12. Roadmap towards lower carbon mobility (2050)

Five roadmaps focus on freight, five on passengers and there are two composite roadmaps for low carbon city logistics and (passenger) mobility respectively. An elaboration per roadmap and the most promising co-created scenario that forms the basis is given in the next chapter. It must be further pointed out that these roadmaps have been, to a large degree, tailor-made for the HARMONY metropolitan areas. However, it is also recognized that they all have the potential for replication in different contexts or cities. To fulfil that and come up with new, also tailor-made roadmaps, adaptations would be needed. To explain a bit further, it is important to keep in mind that factors such as a more or less favourable environment or a more or less mature starting point, would affect - timewise - the roadmap acceleration.

Step 2: Selection of basic components

Based on the selected co-created scenarios, the most promising basic components are listed, e.g., the policy measures needed to move towards the goal of each roadmap. Especially the HARMONY Deliverables 1.4, 2.5, 6.4 and 7.6 serve as input. Each roadmap consists of various sub-components (which can be goals, actions, etc.). Those sub-components are categorised across the following basic components:

- Research (including data and models)
- Technology (e.g., new vehicle technologies, platform)
- Policy (measures and regulations)
- Infrastructure (physical and digital)
- Market (user acceptance and feasible business models)

The first four basic components are requirements towards uptake by the market and user acceptance. Figure 2 shows an example from a roadmap that was developed by ALICE-ETP & POLIS (2021). The components are depicted from the bottom left to top left. The outcome of this step is a definition of the roadmaps to be developed, the goal, timeline, and overview of the basic components. Input comes from the scenarios, the deliverables (which include interviews with different stakeholders) and additional literature for the different roadmaps.

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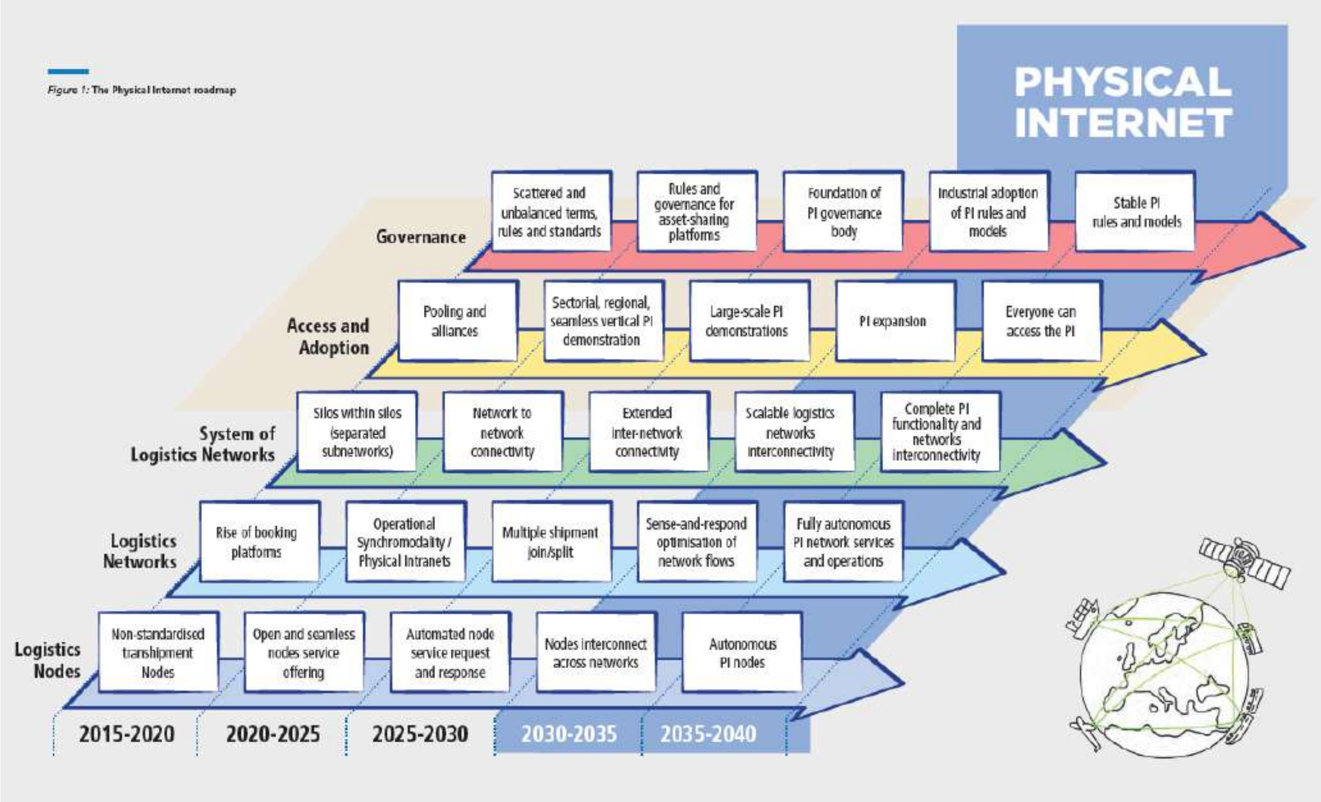

Figure 2 Example of a Roadmap by ALICE towards the Physical Internet (ALICE)

Step 3: Classification of basic components

After the selection of the basic components, these are classified. In this step the contributions of each component to the roadmap are provided. These are the requirements and described in:

- Time: the timeline per component towards the target year
- Effort or the ease of implementation (e.g., some policy measures might require physical investments and others are mainly a matter of setting (and enforcing) different rules)
- Expected impact of the different basic components
- Stakeholders that need to contribute (Table 1).

Table 1 Stakeholder groups and sub-groups (Deliverable 1.4)

No.	Stakeholder Group	Sub-group/Individual Stakeholder
1	Technology providers	Software providers
		Telecommunication and network providers
		Integration service providers
		Data providers
		UTM providers
2	Original equipment manufacturers (OEMs)	AV manufacturers
		Drone manufacturers
		Technology integrators
3	Research entities	Mobility-as-a-Service (MaaS) department
		Emissions department
		Safety department
4	Firms	Mobility related consultancy companies
		Traffic planning consulting companies
		Freelancers

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		Civil engineering companies (ALTRAN, ALSTOM, JACOB, SWARCO, SWECO)
		Survey firms
		Traffic simulation/software companies
5	Universities	Traffic planning researchers/Labs
		Transport policy researchers/Labs
		Modelling experts
		Students
		Cooperation overseas
		Valorisation centre
6	Cities and regions	City and regional governments
		Public transport authorities
		Transport infrastructure authorities (road, rail, UAM)
		Traffic and transport planning experts; civil engineers
		Policy makers
		Police
		City and regional associations
7	Civil Society	NGOs
		Associations of drivers
		Active travel users (different user groups, e.g., disabled, vulnerable etc.)
		Advocacy groups
		Public transport passengers (different user groups)
		Citizens
8	Service Providers	Passenger transport providers
		Freight operators
9	Infrastructure	Road operators
		Toll operators
		Rail network
		Tube / Metro / Tram
		Traffic operators (traffic lights)
		Parking providers
		Charge point operators (CPOs)
10	Unions	Pharmacists
		Taxi drivers
		Logistics / Truck drivers
		Public transport operators
11	Public Health	Hospitals

Step 4: Specification of the pathway

Based on steps 1-3, the pathway is described. In this step the basic components per category are plotted over time to work towards the market uptake in the target year. An important aspect is the identification of business cases for the HARMONY metropolitan areas for attracting funding/ investments. This step is mainly descriptive. This makes the roadmap more than a list of potential measures as the practical issues related to the implementation of the policy measures are additionally considered: timing, stakeholders involved, soundness of potential business models, and others.

Step 5: Roadmap elaboration and design

In this step, each roadmap is visualized. The roadmap design and visualization are based on two different parts. The first is the synthesis table, which brings information about the basic components, the sub-components, the requirements related to each sub-component and the stakeholders that will be involved in the process. Second, is the image that brings together the components and sub-components from the table, assigning them into relevant time frames. For integrated information and understanding of the roadmaps, the information in both parts should be considered.

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3. Roadmaps

In this chapter, the HARMONY roadmaps, aiming to support the different authorities in the transition to the new mobility services' era, are developed and presented. In total, 12 HARMONY roadmaps have been developed, each one focusing on specific components, which can all contribute to the specification of the pathway needed in order to proceed towards specific scenario goals. These components pertain to **Research**, **Technology**, **Policies**, **Infrastructure** and **Market**, while the involvement of different stakeholders is mentioned in each one of those. Further, the process includes the identification of some business cases, looking into elements like feasibility, viability, desirability, and stakeholders fit. This process makes the roadmaps more than a list of potential measures, as the practical issues related to the implementation of the policy measures are additionally considered: timing, relationships between different requirements, stakeholders involved, soundness of potential business models, and others.

3.1 Roadmap: Zero Emission Zone City Logistics

Zero emission city logistics is a goal for major European centres by 2030 (European Commission, 2011). More recently several how-to guides and roadmaps on the topic have been published (ALICE-ETP & POLIS, 2021; City of Rotterdam, 2020; Holtslag, Miclea, & Lozzi, 2020). In light of the goal of zero emission city logistics, a scenario with a zero-emission zone (ZEZ) has been modelled for Rotterdam. One co-created scenario is modelled. It includes two important aspects: per logistical segment varying shares of trips go via an urban consolidation centre (UCC) and the rest of the trips are zero emission (see D2.5 and D6.4 for the set-up and results). The distinction between different types of logistics segments is an important component. The following segments are distinguished: temperature controlled, fresh goods (general cargo), miscellaneous (general cargo), waste, express and parcels, facility, construction and dangerous. Each segment has a different UCC propensity. Furthermore, the ZE vehicle types also vary per segment: light electric freight vehicles such as a cargo bike, vans (electric and hybrid), trucks/tractor trailer/waste collection (electric, hydrogen and hybrid), and special construction (hydrogen and biofuel).

The simulations show that emissions in the zero emission zone are reduced dramatically, but at the city scale, the reduction is more modest. At a regional level, the reduction of impacts is marginal. The simulations also show that the rerouting of freight vehicles around the ZEZ or to and from the UCCs can lead to substantial increases in local freight traffic: this is an important side effect that needs to be considered in the implementation of a zoning scheme.

Table 2 Zero emission zone for city logistics

Basic Components	Sub-components	Requirements	Stakeholders
Research	Data on trips and vehicles	Continuously collect trip data in a database from companies, license plate scans and traffic models, which can be used as representative for different cities	Universities Technology providers Firms Cities and regions
	Modelling effects of a zone	Use a model (Tactical freight simulator) to assess the effects of a zone in terms of vehicles, kilometres, and emissions	Universities Cities and regions
	Simulating effects of a UCC	Further develop simulation tools for the effect of a UCC, enriched with	Universities Firms

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		data from private companies to provide policy advice	
	Feasibility of electric vehicles (TCO)	Provide a TCO tool that can be used by companies (logistics and SME)	Technology providers Firms OEMs
	Feasibility of a UCC	Test requirements to successfully decouple transport including business case and effects in existing use cases and pilots and disseminate learnings. Tailored UCCs to the different segments are important.	Universities Firms Cities and regions Service providers Infrastructure
	Routing with electric vehicles, including charging	Add new constraints in commercial routing tools	Technology providers Firms Universities
Technology	Zero emission vehicles (equivalents and alternatives)	Development of ZE vehicles and market readiness with turnkey systems	Technology providers OEMs Cities and region Service providers
	Charging infrastructure	Development of public and opportunity charging strategies and locations	Technology providers OEMs Firms Universities Cities and regions Infrastructure Service providers CPOs
	Electricity grid	Impact assessment tool for readiness of the grid (considering demand from other sectors)	Firms Universities Cities and regions Infrastructure
Policies	Zero emission zone (demarcation and vehicles)	Demarcation of the zone and types of vehicles that over time must become ZE, including campaign to involve stakeholders and harmonization between (national and local) governments – National government and municipalities. The rerouting of freight vehicles around the ZE-zone should be considered in the demarcation of the zone.	Cities and regions Universities

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	Stimulating policies on zero emission vehicles and hubs	Develop policies to stimulate frontrunners that implement alternative logistical models and ZE vehicles	Universities Cities and regions Service providers Infrastructure
	Restrictive policies on convention vehicles	Stepwise outsourcing conventional vehicles based on Euro class	Cities and regions Unions
	Monitoring and enforcement	Procure a (ANPR; automatic number plate recognition) camera system around the zone that can be used for monitoring and enforcement in a harmonized way in cities on a national level	Cities and regions Firms Technology providers Infrastructure
	Stakeholder involvement	Involve and inform local stakeholders that are affected by and can affect ZE city logistics to develop strategies in a periodic forum. This includes OEMs, transport companies, receivers (businesses and institutes), shippers, SME, construction companies, waste collection companies, energy companies, real estate owners,	Cities and regions OEMs Firms Civil society Service providers Infrastructure
Infrastructure	Charging infrastructure (public and private)	Rollout robust charging infrastructure on locations with logistics facilities, public charging infrastructure in residential areas (for vans) and fast charging stations	Technology providers OEMs Firms Cities and regions Infrastructure Service providers
	Electricity grid	Prepare the electricity grid for the additional energy demand	Firms Cities and regions Infrastructure
	Locations for hubs around the city/zone	Facilitate locations for transhipment. In the allocation of new hub-locations the rerouting of freight vehicles need to be considered to mitigate negative externalities outside of the zone.	Firms Cities and regions Service providers Infrastructure
Market	Acceptance ZE vehicles	Acceptance, both operationally and financially, of ZE vehicles with sufficient charging infrastructure	Service providers Civil society
	Acceptance of last mile services	Acceptance, financial benefits and added value for outsourcing last mile deliveries to companies that provide these from a UCC	Service providers Civil society

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The goal of this roadmap is zero emission logistics in major European centres by implementing zero emission zones. The focus is on all vehicle movements in urban areas related to the transport of goods and services. This roadmap is largely based on the use case in Rotterdam that serves in multiple ways as a reference scenario (both in modelling and through the policy documents that are available). The implementation of the zone is a policy measure that enables two other possibilities. On the one hand, efforts must be undertaken to enable the use of ZE vehicles. To this end, charging infrastructure is required so operations are not affected. On the other hand, it can also be an enabler to outsource deliveries to a company that can consolidate and transport the last mile zero emission. Therefore, locations for UCCs are required. This roadmap thus consists of three major goals to which the other requirements contribute:

- The gradual implementation of the zone, including clarity towards stakeholders such as the size and the type of vehicles that are (gradually) not allowed anymore. Communication is an important part.
- Enabling zero emission vehicles to be able to conduct operations inside the zone in the future. In addition to replacing conventional vehicles, operations should be affected as little as possible, but this requires charging strategies (in planning and routes), (sufficient) locations with charging infrastructure both on private and public ground, and security of supply with sufficient capacity of the electricity grid.
- Enabling other delivery models whereby the last mile is outsourced. If the switch to ZE vehicles becomes truly costly, outsourcing deliveries to a last mile service provider might become interesting.

The different requirements as listed in the roadmap work towards the three main goals that are interlinked. The four components (research, technology, policies, and infrastructure) should eventually contribute to user acceptance of the two enabling factors (either acquiring ZE vehicles or outsourcing last mile deliveries via a UCC). The TCO, and herewith the business model, of ZE light commercial vehicles becomes increasingly comparable to conventional equivalents (Figenbaum, 2018; Kin, Hopman, & Quak, 2021). For trucks, this depends on the mass production by OEMs and demand by companies (Quak, Nesterova, Van Rooijen, & Dong, 2016). The latter can be stimulated if multiple European cities set clear goals regarding the implementation of the zones. In both cases, charging infrastructure is an important enabler (Top Sector Logistics, 2019). The business models for last mile services (i.e. UCC) have been studied extensively (Björklund, Abrahamsson, & Johansson, 2017). In order to increase the demand for last mile services, a combination of factors must be considered (based on CILOLAB, 2022):

- A UCC should have an added value, wider than just ‘moving cargo’ from one vehicle to another. The services to its user should be tailored to the specific freight flow, the supply chain and involved stakeholders. A construction hub, for instance, differs from a cargo bike hub for parcels.
- Locations should be available close to, around and inside the city (the latter in case of parcel lockers and micro-hubs).
- The ZE zone can be an enabler as it becomes more difficult to enter the city, but other restrictions and the spatial organization of the urban area is also important.
- There is an important role for shippers and receivers. In case of the latter, for instance, large institutions (health care, municipalities, schools, offices) can demand zero emission and/or more efficient transport to their suppliers through procurement policies (Nesterova, Quak, Streng, & van Dijk, 2020).
- In the demarcation of the zone, and the selection of UCC locations, the secondary impacts of rerouting freight traffic needs to be considered to avoid unexpected negative externalities.

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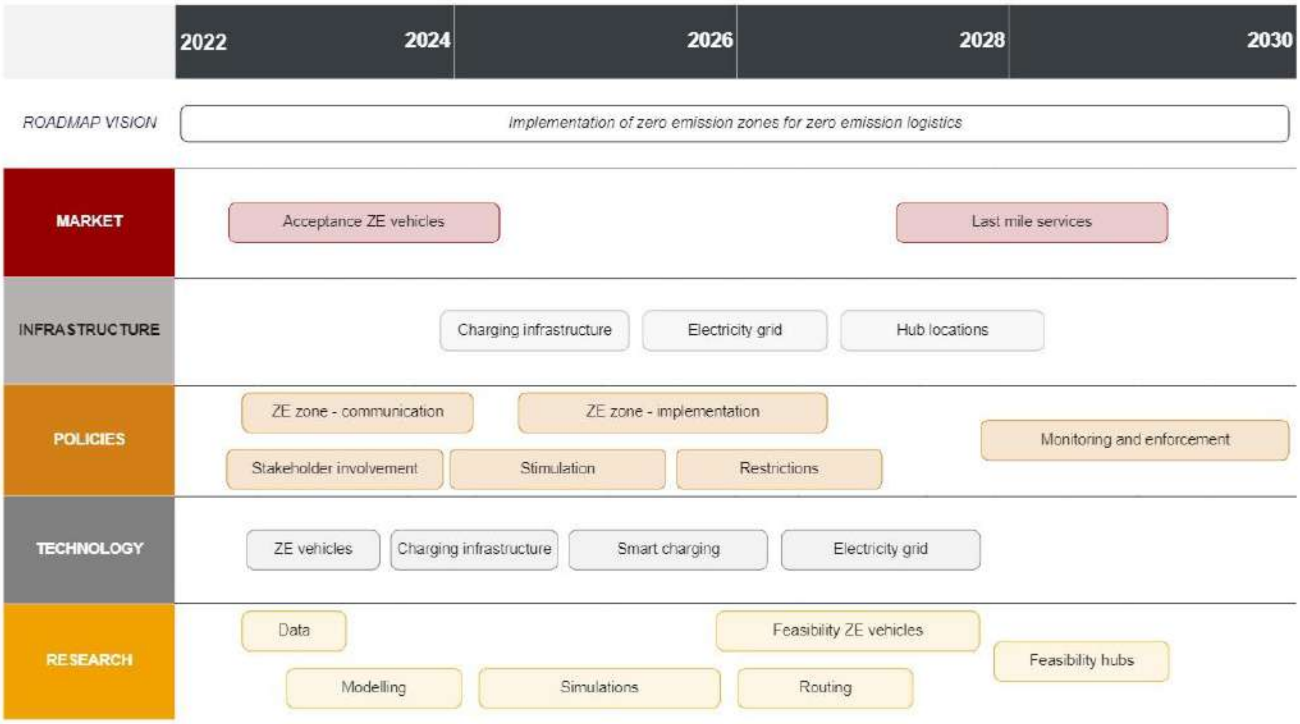

Figure 3 Roadmap ZEZ city logistics

3.2 Roadmap: Micro-hubs

Micro-hubs can contribute to zero emission (last mile) transport and the use of fewer and/or lighter freight vehicles (see also Katsela, Günes, Fried, Goodchild, & Browne, 2022; Urban Freight Lab, 2020). To investigate what the impacts and effects of micro-hubs and the use of light and zero emission freight vehicles are, a large-scale implementation of micro-hubs was explored for the city centre of Rotterdam (as use case area). In total nine different scenarios of micro-hubs have been explored by modelling the impact on the transportation system. The scenarios differ on three aspects which are: the number of micro-hubs, the business model, and the type of zero emission vehicles used. The zero emission vehicles that were considered are electric bicycles, light electric vehicles (LEVs) and autonomous robots. The focus of this use case is on parcel delivery. The outcome of the nine scenarios is compared to the current situation of last-mile logistics of parcel deliveries, with several depots located outside the city centre of Rotterdam and delivery with conventional vans to final destinations. The use case has shown that scenarios with light electric vans on average make fewer tours from the micro hubs due to its larger capacity compared to cargo bikes and autonomous robots; this is considered an operational advantage. The hybrid and full-collaboration models show better vehicle utilisation than the individual carrier model. The full collaboration model with light electric vehicles leads to the fewest vehicle kilometres in and outside the study area.

Table 3. Micro-hubs

Components	Basic components	Requirements	Stakeholders
Research	Data on trips and vehicles	Continuously collect trip data in a database from companies, license plate scans and traffic models, which can be used as representative for different cities	Universities Technology providers Firms Cities and regions

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	Conditions for success of micro-hubs	Identify which conditions contribute to the success of micro-hubs, i.e., in what type of areas are micro-hubs potentially successful (density, availability of space for loading/unloading, parking, policies that are in place etc.)	Universities Cities and regions
	Impact and potential of micro-hubs in other city logistics segments	Extend research on micro-hubs to other city logistics segments than parcel delivery (based on micro-hub typologies) to identify upscaling potential.	Universities Cities and regions Firms
	Combination with other functions	Explore how micro-hub locations can be combined with other functions to increase its value for the neighbourhood (such as mobility hub, storage locations, public toilets, pick-up points etc.).	Universities Firms Cities and regions
	Impact on a range of other aspects such as air pollution, congestion, and safety.	Understand potential additional value of micro-hubs as opposed to traditional van delivery on multiple aspects to advocate for implementation of micro-hubs (also when gains on CO_2 emissions diminish due to transition towards zero emission city logistics).	Universities Cities and regions
	Impact of freight traffic in direct surroundings of micro-hubs	Increase understanding of potential adverse impact (and possible mitigation) of micro-hub traffic on traffic safety, air pollution (e.g., of vehicles that supply micro-hubs), road / sidewalk congestion and the perception of residents in the vicinity of micro-hubs.	Universities Cities and regions
	Feasibility of micro-hubs	Develop and provide a TCO model of micro-hub scenarios that can be used by companies (logistics and SME).	Universities Technology providers Firms
Technology	Light zero emission vehicles	Availability of light zero emission vehicles.	Technology providers OEMs
	Charging infrastructure	Development of public and opportunity charging strategies and locations (around micro-hub locations).	Technology providers OEMs Firms Universities Cities and regions Infrastructure Service providers

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	Electricity grid	Impact assessment tool for readiness of the grid (considering demand from other sectors)	Firms Universities Cities and regions Infrastructure
Policies	Stimulating policies on micro-hub facilities	Design stimulating policies to implement micro-hubs, for example subsidizing logistics spaces in the city centre.	Cities and regions
	Indirect policy measures that promote the use of light and zero emission vehicles	Implement indirect measures, such as zero emission zones, shared spaces, strict delivery time windows, to make the use of light and zero emission vehicles more attractive.	Cities and regions
	Loading bays and urban spatial planning	Urban planning measures and parking requirements to reduce nuisance around micro-hub locations. Stimulate the (re-)development of real estate with minimal logistics footprint in public (traffic) space	Cities and regions Infrastructure
Infrastructure	Appropriate width (or capacity) of bicycle lanes to accommodate LEVs and cargo bikes	Explore adequateness of shared use of bicycle lanes with other road users.	Cities and regions
	Establish loading zones for light zero emission vehicles	Accommodate for loading operations of LEVs and cargo bikes to make drop-offs easier and to reduce nuisance.	Cities and regions
	Loading/unloading bays availability in surroundings of micro-hub	Facilitate unloading space in the surroundings of micro-hubs to reduce nuisance.	Firms Cities and regions Service providers
	Accessible locations for micro-hubs	Facilitate locations for micro-hubs in the city centre. Appropriate accessibility for safe and efficient delivery to micro-hubs by vehicles with higher capacity.	Firms Cities and regions Service providers Infrastructure
	Charging infrastructure (public and private)	Rollout robust charging infrastructure on micro-hub locations, public charging infrastructure in residential areas and fast charging stations.	Technology providers OEMs Firms Cities and regions Service providers
	Electricity grid	Prepare the electricity grid for the additional energy demand.	Firms

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			Cities and regions Infrastructure
Market	More sophisticated demands by customers on increased flexibility and zero emission delivery	Micro-hubs enhance speed and agility of the last-mile and can be a means to fulfil high demand of customers on reliable, flexible, and sustainable deliveries (and to provide a high service level).	Civil society
	Collaboration between logistics service providers	Potential benefits of micro-hubs are increased in case of a hybrid or full collaboration model.	Service providers Cities and regions

Micro-hubs are located closer to end-users than traditional urban consolidations centres and hence can facilitate a shift to lighter and zero emission vehicles (whose travel ranges are shorter than those of conventional vehicles). As the simulations in this study showed, micro-hubs can contribute to less vehicle kilometres and less emissions in inner cities and may help to ease congestion and accelerate the transition to zero emission logistics. Besides their potential positive impact on environmental KPIs and improved logistics efficiency, micro-hubs are also expected to contribute to a better quality of service due to increased flexibility in delivery times, stricter time-windows, and green deliveries. Further research is necessary, however, to evaluate the impact of micro-hubs on a broader range of KPIs (such as spatial impact, impact on quality of service, impact on traffic safety, etc.) and how this varies for different types of micro-hubs. This is especially relevant as the positive effect on emission reduction diminishes in the long term due to the increasing share of low and zero emission vehicles in the fleet. Hence, the extent to which micro-hubs contribute to social KPIs increases in relevance.

The potential success of micro-hubs depends on several factors, such as locations, type of vehicles and openness of its network (single carrier, multiple carriers or white label). Each of these factors should be considered carefully for each type of service area. The simulation case studies show huge reductions in vehicle kilometres if open networks or business models for micro hub operation are applied. Studies that address financial viability of micro-hubs point out that incentives or financial support by governments are often necessary, amongst others due to high costs of real estate and zero emission vehicles (Lee, Kim, & Wiginton, 2019; Lozzi et al., 2022). Further research is recommended to gain a better understanding of the financial viability of micro-hubs and what factors might positively influence their business case (such as increasing volume, providing services at the micro-hub, etc.). Indirect measures, such as zero emission zones, might also help to speed up the implementation of micro-hubs.

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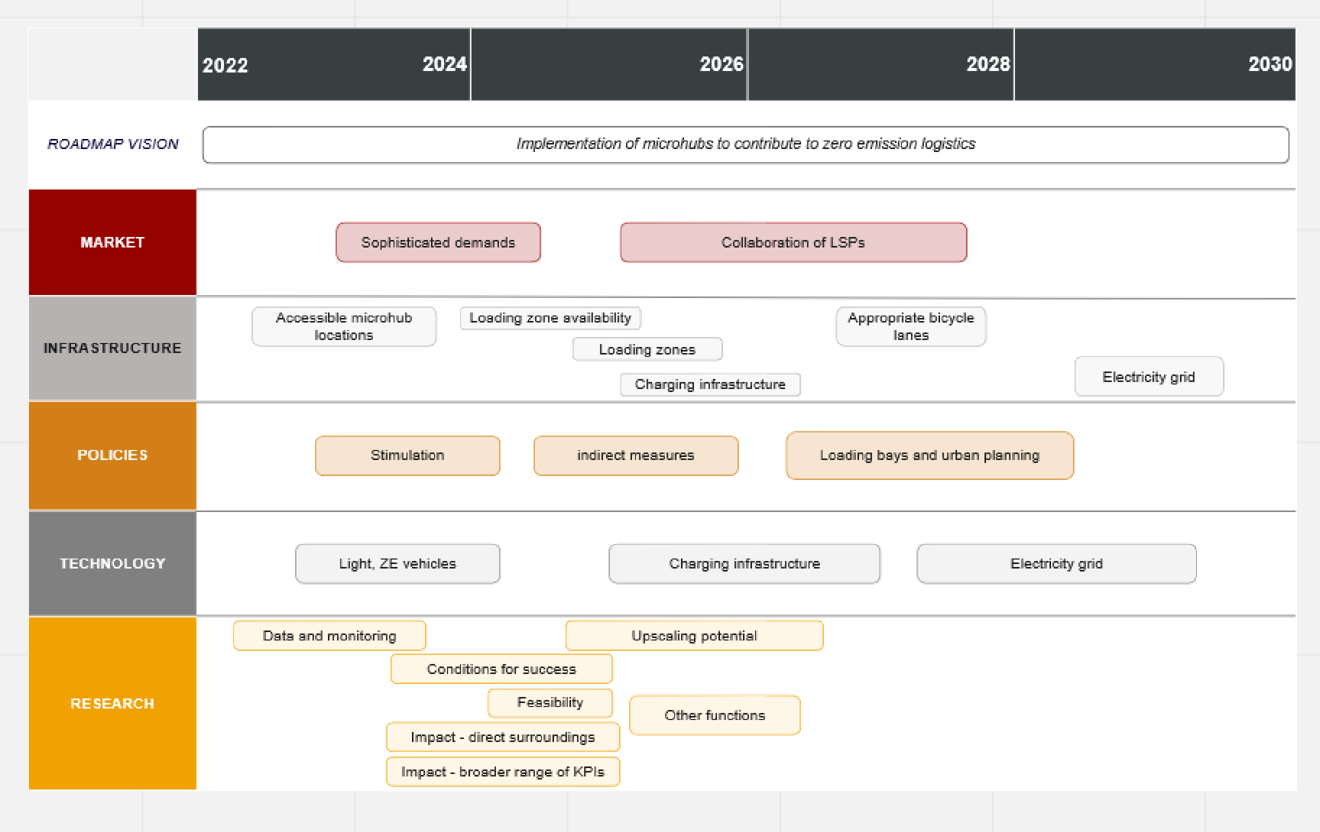

Figure 4 Roadmap Micro-hubs

3.3 Roadmap: Autonomous vehicles (AVs) – freight

Autonomous freight vehicles are mobile electric vehicles that can deliver parcels to customers without human intervention by making use of sensors and algorithms. Results from modelling the use of AVs in the micro-hubs use case indicate that the impact of the use of autonomous robots on the total number of kilometres travelled is low. Also previous studies have shown no significant impact on total number of kilometres when using autonomous delivery robots on the last mile (Poeting, Schaudt, & Clausen, 2019). Autonomous robot operations are not expected to be able to operate independently in a large area due to limitations in capacity, speed, and range, and should therefore be complemented by other vehicles such as cargo bicycles. However, potential benefits are lower costs for last mile delivery, precise specifications of delivery times (increased customer experience), increased safety and improved operation optimization (Jennings & Figliozzi, 2019, 2020). Furthermore, AVs can potentially reduce emissions on the last mile significantly (Figliozzi, 2020).

Table 4 Autonomous vehicles (AVs) – freight

Categories	Basic components	Requirements	Stakeholders
Research	Data on trips and vehicles	Data collection on origins of deliveries, destinations and trips which can be used to further research the potential of AVs.	Universities Technology providers Firms Cities and regions
	Impact assessment	Perform analyses on the conditions under which the use of AVs provides	Universities

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		environmental benefits or creates undesired externalities by running simulations.	Firms Cities and regions
	Routing with AVs, including charging	Add new constraints in commercial routing tools	Technology providers Firms Universities
	Integration of AVs with all modes of traffic, urban environments, road users and citizens in general	Support ongoing research and analysis of the implications of AVs for urban and mobility planning	Cities and regions Technology providers Firms Universities
	Ethics	Ethical considerations in the design of AVs should be researched to create more transparency in and awareness for ethical decision that are made in the design of AVs.	Universities OEMs Technology providers Civil society
	Pilots	Enable real-world pilot projects to perform controlled tests with AVs in urban areas.	Cities and regions Universities Firms Civil society
	Conditions for success	Identify which conditions contribute to the success of AVs, i.e., for what logistics patterns, logistics segments, demand density etc. and how this differs for each AV design.	Universities Firms Cities and regions
Technology	Design and build vehicles	Develop ZE vehicles and market readiness with turnkey systems	Technology providers OEMs Cities and region Service providers
	Vehicular communication systems	Vehicle technology and communication systems that enable vehicles to exchange data to one another and capture data about its surroundings (such as V2V, V2I and V2X) and the environment should be further enhanced.	Technology providers
	Tested for safe use in streets	Autonomous vehicles on the last mile should be able to operate in a highly dynamic, unstructured, congested, and crowded environment as well as must be able to deal with unpredicted situations.	Technology providers Universities Firms Cities and regions

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	Design enhanced technologies for data protection to AVs	AVs should be equipped with enhanced data protection technology to prevent privacy leaks.	Technology providers
Policies	Subsidies	Public authorities can help to accelerate AV adoption by supporting pilots and funding innovation	Cities and regions
	Permissions	Determine legal restrictions for AVs (such as street types and speed limits).	Governments Cities and regions
	Harmonization	Harmonization between governments about regulations for AVs, for example about the area of operation (sidewalks, bicycle lanes, streets).	Cities and regions
	Compliance	By design AVs are equipped with sensors, microphones and cameras that register information. AVs should comply with data protection and privacy regulations.	OEMs Technology providers Firms
	Adapting regulations to the use of AVs	Regulations should be adapted to the fact that AVs have no driver. Due to this also liability should be dealt with differently.	Governments Cities and regions
Infrastructure	Charging infrastructure (public and private)	Arrange appropriate infrastructure for charging of AVs	Cities and regions Technology providers Firms CPOs
	ICT infrastructure	Arrange appropriate ICT infrastructure to enable for data exchange, artificial intelligence, and cloud computing.	Technology providers firms
	Controlled areas / dedicated routes for autonomous vehicles	Decide on in which areas / roads AVs have access (no vehicles area, exclusive lanes)	Cities and regions Technology providers
Market	Investments AV industry	Both private and public sector should be engaged and willing to invest in research and testing of AV technologies.	Firms Cities and regions Technology providers OEMs
	Acceptance by users and public	Consumers should accept receiving deliveries by AVs and notice its potential advantages. The public should also accept driverless vehicles driving around in the streets, which requires trust from public in new	Civil society Technology providers Firms Cities and regions

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		technologies. Encourage social debate on AVs.	

As the above presented roadmap indicates, the integration of AVs for last mile delivery is not mature yet and cannot be realized soon as the technological, regulatory, and societal implications of the business model of AVs still need to be researched. However, the roadmap shows potential fields of action to prepare for the implementation of AVs in the longer term. This includes funding of further research on technologies such as communication and safety systems, but also running simulation studies and pilots to increase understanding of the potential benefits of AVs. Furthermore, AVs must be accepted by the public to be successfully implemented in the future. Apart from the acceptance of the technology itself, ethical aspects should also be considered to support public acceptance and trust. Adaption of policies and regulation as well as compliance of technologies with privacy regulations are of utmost importance to enable implementation of AVs. Governments can play a major role to encourage development of AVs by funding research and innovation, and by adopting regulations to enable experiments with self-driving freight vehicles.

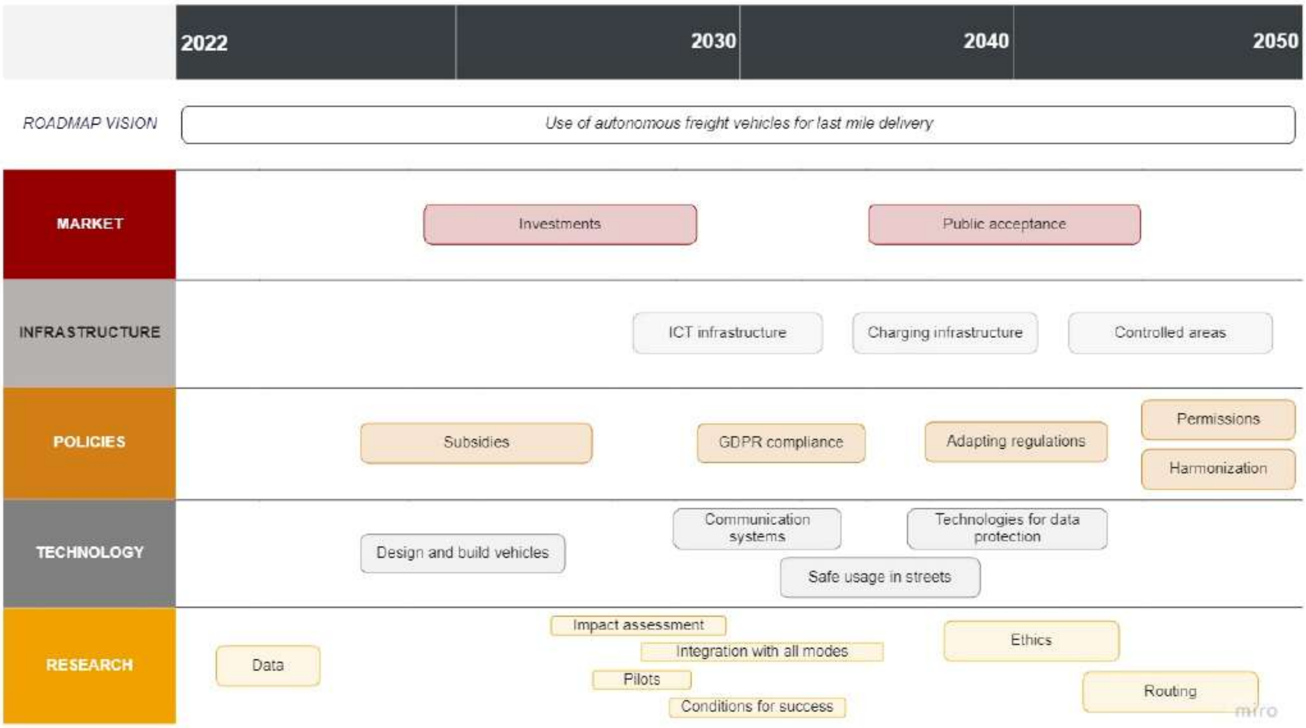

Figure 5 Roadmap autonomous vehicles (freight).

3.4 Roadmap: Crowd-shipping

Crowd-shipping is a concept that can be used to transport parcels with the ‘spare capacity’ of passenger transport – on foot, by bike, public transport or by car. An individual (the ‘crowd’) transports goods (often one or a limited number of parcels) to a receiver, which is mostly a consumer. The individual can do this on an already planned trip, but it can also be a job (also known as gig-workers), which we see with the rise of instant deliveries (Dablanc et al., 2017). In case of the latter, additional trips are made. The outcomes of the modelling scenarios show that the design assumptions of the crowd-shipping solution have a big influence on the impacts. In the studies scenarios, crowd-shipping had an adverse impact as it increased traffic and greenhouse gas (GHG) emissions (due to detours and additional rides with cars). This is under the assumption that a share of these parcels is eligible to shift to a car (57%) or a

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bike (43%) (not all parcels that are currently transported by parcel carriers). Overall, it leads to a marginal reduction in van kilometres driven and an increase in kilometres driven in the transport system. It is known that (B2C) parcel deliveries transported by companies such as DHL are efficient due to the high vehicle fill rate and high stop density.

Despite the outcomes of the modelled use case that shows that crowd-shipping has a low potential to reduce negative side-effects of parcel deliveries, this roadmap sketches a path for crowd-shipping towards 2030 by discussing the potential deliveries to which crowd-shipping can be a substitute. From the model use case in the HARMONY project and the literature, it is clear that various factors can affect the potential of crowd-shipping as an alternative to deliveries by a parcel carrier. The main factors are the existence of a digital platform, the transport mode that is used for crowd-shipping and whether an existing trip is used or a detour must be made, the pricing strategy, liability and flexibility (Buldeo Rai, Verlinde, & Macharis, 2018; Le, Stathopoulos, Van Woensel, & Ukkusuri, 2019; Pourrahmani & Jaller, 2021). Whereas crowd-shipping is less interesting for consolidated flows in urban areas, transported by parcel carriers, there are roughly two interesting applications: 1) consumer-to-consumer (C2C) deliveries, whereby the origin is a household; and 2) ship-from-store concepts, where orders are done online at a (local) store, whereby these stores come to function as hubs (Buldeo Rai, 2019; Devari, Nikolaev, & He, 2017; Pourrahmani & Jaller, 2021). Additionally, outlier deliveries to rural or low density areas are interesting, but this is not considered herein as the focus lies on metropolitan areas.

The first explorative simulation of crowd-shipping in the HARMONY project is followed-up in other H2020 projects such as LEAD and URBANE. In LEAD, the simulation of crowd shipping is elaborated in an integrated last-mile logistics living lab in the city of The Hague. This living lab involved various local stakeholders (logistic service providers and retailers) and the implementation of an integrated crowd-shipping platform with parcel lockers (Tapia et al., 2023).

Table 5 Crowd-shipping

Components	Basic components	Requirements	Stakeholders
Research	Data on trips and vehicles	Data collection on origins of deliveries, destinations, and mobility behaviour and trips.	Universities Technology providers Firms Cities and regions Civil society
	Impact assessment	Analyses on the conditions under which crowd-shipping provides environmental benefits. This requires a link to traffic modelling and can be related to the physical internet as a research initiative	Universities Firms Cities and regions
	Condition setting	Based on the impact assessment, combined with qualitative research, the conditions must be set how crowd-shipping is organized, including the legal requirements and labour conditions	Universities Cities and regions Firms Civil society Unions
	Open platform	Research on the requirements to develop an open platform where	Universities Technology providers

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		demand for goods and supply of transport services is connected	Firms Cities and regions Service providers Unions
Technology	Digital platform	The development of a platform that is open to any user – stores and consumers that offer products, people that have spare capacity of transport and receivers.	Technology providers Firms Service providers
Policies	Labour market and regulation	Basic labour protections	Technology providers Cities and regions Unions Service providers
	Pick-up locations	Conditions under which a location can serve as pick-up location to avoid (traffic) nuisance around the premises in the direct environment (e.g., like dark stores)	Cities and regions Infrastructure
	Parking and urban planning	Urban planning measures and parking requirements to reduce nuisance around locations that serve as an origin (e.g., store) or pick-up location (e.g., micro-hub)	Cities and regions Infrastructure
Infrastructure	Digital platform	The development of a digital platform that is accessible to users – both entities that offer and demand transport services	Technology providers Firms Service providers Civil society Unions
	Urban planning	Regulations and interventions in urban infrastructure to reduce the nuisance of traffic around locations	Cities and regions Infrastructure
Market	Pricing strategy	A flexible pricing strategy that is accepted by users and providers of crowdsourced deliveries	Technology providers Firms Service providers Civil society Unions
	Collaboration	One platform to which different operators, users and providers can match demand and supply. This is a requirement to create volume and match demand and supply	Technology providers Firms Service providers Civil society Unions

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	Public acceptance	Volume is important and the public are potential users who demand transport services	Service providers Civil society Unions
	Crowd	Volume is important and the public are potential users who offer transport services	Service providers Civil society Unions
	Legal arrangements	Safety, liability, and responsibility of goods transported	Cities and regions

Crowd-shipping, as modelled in the scenario, has a low potential to be a substitute for (B2C and B2B) parcel deliveries by carriers in urban areas. There are, however, specific applications for which there is potentially a business model. As elaborated above, this applies to less consolidated flows such as C2C and ship-from-store deliveries. Some important requirements include an open platform where different providers can be connected. This is already partly taking place with different gig-platforms.

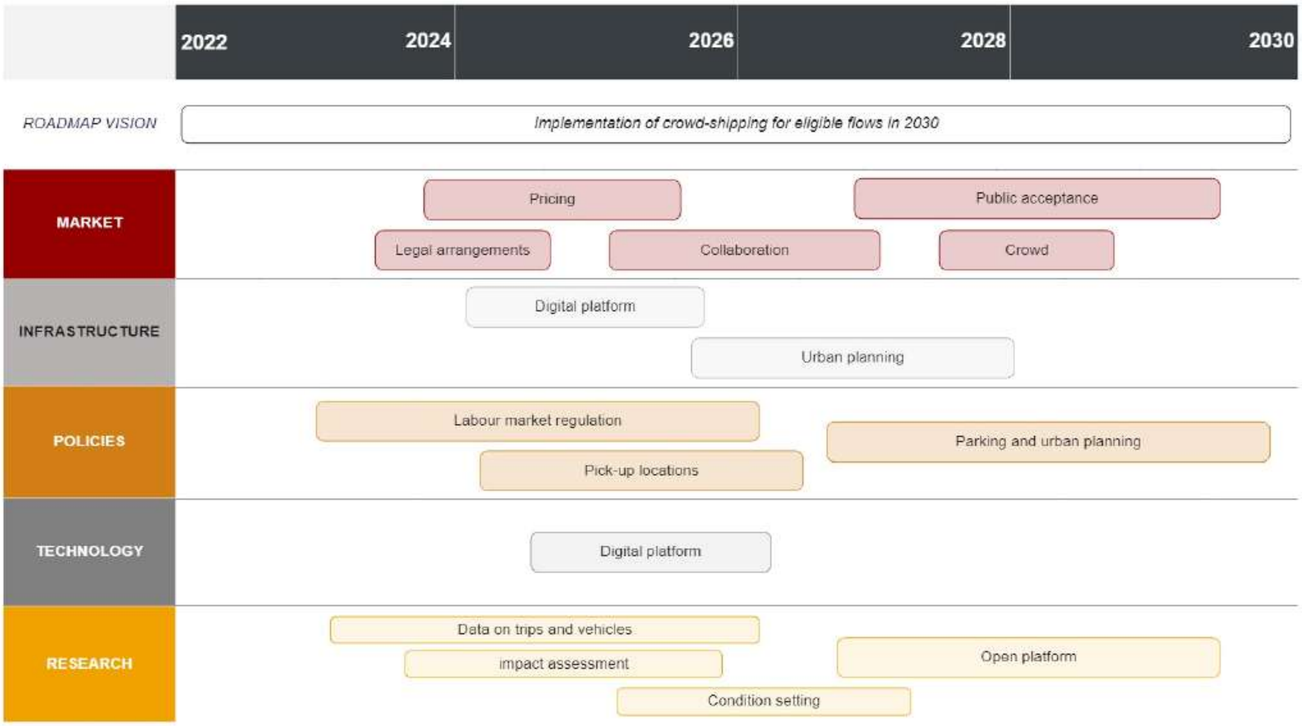

Figure 6. Roadmap Crowd-shipping.

3.5 Roadmap: Drones for freight

Globally, unmanned vehicle technology is gradually advancing, and drone trial flights are being performed nearly everywhere. Infrastructure needs and costs are relatively low as it is mostly a matter of different planning and integration in existing networks. The need for a clearly defined ecosystem for U-Space/UTM is an urgently needed asset. U-space is a set of services to help drone operators comply with the new rules and regulations, which will help enable the EU member states to manage the ever-increasing volume of drones in their airspace. Many authorities (like, and not limited to: ICAO

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(International Civil Aviation Organization), EASA (European Union Aviation Safety Agency), Eurocontrol, National Aviation Authorities (NAAs), Air Navigation Service Providers (ANSPs), EUROCAE (European Organization for Civil Aviation Equipment), ISO (International Organization for Standardization), GUTMA (Global UTM Association), JARUS (Joint Authorities for Rulemaking on Unmanned Systems), RTCA (Radio Technical Commission for Aeronautics), ASTM (American Society for Testing and Materials)) are working towards a clear concept, defined rules and regulations for the U-Space/UTM ecosystem. Around the globe, regulators are working hard to prepare the environment for safe and sustainable operations of unmanned aircraft. A good overview on the evolution in this sector can be gained from the internet page www.unmannedairspace.info. Based on this fact, a solution (concept, software, and tools) to enable local authorities and city planners to decide, plan and manage the airspace above the city's territory will be needed widely.

Table 6 Drones for freight

Basic components	Sub-components	Requirements	Stakeholders
Research	Data (traffic, trips, weather)	Collection of the necessary data and their analysis Integration with existing models can be challenging and not straightforward	Research entities Universities
	Geo-information	Geofencing database	Research entities Cities and regions
	Impacts in terms of energy consumption, noise, air quality, safety, noise abatement, visual pollution, and operational use/potential of "their airspace".	Evidence-based decision making can be enabled via quantification of impacts. The connection of smart city planning tools such as HARMONY Modelling Suite (MS) to a U-Space/UTM solution seems unique, with some additional potential.	Research entities Universities
	Pilots	Actual field testing and pilot co-creation, which is necessary to ensure that what is expected can be provided and at what level	Cities and regions Service providers Technology providers Civil society Drone providers, manufacturers, and pilots Industrial sector
	Safe and reliable airspace planning and management	Different sectors for transport planning Traffic scheduling	Cities and regions UTM providers
Technology	Unmanned aerial vehicles capabilities	Hardware and software requirements Ensure safe and reliable service	Technology providers (Drone manufacturers, Technology integrators)

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	Drone tracking services	Surveying and inspection purposes	Drone pilots Municipalities
	ATC personnel training	Education and training required for personnel to adapt to the drone use requirements, especially in mixed environments, with manned aviation that will use the traditional ATC services.	Cities and regions Service providers UTM providers Drone pilots
	Geofencing – using position location technology such as GPS (Global Positioning System) satellites, RFID (Radio Frequency Identification), WIFI, and the drone's software	For necessary restrictions in the movements of the drones; Information on restricted zones/ areas is necessary; to define the best way how to use the airspace above the cities' territory	Technology providers
Policies	Defining the UTM/U-Space concepts and procedures	Requirements related to societal impacts in terms of environment, privacy and security are not yet properly addressed in developing U-space. Connection of ground and aerial transport is needed. Alignment of city planning and management processes with airspace management and very low-level flight planning. Alignment with airspace management and ATM solutions	Cities and regions; Country and city councils UTM providers ATM centres
	Regulatory framework for drones' operations, which enables the registration process too	Drone delivery guidelines – Guidance on the aviation regulatory framework Recommendations regarding land use and planning	Cities and regions; Country and city councils UTM providers
	Urban Mobility policy tools, Sustainable Urban Mobility Plans (SUMPs) or Sustainable Urban Logistics Plans (SULPs)	Urban Air Mobility as a Priority area, specific measures in the urban mobility domain	Cities and regions Country and city councils
Infrastructure	Dedicated pads for loading, take-off, and landing of aircraft	Infrastructure required is quite simple and easily accommodated (Drone docking stations with a control panel) Faster, safer, and cheaper oversight and maintenance of transportation and infrastructure projects	Air traffic operators Drone industry

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	Charging facilities	Efficient batteries/ charging process for fast charging	Technology providers Drone industry CPOs
Market	User acceptance	Value for end customers to be created	Service providers (freight operators); Unions; Products providers Drone professionals Aviation sector UTM service suppliers Government agencies, private business
	Citizen acceptance	Research needed to explore citizens' preferences on drone services (both as recipients and as bystanders)	Civil society (citizens) Research/ knowledge institutes Municipalities
	Market for UAV Traffic Management services	Full adoption can be enabled via moderation of start-up costs, staffing and training needs, and government regulations that limit the scope of operations	Variety of stakeholders involved: from IT-development (Internet of Things), from simulation, or from drone mission planning software development, but also from traditional ATM environment.

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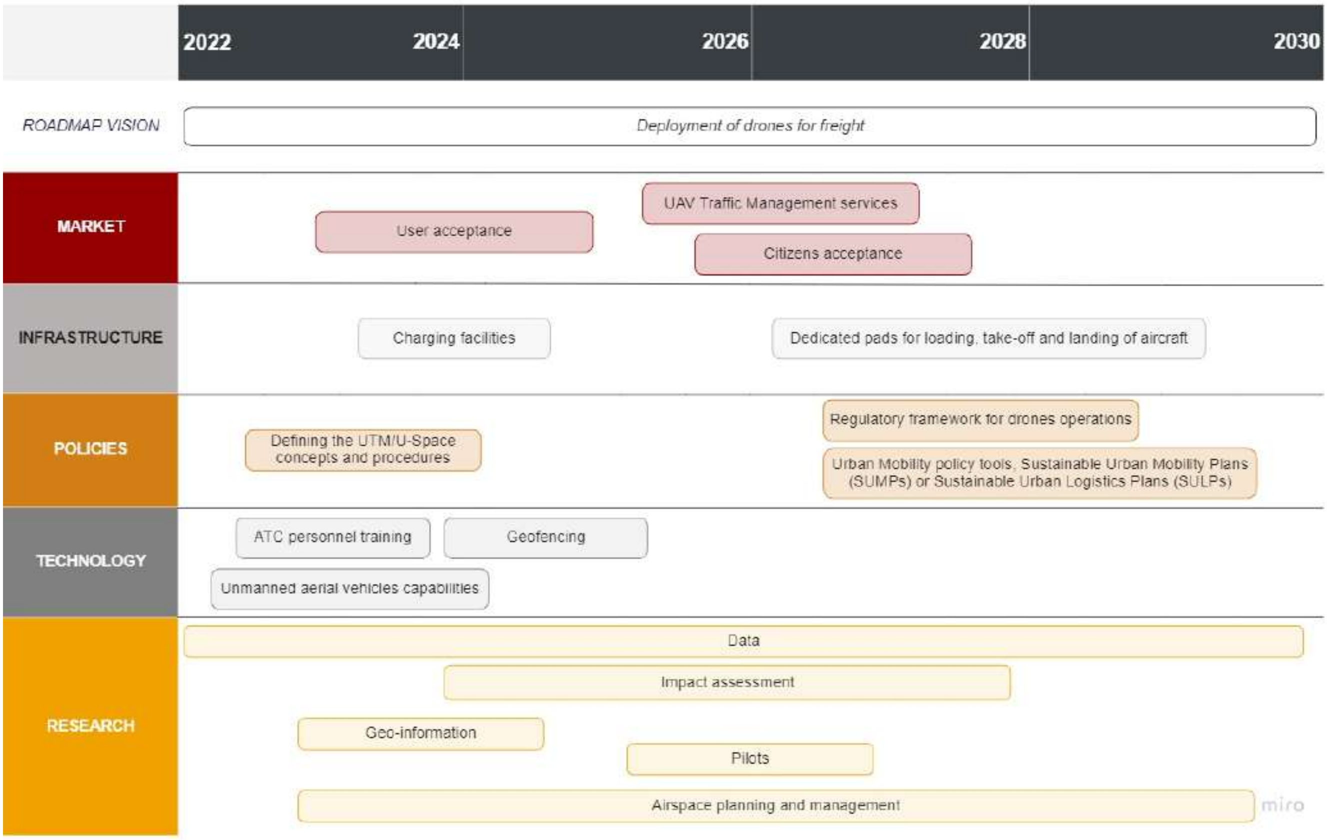

Figure 7 Roadmap drones for freight.

Solid scenarios for UAM, as conceptualized and developed in HARMONY, pertain to express delivery services (for dedicated high value deliveries inside urban areas), port delivery services as well as express delivery in remote areas, for better connection of cities with the surrounding rural areas and villages. Short to medium distances could be covered by drones delivering goods to nearby customers, and this could be done with the drone departing from either the customer's premises or a delivery truck, as has been tested in Trikala and Oxfordshire demonstrations (see D9.5). Such a solution could be especially appealing and timesaving in rural areas where delivery trucks need to serve many locations.

At an operational level, advanced drone technology is already a reality. However, it needs to be noted that the market is currently fragmented and not very clear. Many stakeholders are approaching this from many different directions, either from IT-development (Internet of Things), from simulation, or from drone mission planning software development point of view, but also from the very traditional in essence ATM environment. The integration of UTM and ATM systems is both a challenge and a necessity that is of paramount importance. Many software solutions are available which cover many different aspects of U-Space/UTM. While the feasibility of a business case can already be proven to a big extent, the viability and desirability of it remain doubtful. Lastly, based on the Trikala drone demonstration (also reported in D9.5), the cities do not seem ready yet for setting up pilots so more time is needed for better preparation.

3.6 Roadmap: Autonomous vehicles (AVs) - passengers

AVs is not a scenario to be implemented on the streets of Athens in the near future. However, mixed traffic, composed of both conventional and autonomous vehicles, is expected to be the norm over the years to come, with increasing AV penetration rates. Among their other characteristics and according to the literature, higher AV penetration rates can have a beneficial effect on the network by increasing the traffic flows due to the shorter headway needed by the autonomous vehicles and the decreased

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reaction times that they exhibit. Therefore, a roadmap is built on passenger AVs, the timeline of which is considered up to 2050, and can be found below. This roadmap is more tailored to the Athens pilot (Table 7 and Figure 8), for which simulations were run also with the HARMONY MS. Results showed that travel times also drop as the AV penetration rates increase and the difference of total network travel time between the base case scenario and the 100% AV penetration rate scenario is -8.97%.

Table 7 Autonomous vehicles (Avs) – passengers

Basic components	**Sub-components**	**Requirements**	**Stakeholders**
Research	Data on trips and vehicles, network capacities Data on population and growth rates Demand data for AVs	Data collection on origins and destinations of trips which can be used to further research the potential of AVs.	Universities Technology providers Firms Cities and regions
	Impact assessment; modal split, emissions, traffic efficiency, safety	Ongoing research and analysis of the implications of AVs for urban and mobility planning (Activity-based demand model; network supply model; multimodal Passenger Service Controller system; LUTI model; Microscopic simulation-based experiments; Macroscopic demand models)	Universities Research entities Cities and regions Firms
	Routing with AVs, including charging	Add new constraints in commercial routing tools	Technology providers Firms Universities
	Integration of AVs with all modes of traffic, urban environments, road users and citizens in general	Support ongoing research and analysis of the implications of AVs for urban and mobility planning	Cities and regions Technology providers Firms Universities
	Ethics	Ethical considerations in the design of AVs should be researched to create more transparency in and awareness for ethical decision that are made in the design of AVs.	Universities OEMs Technology providers Civil society
	Pilots	Enable real-world pilot projects to perform controlled tests with AVs in urban areas.	Cities and regions Universities Firms Civil society

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	Conditions for success	Identify which conditions contribute to the success of AVs, i.e., for whom, where etc. and how this differs for each AV design.	Universities Firms Cities and regions
Technology	Design and build vehicles	Develop AVs and market readiness with turnkey systems	Technology providers OEMs Cities and regions Service providers
	Tested for safe use in the streets	Disruptive technology which will bring many changes at a societal level. Data collection and liability issues; Safety and security concerns	OEMs Technology providers Firms Research entities Universities Cities and regions
	Vehicular communication systems	Vehicle technology and communication systems that enable vehicles to exchange data to one another and capture data about its surroundings (such as V2V, V2I and V2X) and the environment should be further enhanced.	Technology providers OEMs
	Design enhanced technologies for data protection to AVs	AVs should be equipped with enhanced data protection technology to prevent privacy leaks.	Technology providers OEMs
Policies	Subsidies	Public authorities can help to accelerate AV adoption by supporting pilots and funding innovation	Governmental authorities Local authorities AV industry
	Permissions and AV-specific legislative and regulatory policies	Stakeholder involvement and communication; Alignment between governmental authorities Policies should cover safety and security, access, social inclusion, equity concerns and wellbeing, multimodal transportation. Currently, AV industry faces an uneven and uncertain regulatory environment and lacks a clear path to large-scale deployment.	Governments Cities and regions
	Compliance	By design AVs are equipped with sensors, microphones and cameras that register information. AVs should comply with data protection and privacy regulations.	OEMs Technology providers Firms

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Infrastructure	Charging infrastructure (public and private)	Enough charging locations, re-design of parking areas.	Cities and regions Technology providers Firms CPOs
	ICT infrastructure	Arrange appropriate ICT infrastructure to enable for data exchange, artificial intelligence, and cloud computing.	Technology providers Firms
	Controlled areas/ dedicated routes for autonomous vehicles	Land use adaptation, new urban and mobility planning. AV deployment should be gradual.	Cities and regions Technology providers
	Change in inter/intraregional transport infrastructure capacity	Mode sharing infrastructure/ public space re-design needed.	Cities and regions Technology providers
Market	Public acceptance/ satisfaction	Citizens, not only road users, should accept driverless vehicles driving around in the streets, which requires trust from public in new technologies. On top, enabling conditions for use should exist, such as sufficient supply of charging points etc.	Civil society Policy makers Industries Electricity companies Transport operators
	Technology accessibility	Reasonable AV pricing Reasonable AV maintenance cost	Firms Cities and regions Technology providers OEMs
	Investments AV industry	Both private and public sector should be engaged and willing to invest in research and testing of AV technologies.	Firms Cities and regions Technology providers OEMs

The above referenced roadmap requirements and actions needed, indicate that the integration of AVs in the roadway mode mixture is not quite mature yet. Safety and security concerns, and technological evolution in this direction rank high in the priorities that need to be taken care of before any meaningful action towards AV integration can actually take place. ICT adaptation issues, development of the necessary regulatory framework as well as public acceptance are also subjects of utmost importance. Indeed, answers from the stakeholders during the first Athens co-creation lab revealed hesitation towards the adoption of AVs as a means of transport, with the hesitation rising as the level of automation increases. As such, establishment of AVs as a viable and safe transport option in more countries is expected to work as a catalyst for the raise of the associated interest (especially in countries like Greece) and the acceleration of the necessary investments, the adaptation of policies and the increase of public acceptance in this regard.

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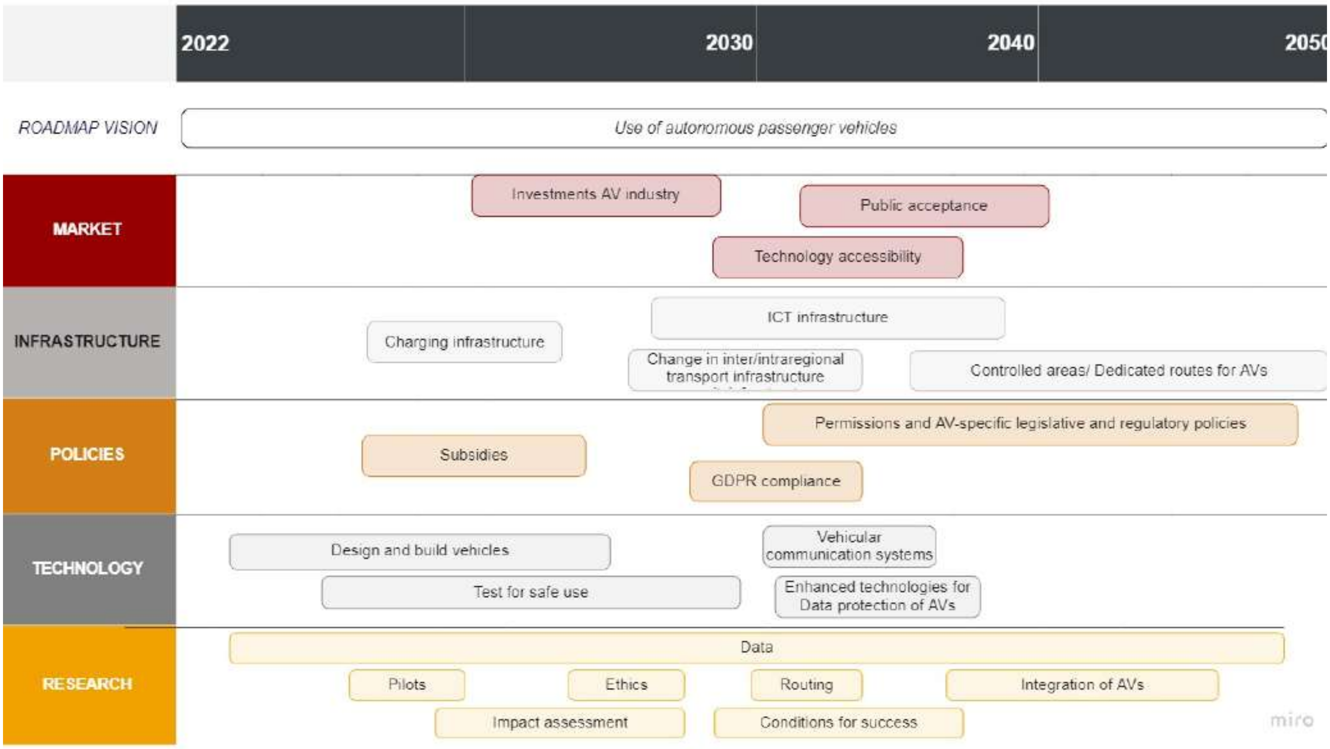

Figure 8 Roadmap autonomous passenger vehicles.

3.7 Roadmap: Public transport electrification

Transportation planning in a city like Athens is an essential element of its everyday functionality. As such, the Athens Public Transport Organization (OASA), the sole public transport operator in the Attica region, has developed a spatially extensive transport network model that covers the entire Athens metropolitan area. OASA has investigated different scenarios that would be of interest to various stakeholders and that, if applied, could have implications on the city's day-to-day operation of transportation means. One of these scenarios is the electrification of public transport (PT): this case study investigates the transition from conventional fuel buses to battery electric ones (BEBs). In the analysis presented in D2.5, we see that the first 50 electrified lines have the potential to halve the CO emissions of the remaining in operation conventional buses and decrease the respective NOx emissions by 46%. Naturally, results may vary on the basis of the number of BEBs available at the various stages of the procurement and the combination of the lines electrified.

The transition from conventional to electric buses has or is already taking place in different cities. The roadmap is based on the actual initiative currently undertaken in the city of Athens, which is expected to be fully realized until 2028. Transition to BEBs is planned to take place in two phases: one up to 2025, with the partial replacement of the bus fleet, and the second one, until 2028, when the replacement of conventional buses is going to be completed. The main goals of the initiative are to: 1) renew the existing bus fleet and increase the passengers' Level of Service (LoS); 2) promote the use of public transport through the improved level of service provided and attract more passengers from the private means of transport; 3) promote the contemporary image of Athens; 4) conform to the European transport and environmental guidelines, and 5) improve the air quality in the capital, and thus provide health benefits to the residents over the short and long run. The electrification of public transport is viewed as the first step towards the transition of the capital to a new, more sustainable, and environmentally friendly, mobility era. Along with the gradual shift of the public to private electric cars and other initiatives that are to be undertaken in the future, it is believed that it is going to contribute towards improved air quality in the city and better health for the residents. A roadmap has been

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developed for this scenario, largely based on the city of Athens, and is presented in the following Table 8 and Figure 9.

Table 8 Public transport electrification

Basic components	Sub-components	Requirements	Stakeholders
Research	Data on PT trips Passenger demand data Network and population data	Data on the energy consumption and the charging efficiency of the buses are now missing	Research entities Universities Cities and regions Service providers Infrastructure
	Effects of electrification in terms of the exhaust emissions (CO_2, NOx, PM2.5 pollutants)	Energy and emission model	Research entities Universities Cities and regions
	Optimal fleet size, battery capacity and charging infrastructure	Identify the needs in terms of optimal fleet size, battery capacity and charging infrastructure	Research entities Universities Service providers
	Short- and long-term traffic planning	Macroscopic simulation tools for traffic studies	Research entities Universities Service providers
Technology	Battery Electric Buses (BEBs) Compressed Natural Gas (CNG) buses	Development of the low emission buses Upgrade of bus network with battery buses; Gradual replacement of the conventional buses Tender for BEBs and CNG buses needed; Vehicle purchase costs	OEMs Research entities Cities and regions Technology providers
	Energy storage/ management; Electricity grid	Impact assessment tool for readiness of the grid (considering demand from other sectors)	Technology providers Cities and regions Infrastructure Service providers
Policies	International commitments and national policies to promote deployment	Conform to the European transport and environmental guidelines	Cities and regions Service providers

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	of electric PT vehicles	Stakeholder involvement and communication; Alignment between governmental and local authorities Subsidies	
Infrastructure	Electric bus charging system	Charging stations at bus depots. Development of public and opportunity charging strategies and locations	Infrastructure OEMs Service providers Technology providers
	Number of Battery Electric Buses (BEB) lines	Identification of the suitable bus lines to be gradually operated by BEBs	Cities and regions Service providers
	Capacity electricity grid and smart charging and associated infrastructure Multi-purpose use of electric PT infrastructure	Prepare the electricity grids and the associated infrastructure for the additional energy demand	Infrastructure OEMs Firms Universities Cities and regions Technology providers Service providers CPOs
Market	Electric bus market penetration	Gradual electrification of the bus lines for the gradual replacement of the conventional buses Future market analysis and modelling tasks are essential components of planning Action plans should be based on robust analyses	OEMs Service providers

As already explained, Athens is already on the way of transitioning from conventional buses to low or zero emission ones. More specifically, the call for tenders that has been issued for both the cities of Athens and Thessaloniki considers the supply of a total of 200 CNG 12m-length buses, 100 CNG 18m-length buses, 250 12m-length BEBs with autonomy of at least 180km and 100 12m-length BEBs with autonomy of at least 135km. For Athens in particular, the supply regards 300 CNG buses and 220 BEBs (140 of which with autonomy of at least 180km and the rest 80 of them with autonomy of at least 135km). According to the specifications, all BEBs are required to be slow charging, with charging taking place at the depots. Supply of the associated charging infrastructure is also part of the call for tenders. According to estimations, the whole tender process is expected to be finalized until the first quarter of 2023, with the first buses arriving to the cities in early 2024.

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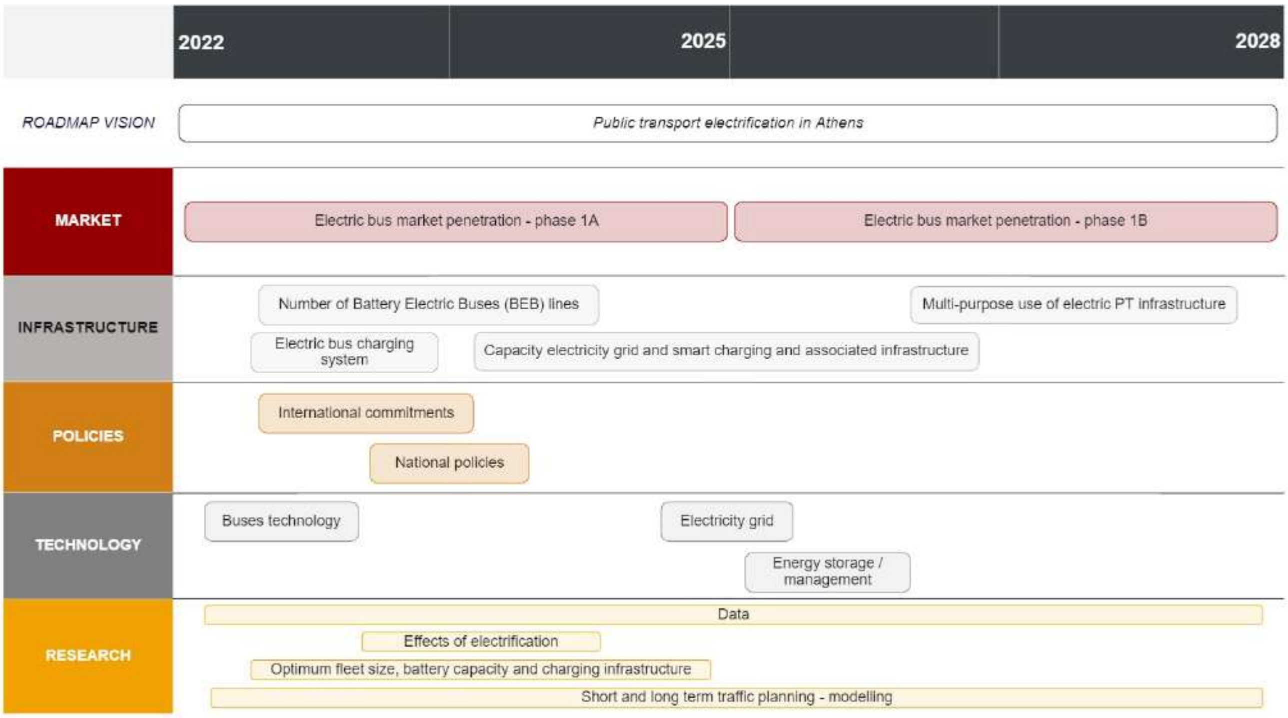

Figure 9 Roadmap public transport electrification in Athens.

3.8 Roadmap: Micro-mobility interventions

Over the next few years, Athens aspires to transform every-day living for the citizens and transport within the city, by implementing a series of measures aiming to enhance passenger mobility, environmental protection, and quality of living. Despite the substantial use of private vehicles over the previous decades, Athens is currently also shifting to more sustainable forms of transport, complying to the overall need to reduce private car dependency in urban areas (European Commission, 2020). The electrification of public transport is the first measure in this direction, followed by the construction of a new metro line 4 in the greater metropolitan area and the application of other soft mobility measures, including micro-mobility. In this context, in June 2020, the Minister of Environment and Energy announced the construction of two major bicycle paths in Athens. Below, a roadmap for Micro-mobility is presented, based mainly on the case for the city of Athens, with a timeframe of up to 2028.

Table 9 Micro-mobility interventions

Basic components	Sub-components	Requirements	Stakeholders
Research	Data on trips/ travel behaviour/ Disaggregate mode choice data Micro mobility transit data; cyclist data, traffic flows Data on network level Population data Land use data	Research and trials would support decision-making on infrastructure guidance	Universities Technology providers Firms Cities and regions Research entities

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	Effects of bike use in terms of environmental impacts, safety, traffic efficiency, accessibility	Macroscopic simulation tools	Universities Research entities Cities and regions
Technology	Battery electric bikes/ scooters	Land suitability	Firms Service providers Research entities
	Applications and websites for access to shared networks	Liability issues	Technology providers Service providers Firms
Policies	Traffic and parking regulations Public safety policies Legislation and legitimization	PPE (Personal Protective Equipment) requirements Integration in SUMP Stakeholder involvement and communication; Alignment between governmental authorities	Cities and regions Research entities Service providers
Infrastructure	Bicycle paths/ protected lanes Cycling and walking routes Connection with existing PT infrastructure	Full construction of two major bicycle paths in Athens. Bicycle paths designed to be connected to subway stations to allow for intermodal transport.	Cities and regions Civil society
	Cycle parking facilities and Docking stations	Sufficient parking facilities for bicycles. Sufficient availability of space and micro-mobility vehicles for rent/ sharing	Cities and regions Service providers Firms
	Charging infrastructure for e-bikes/ e-scooters	Enough charging points for electric micro-mobility	Cities and regions Technology providers Firms CPOs
Market	Acceptance of micro-mobility modes by users/ target groups	Viable business model Business and industry should be brought together	Service providers Civil society
	Deployment and Acceptance of Mobility-as-a-Service (MaaS) system	Proper development and deployment of a MaaS system Viable business model	Service providers Civil society

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Sustainability and environmental protection lie in the core of all transportation planning activities currently taking place in Athens. Indeed, the eagerness towards more sustainable forms of transport is clearly displayed by the measures proposed in the SUMPs developed by the municipalities of the greater Athens metropolitan area. In these strategic-level SUMPs, a multitude of soft-mobility measures are suggested including the reduction of speed limits, the pedestrianization of streets, the increased use of public transport and the increase in walking, cycling and use of scooters. Even though many of the SUMPs of the greater Athens area have reached a significant level of maturity, the process is still progressing for another few. After all, soft mobility measures and micro-mobility are also going to be examined within the Attica Strategic Transport Plan which is going to commence in 2023 and will be completed over the span of two years (2025). In the Attica Strategic Transport Plan, the most promising measures of all that have been proposed in the Athens' SUMPs will be investigated in an integrated manner to decide upon an achievable implementation plan.

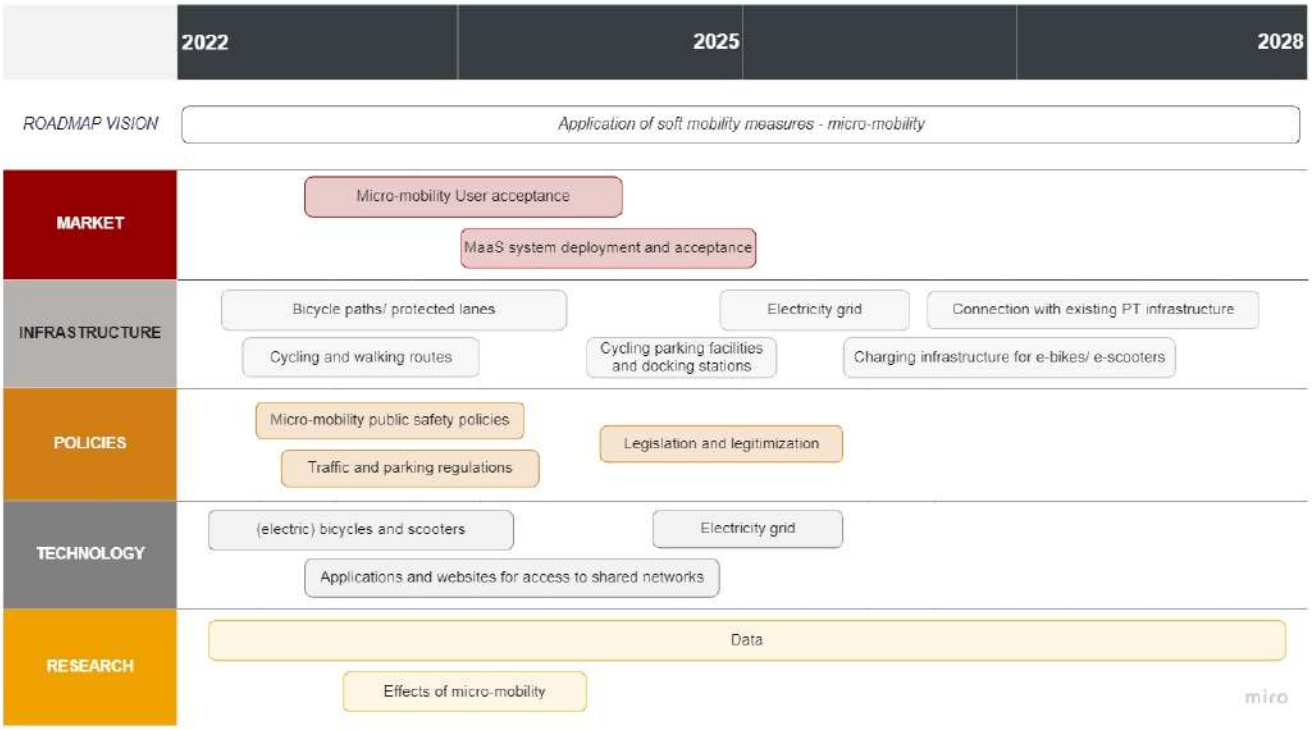

Figure 10 Roadmap micro-mobility in Athens.

3.9 Roadmap: New housing developments as part of the SUMP

Oxfordshire currently aims to create new housing developments, for which four strategic models will be applied. These strategic models take into consideration the transport needs of the selected areas and the transport needs of the newly created houses and the surrounding areas. The current timeline which has been passed, envisions the creation of 8,000 houses by 2025 and 33,263 houses in 2030. When applying the LUTI model to the 2030 plans, we can correctly find appropriate areas which can sustain such an increase in housing as well as the areas that will be more profitable to the people living there (demand and price predictions). This housing increase will also bring an increase in job accessibility. In general, the application of the model supports the timeline and the decisions for the SUMP roadmap for Oxfordshire. With the results from the model simulation, the following roadmap on new housing developments and mobility (also considering developments on demand responsive transportation) was built for Oxfordshire.

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Table 10 New housing developments as part of SUMP

Basic components	**Sub-components**	**Requirements**	**Stakeholders**
Research	Research on accessibility levels in terms of the new housing developments and the mobility network.	Data collection, output from housing forecasting modelling	Universities Research entities
	Impact indicators creation (average trip lengths from home to work associated with the new development, density, accessibility to the rest of the system, and access to utilities, retailing, schools, and health centres)	Increase data collection and resolution for monitoring and evaluation of the planning Research in transport models including forecasting DRT, shared mobility, and electric vehicles (EVs)	Universities Research entities
	Modelling of housing forecasting in terms of regional economic, demographic forecasting, land-use transport interaction and land development	Land Use Transport Interaction (LUTI) model Land development model for predicting land availability/suitability Population model Regional Economic Model (REM)	Universities Research entities
Technology	EVs manufacturing	Technical development in the deployment of EVs	OEMs Technology providers
	Shared mobility integration	Development and deployment of shared mobility	Service providers Technology providers
	Demand Responsive Transit (DRT) provision	Development of DRT for multimodal regional transport	Service providers Technology providers
Policies	Implementation of the Local Transport Plan (LTP) –Policy & Overall Strategy, Strategies for specific Transport Areas, Strategies for specific Transport Corridors (includes district level plan) Science Transit Strategy with focus	Legislation suitability for the Green Belt and Flood risk areas Sustainable Urban Mobility Plans (SUMP) for Oxfordshire	Cities and region Civil society

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	on new mobility services.		
Infrastructure	Increase active travel and public transport (OCC commitment)	LUTI's outcome on different mobility patterns	Cities and regions Infrastructure
	Mobility infrastructure (road infrastructure + parking) for the accessibility of people in the new housing developments considering	LUTI's outcome on different mobility patterns	Infrastructure Firms Service providers Cities and regions
	Connecting Oxfordshire and outer region, Rural area connectivity	Integration and access, Reliability of public transport, Creation of Bus Network Hierarchy, Phases of implementation, Quality Bus Partnership	Cities and regions Infrastructure
	Enhanced bus network connectivity	Development of rapid transit routes and services, Traffic management, Smart payment,	Cities and regions Infrastructure
Market	Collaboration between the transport providers for integration of the network	Transport providers with up-to-date data and models DRT companies up to date with the research and scenarios output	Cities and regions Service providers
	Alignment between the stakeholders for healthy urban development	Integration of the region's development plan with transport operators	Cities and regions Service providers

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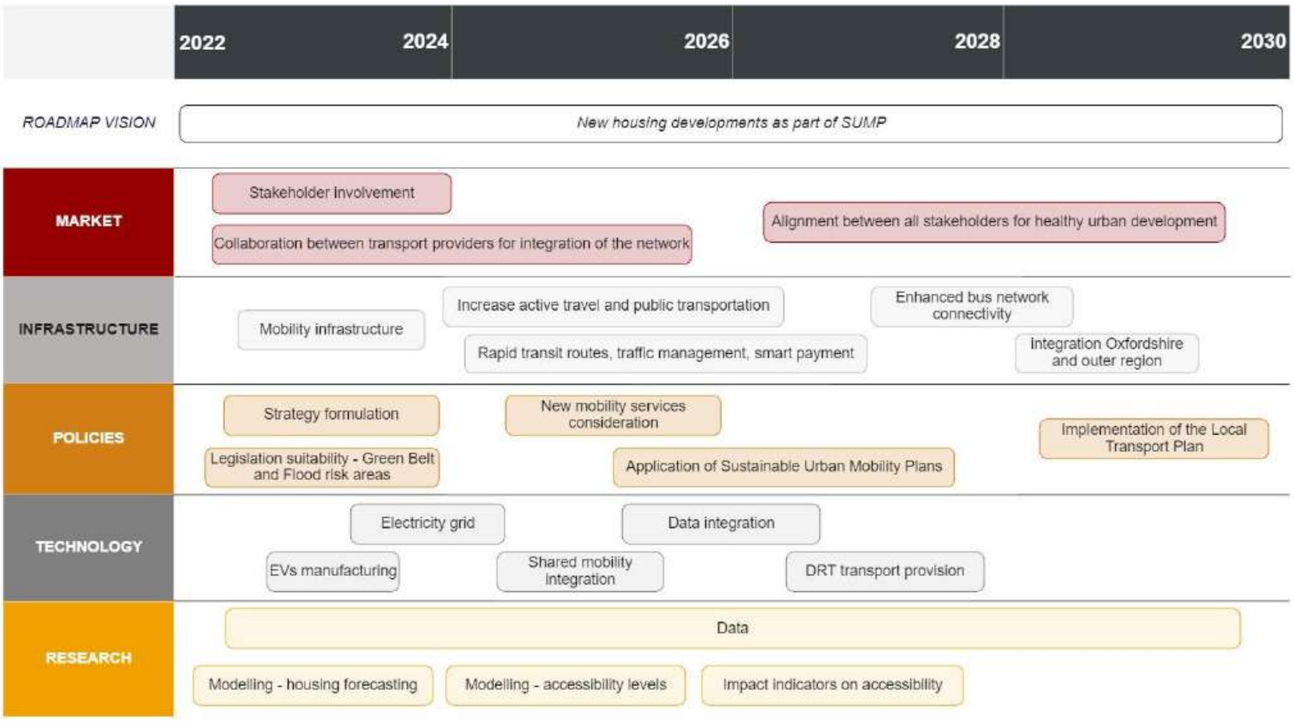

Figure 11 Roadmap new housing developments Oxfordshire

3.10 Roadmap: Urban vehicle regulation measures

This roadmap focuses on urban vehicle regulation measures, mainly based on the scenario developed for Turin municipality, with a timeframe up to 2030. All around the world, and particularly in Europe, several instances of urban vehicle regulation measures exist, with over 700 schemes with varying impacts (Schemes by Country (urbanaccessregulations.eu)). The Turin municipality pursues the goal of rebalancing the demand for transport between collective and individual modes, reducing congestion and improving accessibility to various urban functions. Pursuing this strategy implies an incisive mobility policy, pushing the collective transport use through large infrastructure implementation (such as the underground and the metropolitan railway service) and through new ITS technologies development, while, on one hand, improving the economy in the use of these services and, on the other hand, developing new sharing services. One of the use cases simulated for the Turin metropolitan area focuses on urban vehicles access regulation, implementing a combination of measures to support a modal shift from private cars as well as the diffusion of cleaner vehicles. The objectives are therefore related to road congestion reduction, mode shift and air pollutant and GHG emissions reduction. As reported in D2.5, the model results present a significant reduction in regular private car trips, a significant rise in the usage of LEVs, especially in the zones affected by the low emission zone and also a significant rise in the PT split. Regarding results on emissions, if only the LEZ area is considered, CO_2 emissions of cars decrease around 25%. It must be noted that the emissions from buses are increased as an increase of the service is required to face the rise of demand in terms of passenger-km.

Table 11 Urban vehicle regulation measures

Basic components	Sub-components	Requirements	Stakeholders
Research	Research on potential reduction in passenger-km by	Land Use-Transport Interaction (LUTI) Model Vehicle stock model	Research entities Universities

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	car and changes in future modal share Data on passengers-km by car, bus, and rail (where rail includes tram, metro, and train), change of traffic flows on the road network	(synthetic) Population model Regional economy model Land development model (LDM) Tactical agent-based passenger model Passenger network traffic assignment model	
	Road traffic flow by vehicle (car, buses) by network link including average speed and distance travelled.	Multi-modal land network model	Research entities Universities
	Impacts in terms of energy and emissions (energy consumption, CO2 emissions, air pollutant emissions (PM2.5, Ox, CO, NMVOC))	Energy and emission model	Research entities Universities
	Data: economic, land use, demographic, housing, topography and boundaries, building, planning policy, network, PT, passenger demand, energy, emission, noise, traffic control data	Access to various data sources	Research entities Universities Cities and regions
Technology	Alternatively fuelled cars	Development of alternative-fuelled vehicles and associated infrastructure	OEMs Cities and regions
Policies	Mobility management Land use developments Regulatory framework (parking etc)	Legislation as enabling condition Part of SUMP	Service providers Technology providers Cities and regions

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Infrastructure	Limited Traffic Zone Traffic calming areas Low emission zones	Improved walking and cycling network are also needed	Cities and regions Research entities Infrastructure Technology providers
	Charging infrastructure	Strategic deployment of charging infrastructure	Cities and regions Technology providers Firms
Market	Citizens' acceptance	Acceptance, both operationally and financially, of vehicles with sufficient charging infrastructure. Acceptance of reduction of spaces for cars to the benefit of pedestrians and bikes.	Civil society Service providers
	Acceptance of station-based or free-floating shared mobility services	Acceptance, both operationally and financially, of different shared mobility services Viable business models	Civil society Service providers

Physical investments are rather low as this scenario is mainly a matter of setting (and enforcing) different rules. However, as has been pointed out in D7.6 and D2.5, this use case stipulates land use developments and new public transport infrastructures in place at the year 2030. Specifically, Turin focuses on an extension of its urban and suburban PT network and its Metropolitan Railway System (SFM), by extending metro and tram lines and adding new SFM lines to increase network connectivity. The area of analysis is the Turin Urban Functional area, which includes the municipality of Turin and 87 municipalities within the province of Turin. Land use developments are also being planned for different areas.

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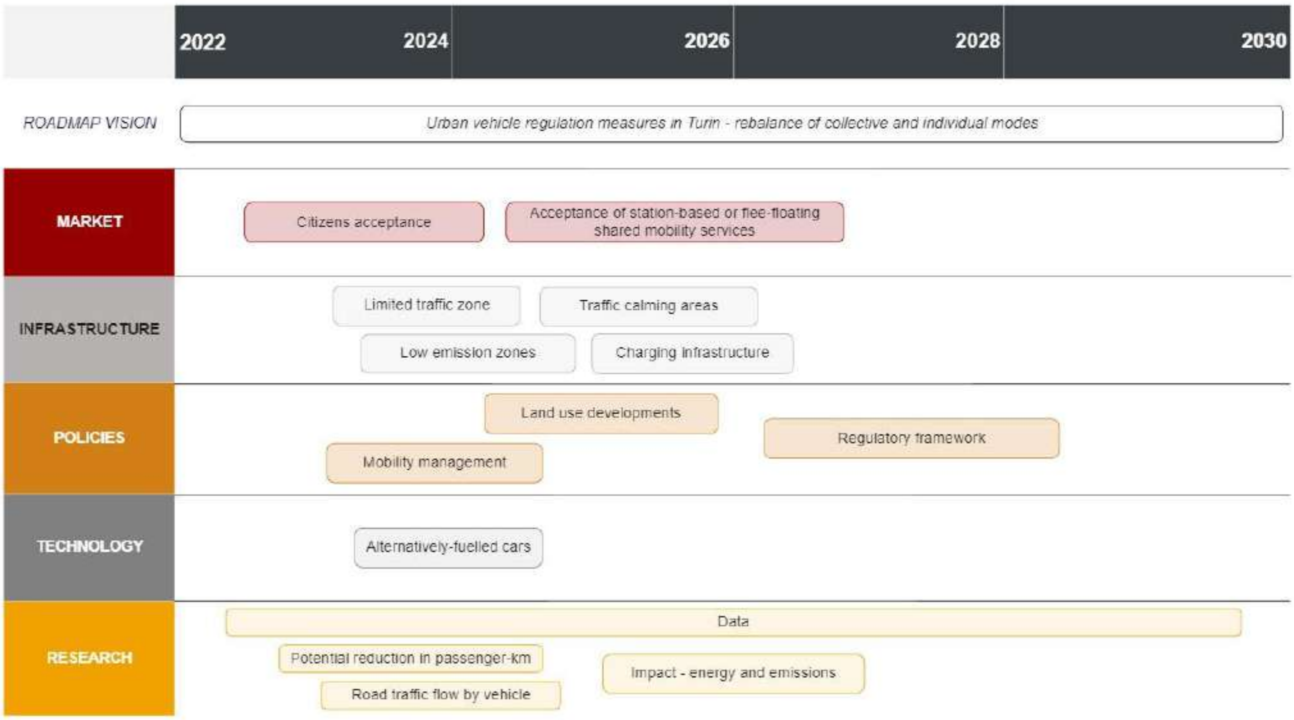

Figure 12 Roadmap urban vehicle regulation measures in Turin.

3.11 Roadmap: Towards lower carbon passenger mobility

In this section, a synthesized roadmap, focusing on a vision towards lower carbon mobility for passengers, is developed. The main input and direction given for this roadmap derives from the previous roadmaps on (passenger) mobility, as well as on other scenarios that have been considered and/ or modelled, in one way or another, during the project. These scenarios can be complementary to the above written roadmaps and the purpose of this synthesized roadmap is to provide an overview of different ‘solutions’ aiming at triggering also the development of combinations of scenarios, for better achievement of the vision towards a lower carbon mobility era. To present this in the most clear and efficient way, this roadmap is formulated as a ‘higher-level’ one, touching upon the most important and indicative sub-components and requirements. Other roadmaps developed in literature have also been considered to some extent for the formulation of this one (Schippl et al., 2016, van Galen et al., 2017).

Table 12 The Roadmap towards lower carbon passenger mobility

Basic components	**Sub-components**	**Requirements**	**Stakeholders**
Research	Green mobility (ridesharing, demand-responsive transit (DRT), active mobility and mass-transit systems)	Alternative transport planning models, to include different types of sustainable modes; set up of pilots and continuous data gathering and analysis	Research entities Universities
	Sustainable travel behaviour (less travelling, sustainable mode preference)	More explanatory demand models	Research entities Universities Civil society

	Smart technologies (low/ zero-emission vehicles, connected vehicles, electrification, intelligent traffic lights)	Real-time traffic management, and connected vehicles into an intelligent transportation system need to be extensively studied Real-time traffic simulation and prediction Advanced algorithms and analytics	Research entities Universities Technology providers Firms
	Integrated spatial and transport planning	Advanced modelling approaches, such as the HARMONY MS	Research entities Universities Cities and regions
Technology	Low/ Zero emission vehicles	Integration of new modes of transport and innovative vehicles Development of the required technologies, implementation, and use of sustainable and smart mobility modes such as cars, trucks, bikes, or drones.	Technology providers Service providers
	Active/ micro-mobility		
	Automated systems for smooth traffic flows	Enhanced traffic management; Advanced technologies for V2X communication	Technology providers Service providers
Policies	Electrification of the transport system	Need to conform to policies on low/ zero emissions vehicles usage	Cities and regions Service providers Infrastructure
	Remote services (working, education, public services)	Need to establish enabling conditions for reduction of the urge to travel	Civil Society Technology providers
	Strategies to reduce the use of private cars and actively promote PT, DRT, shared mobility.	Legislative changes and the right policies are important factors in the developments related to low carbon mobility. Frameworks and measures to enable the creation of a more sustainable mobility system are needed. Awareness is required for a collective shift towards more sustainable solutions.	Cities and regions
	Urban vehicle regulation measures	Monitoring and enforcement needed	Cities and regions Firms Technology providers Infrastructure
Infrastructure	Cycling and walking networks and schemes	Every city needs to have a walking and cycling network, to actively promote these forms of mobility	Cities and regions

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	Charging infrastructure for electric vehicles	Enough charging locations, re-design of parking areas.	Cities and regions Technology providers Firms CPOs
	Mobility hubs	Hubs to facilitate multimodal and more sustainable transportation	Cities and regions Technology providers Service providers
	ICT infrastructure	Communication between drivers, vehicles, and infrastructure, IoT, sensors, cameras, mobile devices to collect data.	Technology providers
Market	Public acceptance	Integrated system to provide 'door-to-door' service	Civil society Cities and regions
	Market for low carbon passenger vehicles (public and private)	Investments are needed for the market of low carbon vehicles to grow	OEMs Service providers
	Pricing strategies	Solid pricing strategies to influence behavioural change	Technology providers Firms Service providers Civil society Unions

For such a roadmap, it is essential to point out that available technologies are not always adequately attractive to gain mass public acceptance. Replacing conventional vehicles and fuels is important but not sufficient alone, as behavioural change needs to be achieved for larger scale positive impacts in terms of shifting to a low carbon mobility era. Technological solutions and policies should serve as enablers, while the necessary conditions in terms of infrastructure and market readiness need to be in place for a successful and smooth transition. The most promising solutions seem to be the ones that combine new technologies with new mobility solutions such as sharing. Another crucial element is collaboration and partnerships for change, also at the political level, to fully embody the transition to a new, low-carbon mobility era.

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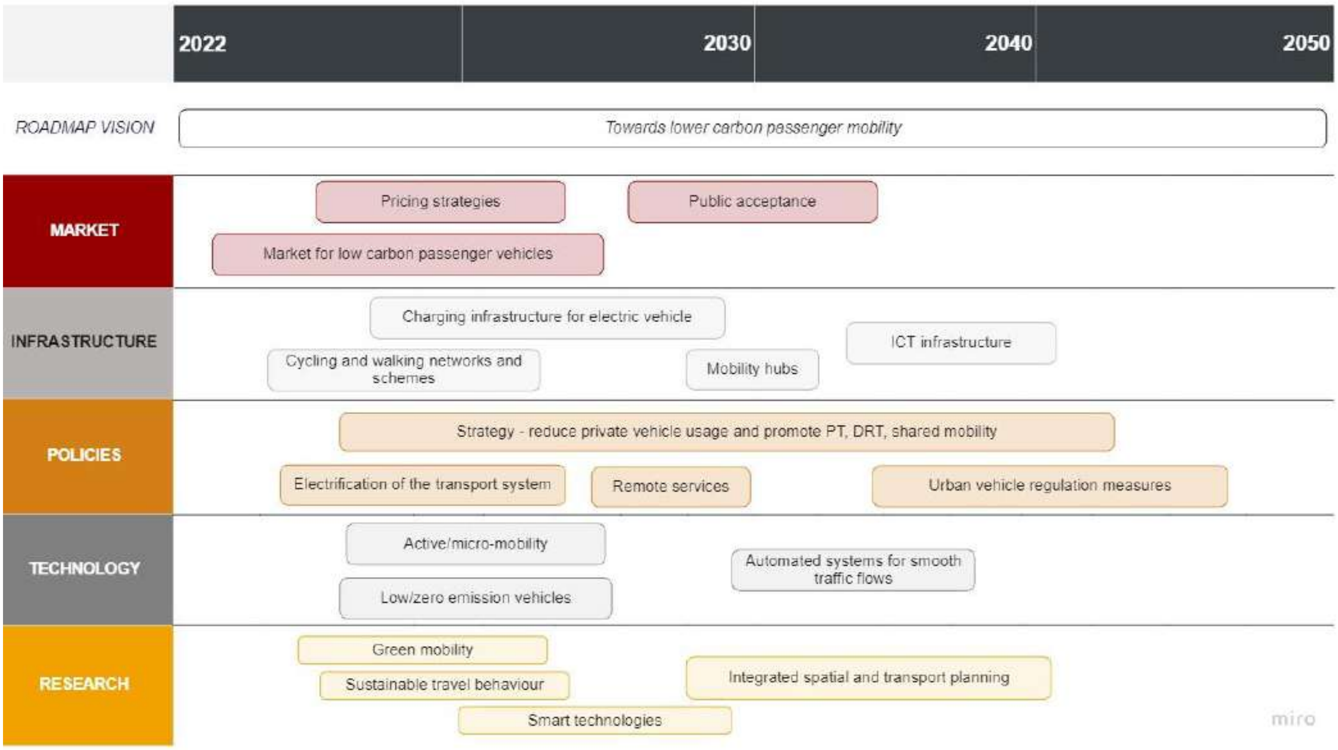

Figure 13 Roadmap towards a lower carbon mobility.

3.12 Roadmap: Towards low carbon city logistics

In this section, a synthesized roadmap, focusing on a vision towards low carbon city logistics, is developed. The main input and direction given for this roadmap derives from the first five roadmaps presented (3.1-3.5), as well as other scenarios that have been considered and/ or modelled, in one way or another, during the project. Furthermore, other roadmaps and literature are consulted. The City of Rotterdam, for instance, has a roadmap (City of Rotterdam, 2020). This synthesized roadmap is to provide an overview of different ‘solutions’ of the vision towards low carbon city logistics in 2030, as also announced by the European Commission (European Commission, 2011). Other visions such as Physical Internet focus on 2050, but the focus here is on the low carbon component. To present this in the most clear and efficient way, this roadmap is formulated as a ‘higher-level’ one, touching upon the most important and indicative sub-components and requirements.

As also elaborated in the roadmap on ZEZ city logistics, the transition evolves roughly around two possibilities: reducing the number of vehicles through different delivery models and a growth of ZE vehicles. Regarding the former, two aspects must be considered. First, the specific supply chain determines in which way the last mile can be organized differently. In light of this, there is often a lot of focus on retail and parcel deliveries, but other flows that should be addressed include temperature controlled, facility logistics, construction logistics and waste collection (Topsector Logistiek, 2017). The possibilities for low – and eventually zero – emission logistics for a heavy truck in construction logistics differ from parcel deliveries. Therefore, a tailored approach is required. Second, it is important to look beyond the entities that actually transport. Transport is an outcome of demand for goods and services, which generates transport. It is therefore key to include shippers and receivers (varying from supermarkets and construction sites to consumers), but also local authorities.

Table 13 The Roadmap towards low carbon city logistics

Components	Sub-components	Requirements	Stakeholders

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Research	Data on trips and vehicles, including segmentation	Continuously collect trip data in a database from companies, license plate scans and traffic models, which can be used as representative for different cities	Universities Technology providers Firms Cities and regions
	Impact assessment	Assessment of the effects of city logistics as well as the impact of other delivery models (including ZE vehicles) on costs and societal indicators	Universities Research entities
	Simulation	Simulating the effects of different delivery models	Universities Research entities Firms
	Feasibility	Feasibility studies on different delivery models	Universities Research entities Firms Service providers
	Behaviour and business models	Research on behavioural change in supply chains, and business models of other delivery models and ZE vehicles	Universities
Technology	New vehicle technologies: ZE vehicles, AVs, drones	Research on new vehicles technologies	Technology providers OEMs Cities and regions Service providers
	Digital platforms	For collaboration (e.g., crowd), data exchange and real time traffic information	Technology providers Infrastructure Cities and regions Service providers
Policies	Zero emission zone	Demarcation of the zone and types of vehicles that over time must become ZE, including campaign to involve stakeholders and harmonization between (national and local) governments – National government and municipalities	Cities and regions
	Spatial planning	Spatial planning policies should also integrate logistics inside and around cities (including space for charging infrastructure)	Cities and regions Research entities Infrastructure

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	Stakeholder involvement	Involve and inform local stakeholders that are affected by and can affect ZE city logistics to develop strategies in a periodic forum. This includes OEMs, transport companies, receivers (businesses and institutes), shippers, SME, construction companies, waste collection companies, energy companies, real estate owners,	Cities and regions OEMs Firms Civil society Service providers Infrastructure
	Coordination and harmonization	Across local authorities and the national government	Cities and regions
	Stimulating and restrictive policies on zero emission vehicles and hubs	Develop policies to stimulate frontrunners that implement alternative logistical models and ZE vehicles	Universities Cities and regions Service providers Infrastructure
	Monitoring and enforcement	Procure a (ANPR; automatic number plate recognition) camera system around the zone that can be used for monitoring and enforcement in a harmonized way in cities on a national level	Cities and regions Firms Technology providers Infrastructure
Infrastructure	Locations for hubs around the city/zone	Facilitate locations for transhipment	Firms Cities and regions Service providers CPOs
	Charging infrastructure for electric vehicles	Enough charging locations, re-design of parking areas.	Cities and regions Technology providers Firms CPOs
	ICT infrastructure	Communication between drivers, vehicles, and infrastructure, IoT, sensors, cameras, mobile devices to collect data.	Technology providers
	Spatial planning	Planning the growth of different vehicle types in relation to a changing urban context	Cities and regions Infrastructure Civil society
Market	Pricing	Acceptance of incorporating the true price	Technology providers Firms Service providers Civil society Unions

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	Acceptance ZE vehicles	Acceptance, both operationally and financially, of ZE vehicles with sufficient charging infrastructure	Service providers Civil society
	Acceptance of last mile services	Acceptance, financial benefits and added value for outsourcing last mile deliveries to companies that provide these from a UCC	Service providers Civil society

The requirements and potential of sound business models in the transition towards low carbon city logistics has been elaborated in 3.1.

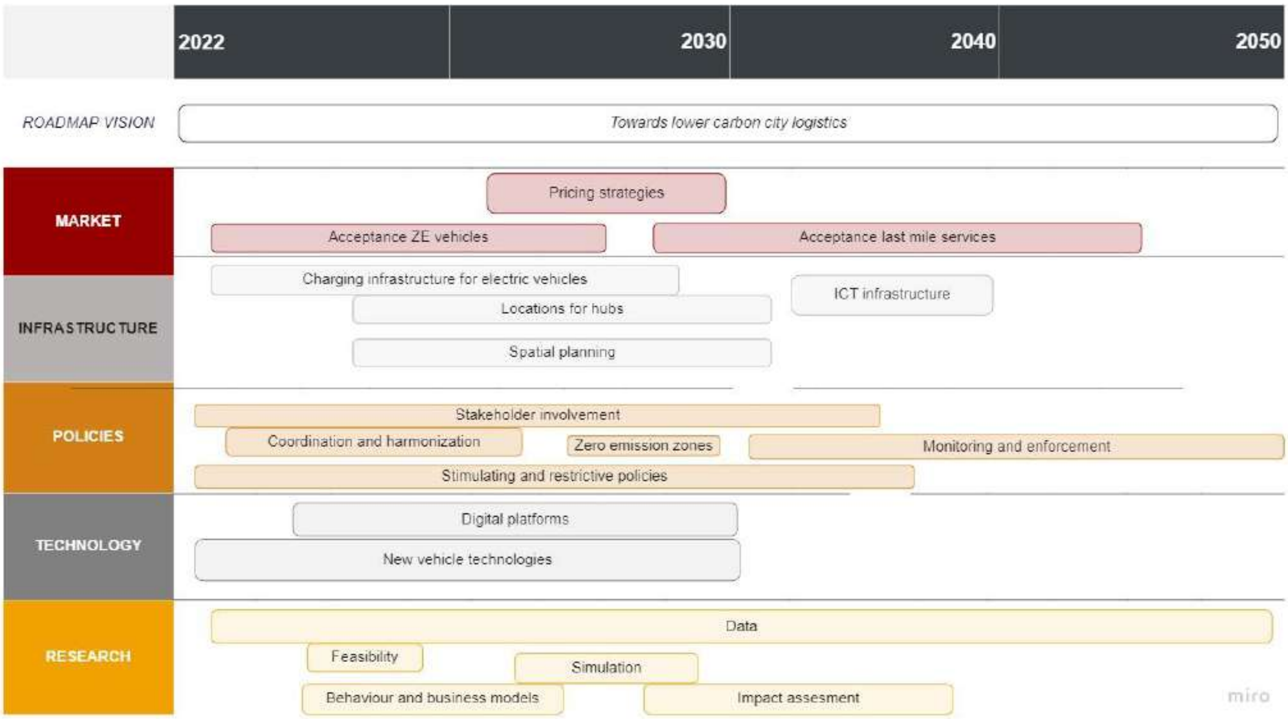

Figure 14 Roadmap towards a low carbon city logistics

4. Summary and discussion

D8.4 has attempted to bring the various HARMONY areas' efforts and activities to the maturity level of a roadmap, tailored to the degree possible to their needs and plans, stemming also from the different co-created scenarios developed. The steps towards building the separate roadmaps have been performed according to a final synthesis approach, which has been slightly adjusted compared to the proposal, so as to match the real outcomes of the project, while still contributing to the overall goal of supporting authorities in the transition to the new mobility services' era. It was essential that the roadmaps were prepared based on the outcomes of the modelling activities, as these have been performed and reported in deliverables from WP2 up to WP7, while valuable inputs have been received from WP9 and all the co-creation and stakeholder engagement activities, as well as the demonstrations. Due to strict timelines and hindering in some communication processes, the roadmaps were created only partially in collaboration with the rest of the task contributors, while they have been reviewed by most of the HARMONY areas. Eventually, 12 roadmaps have been developed, five of them focusing on city logistics, five of them focusing on passenger mobility ones and two of them synthesizing

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scenarios in two higher level roadmaps. Depending on the input, the roadmaps are more general or more tailored to a specific innovation or city.

Transition towards low carbon mobility and logistics necessitates the maturation of different technologies (supported by innovation policies (for R&D for instance)), but also local-scale spatial and traffic policies (such as adaptation of the infrastructure). Other important components throughout the roadmaps include built environment issues, the impact of different innovations, monitoring and building of business models and a different distribution of public spaces. An important aspect is to harmoniously integrate these developments into spatial and transport plans in order to improve the citizens' wellbeing and achieve environmental targets. Given the rapid technological advances and the emergence of new mobility services, metropolitan authorities are often in need of expertise, knowledge, and tools for multiscale spatial and transport planning. One of the biggest challenges faced is the establishment of business cases. For most of the use cases, developing a market with a robust customer base takes time, well-designed technologies, sufficient demand to support the service and more. All roadmaps are designed in such a way that the inter-relations between research, policies, infrastructure, and technology eventually contribute to an uptake by the market. This uptake applies on the one hand to user acceptance (and willingness to use and pay) and on the other hand to market parties that provide a service, technology, etc. It is noted that the developed roadmaps have a broader perspective, which results in the need of refinement for many of the elements included. For example, with respect to stakeholder collaborations, partnerships etc., more information is needed on how to reach such agreements on the local, regional, and national levels.

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HARMONY D2.5 Spatial and transport planning scenarios simulation results.

HARMONY D6.4 Applications of the freight tactical simulator and forecasting.

HARMONY D7.6 Applications of the operational simulator and forecasting.

HARMONY D9.1 The HARMONY area's orchestration, engagement plan and data collection guidelines.

HARMONY D9.2 Secondary data from the HARMONY areas.

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