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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

D8.3 Extended SUMP guidelines for metropolitan areas in the new mobility era

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SUMMARY SHEET

PROJECT

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AVs	Autonomous Vehicles
CAA	Civil Aviation Authority
CAV	Connected and Autonomous Vehicles
DRT	Demand Responsive Transport
EASA	European Union Aviation Security Agency
EC	European Commission
EU	European Union
EVs	Electric Vehicles
ICT	Information and Communication Technology
ITL	Intelligent Traffic Light
ITS	Intelligent Transport System
KPIs	Key Performance Indicators
LUTI	Land Use/Transport Interaction model
MS	Model Suite
PT	Public Transport
SMEs	Small and Medium Enterprises
SSMS	Smart and Sustainable Mobility Strategy
SUMP	Sustainable Urban Mobility Plan
TFS	Tactical Freight Simulator
TRUST	TRansport eUropean Simulation Tool
TEN-T	Trans-European Transport Network
SUMP	Sustainable Urban Mobility Plan
UAM	Urban Air Mobility
UAS	Unmanned Aircraft Systems (civil drones)

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UAV	Unmanned Aerial Vehicles
UTM	Unmanned Traffic Management
UVAR	Urban Vehicle Access Regulation
VTOL	Vertical Take-Off and Landing
ZECL	Zero-Emission City Logistics

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EXECUTIVE SUMMARY

In a context of decarbonisation, climate neutrality and digitalisation, new mobility services and technologies are changing the transport ecosystem faster than ever before. They are shaping the future of mobility and related planning processes. At the same time, they also bring unprecedented opportunities and challenges to actors across both the public and private sectors.

The vision of the HARMONY project (www.harmony-h2020.eu) was to enable metropolitan area authorities to lead a sustainable transition to a low-carbon new mobility era. In doing so, the project's spatial and multimodal transport planning tools contributed to support cities in framing the Sustainable Urban Mobility Plans (SUMPs) of the future.

This deliverable is the output of HARMONY's Work Package 8, which focuses on process assessment, SUMPs recommendations and roadmaps. These "Extended SUMP guidelines for metropolitan areas in the new mobility era" build on two tasks:

One the one hand, they use the lessons learned from the HARMONY demonstrations and deliver policy **recommendations to enable the urban air mobility (UAM) and autonomous vehicles (AVs) market in the EU (Task 8.3)**, as well as their seamless integration into the transport system. The disruptive nature of AVs and drones requests an orchestrated transition, with careful adaptations, tailored regulations, policy interventions and practical guidelines to not sacrifice security, safety, data, protection, and social inclusion during the transition process. For example, the integration of AVs into the transport system of a metropolitan area is dependent on a series of technical and regulation measures that involve local, regional and national authorities.

On the other hand, this document derives useful information from HARMONY's experience for the **new generation of SUMPs in the context of mobility transition and take-up of new services for passengers and freight in metropolitan areas (Task 8.4).** Policy recommendations on SUMPs are complemented by another HARMONY deliverable, namely the HARMONY **Guidelines on Modelling Tools for Sustainable Urban Mobility Plans in the new mobility era**, reported in the Annex. The latter provide local planning authorities with guidance on transport modelling applications in their SUMP implementation process. They build on the project achievements related to the development of the Harmony Model Suite and its application to case studies in Rotterdam, Oxfordshire, Turin and Athens.

Following an introduction on new mobility technologies and services for passengers and freight, the document presents challenges linked to SUMPs and presents the HARMONY impact on mobility planning in the 6 demonstration cities and metropolitan areas of HARMONY (Athens, Trikala, Turin, Upper Silesian-Zaglebie Metropolis GZM, Rotterdam and Oxfordshire). The document continues with the presentation of some elements based on key lessons learned from the HARMONY demonstrations, with a focus on UAM and AVs. The document concludes with policy recommendations for the new mobility era.

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1. Introduction

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 citizens' wellbeing and achieve environmental targets. Given 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.

Against this background, **HARMONY's vision was to enable different city or regional authorities to lead a sustainable transition towards a low-carbon new mobility era**. This has been guided by the project's harmonised spatial and multimodal transport planning tools, which comprehensively modelled the behavioural and operational dynamics of the changing transport sector as well as metropolitan areas' spatial organisation.

HARMONY set ambitious targets for the co-creation of metropolitan scenarios, informing updated spatial and transport planning tools and establishing comparisons across **six different geographic areas: Rotterdam (NL), Oxfordshire (UK), Turin (IT), Athens (GR), Trikala (GR) and Upper Silesian-Zaglebie Metropolis GZM (PL)**.

The **HARMONY planning tool is called HARMONY Model Suite (MS)** and it consists of strategic, tactical and operational models allowing for multi-scale spatial and transport planning. This integrated approach is necessary for authorities to understand if policies are sustainable, while also contribute to meeting COP22 targets, social welfare, quality and wellbeing. The MS has been linked to six above-mentioned EU metropolitan areas assisting research: **drones, on-demand autonomous and electric mobility** are some of the concepts that have been investigated in the HARMONY MS simulation environment by utilising and adjusting accordingly regional and urban models.

The content of this deliverable is based on the scope of **HARMONY'S Work Package 8**, which focuses on translating the results of the HARMONY integrated spatial and transport planning MS into recommendations for updating spatial and transport strategies and the SUMP framework, and developing roadmaps for transition to new mobility services.

More specifically, the scope and objectives of this deliverable are two-fold: on the one hand, it includes policy recommendations originated by the HARMONY demonstrations (**Task 8.3, Policy recommendations for new mobility technologies**), while it also extends the SUMP guidelines based on the HARMONY experience (**Task 8.4, Recommendations for a new generation of SUMPs and long term regional planning process**).

Policy recommendations on SUMPs are complemented by the **HARMONY Guidelines on "Modelling tools for Sustainable Urban Mobility Plans in the new mobility era"**, reported in the Annex. The scoping process for some new guidelines for SUMPs generated by HARMONY led to modelling tools, acknowledging that SUMP guidelines about metropolitan areas, UAM and AVs were already existing, as part of the SUMP 2.0 materials[1].

1.1 Objectives of the deliverable

This document used the lessons learned from the HARMONY project to deliver:

- **Policy recommendations for new mobility technologies and mobility services**, helping to enable the AVs and UAM market in the EU;
- **Policy recommendations on innovative sustainable urban mobility planning**, in the form of guidelines on Modelling Tools for Sustainable Urban Mobility Plans in the new mobility era.

[1] https://www.eltis.org/mobility-plans/sump-guidelines

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Recent developments in transport modes and mobility services are yet to be implemented or fully integrated into the transport policy arena – therefore, there is a need for specific policy recommendations and support. The HARMONY policy recommendations are aimed at decision-makers of metropolitan areas across Europe to enable them to lead a sustainable transition to a low carbon mobility era.

The disruptive nature of AVs and drones requires an orchestrated transition, with careful adaptations, tailored regulations, policy interventions and practical guidelines to safeguard security, safety, data protection, and social inclusion during the transition process. For example, the integration of AVs into the transport system of a metropolitan area is dependent on a series of technical and regulation measures that involve both local and regional/national authorities. In the case of drones, additional measures that include another set of considerations, guidelines, and control instruments (specifically a flight control system) are necessary.

HARMONY attempts to support and accelerate this process by presenting policy recommendations for seamless integration of AVs, drones or other innovative mobility services into the transport system while pointing out potential effects of this integration.

The effects of these new forms of mobility are being evaluated together with existing transport modes in the transport system to assess additive effects and identify opportunities and threats of the co-existence of traditional, innovative, and new forms of mobility.

This document also derives information for the preparation of SUMPs in the context of mobility transition and take-up of new services for passengers and freight in metropolitan areas. While much EU guidance already exists on SUMPs, this document intends to extend the SUMP guidelines to deal with the new mobility concepts for both passenger and freight.

It considers the multidimensional approach needed to steer the transport mobility innovation to the benefit of citizens. It also provides city and metropolitan area authorities the recommendations for driving the transition in the direction of sustainable mobility according to a path where the cities are not only passive subjects of market-driven development, but drivers of a new mobility era.

SUMP recommendations are complemented by the HARMONY Guidelines on Modelling Tools for Sustainable Urban Mobility Plans in the New Mobility Era (see Annex).

1.2 New mobility technologies and services for passengers and freight

New mobility technologies and services such as autonomous vehicles and urban air mobility systems are about to change our ways of moving, sharing and using the traffic infrastructure. They can help to address a series of transport-related problems such as pollution, congestion, unpleasant travel experiences, as well as first- and last-mile in-connectivity. However, authorities face several challenges when it comes to harmoniously integrating these developments into spatial and transport plans.

Whilst the spectrum of businesses in new mobility is growing rapidly, the pace of change indicates that it is now more important than ever for sector players, especially cities, to stay ahead of the game. To do so, cities need to understand the key factors which influence the adoption and enable the deployment of the new mobility technologies and services.

Technological innovation for passenger and freight transport has particular potential to provide solutions for a more efficient use of the various modes of transport, the reduction of dependency on fossil fuels, the adaptation of transport systems in preparation for demographic change, and the further tightening of road safety with assistance systems to provide technical information. Progressively people and goods will have better accessibility in areas that were underserved. Technological innovation also helps countries, regions and cities to maintain their position as an attractive and competitive location for business and investment in terms of their transport system.

However, technological advances have resulted in a volatile state of transport where supply and demand are constantly transitioning. The policy impacts, individually and in combination, of new mobility solutions, which are at different levels of maturity, are not clear yet. Innovative disruptive schemes for

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passengers (mobility as a service, ride-hailing, carpooling, car clubs, etc.), sustainable last-mile logistics offerings (e-vehicles, crowdsourcing, physical internet for logistics, etc.), and the advent of connected and autonomous vehicles constitute a powerful, but untested mix of transport supply.

In addition, policies for low or zero emission zones are starting to become part of cities' urban mobility and logistics plans, and the recent pandemic has impacted working and consuming habits, whose long-standing effects are still unknown.

As a result of the above, decision-makers require tools which will allow them to effectively prognose short- and medium-term states of transport supply and demand, and assess the impact of different policies and strategies in better managing such states. Transport modelling and simulation approaches and tools can support decision-makers in planning sustainable transport systems by considering different eventualities and anticipate transport impacts. At the same time, integrated and data-driven technologies can facilitate the rapid adoption and deployment of sustainable transport systems and innovative mobility services.

There are many open questions about how policy makers should react and how Sustainable Urban Mobility Plans (SUMPs) and other sectorial policies that affect urban mobility should respond and adapt to these developments. Therefore, research is necessary to improve the understanding of the impacts of new urban mobility solutions on policy making.

1.3 The challenges for Sustainable Urban Mobility Plans (SUMPs)

Innovative sustainable urban mobility planning uses new technologies to provide answers to various mobility challenges, expanding the possibilities of the urban population (i.e., the set of mobility options), and serving higher level societal goals. Urban mobility planning mainly serves societal goals such as sustainability, social inclusion, or quality of life.

At the same time, urban mobility planning usually represents a core element of innovation strategies and aims to attract talents and businesses to ensure economic growth, as well as increase the quality of life of the citizens. This is particularly true for large cities, metropolitan areas, and regions.

New mobility services such as drones or autonomous vehicles are becoming key elements of urban mobility. They also determine the formation of urban innovation strategies. Cities typically ask themselves: how innovative do we want to be as a city (in general), and how can new services like urban air or autonomous mobility and their enabling technologies contribute to our urban innovation strategy?

The acceleration of technology evolution is changing urban mobility at a much faster pace than we have seen in previous decades. While new mobility solutions and technologies hold great promise for moving towards a more sustainable and resilient mobility system, they also raise concerns such as the induction of new trips, the switch from public transport to less sustainable modes, and the exclusion of vulnerable groups.

Planners and decision-makers need to understand these changes and evaluate the impact of different policies under a range of possible alternative futures, if they want to be prepared and avoid situations without public acceptance. This will enable them to make informed decisions, to prepare for them and to influence them where possible.

However, to date most Sustainable Urban Mobility Plans and other policy instruments still lack a clear and integrated vision of how to harness the potential of new emerging services and technologies. Most existing research tends to highlight isolated positive findings, often overlooking the complex links between behavioural changes and new transport options.

Policy-makers should further consider emerging mobility solutions in urban mobility planning processes, and this document provides clues on how to make it happen.

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1.4 Structure of the deliverable

Policy recommendations for new technologies and mobility services are the main outputs of Task 8.3 and the core part of this deliverable. The HARMONY Guidelines on “Modelling Tools for Sustainable Urban Mobility Plans in the New Mobility Era”, which is a separate document edited for broad dissemination and reported here in Annex, are the main outputs of Task 8.4.

This document is organised in 4 Chapters and 1 Annex. After this introduction, the document is structured as follows:

- **Chapter 2** screens through transport policies and the integration of new mobility technologies and services in SUMPs. In doing so, it examines HARMONY’s impact on mobility planning in each of the six metropolitan areas, where demonstration activities have been carried out: Athens, Trikala, Turin, Upper Silesian-Zaglebie Metropolis (GZM), Rotterdam and Oxfordshire.
- **Chapter 3** then outlines key learnings from the HARMONY demos. The reported work emphasises the importance of integrating new mobility services and technologies into the sustainable urban mobility planning process, with a focus on drones and autonomous vehicles.
- Finally, **chapter 4** summarises the key findings and proposes policy recommendations for the new mobility era.
- The **Annex** includes Guidelines on Modelling tools for Sustainable Urban Mobility Plans in the new mobility era, which complement this document.

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2. Transport policies and the integration of the new mobility technologies and services in SUMPs

All HARMONY metropolitan areas developed co-creation labs, varying in objectives and scope, depending on the area. Alongside modelling use cases, physical pilots with demonstrations took place in Trikala, Rotterdam and Oxfordshire. HARMONY co-creation labs in the above-mentioned areas as well as in Turin, Athens and Katowice focused on stakeholder engagement activities necessary to fulfil their identified scope of activities. The orchestration approach of the co-creation labs has been described in HARMONY deliverables D9.1[2] and D9.4[3].

In this chapter, the objectives and scope of each co-creation lab have been presented along with the description of the transport policies in effect and performed physical demonstrations. ***The aim of this chapter is, in other words, to analyse the current state of transport policies in the six case-study areas, to evaluate HARMONY's impact on mobility planning compared to the starting point that was described at the beginning of the project in deliverable D1.1[4], through the results obtained from the use of the HARMONY MS, surveys, and demos achievements with respect to the integration of the new mobility technologies and services in SUMPs***.

2.1 Athens

2.1.1 Context and background

Attica is an administrative region of Greece, that encompasses the entire metropolitan area of Athens. Located on the eastern edge of Central Greece, Attica covers about 3,808 km^2. The Athens metropolitan area consists of more than 60 municipalities and is inhabited by 3,792,469 people (2021 Census Data), with the municipality of Athens being the most dense and compact of all. It is a metropolitan area with a dynamic services sector and one of the major exporting gates of Greece. Apart from being the capital city of Greece, Athens is also the centre of political, social and business activities in the country as well as a world-wide known tourist destination. In addition, the port of Piraeus, located in the south-west end of the broader city area, is the largest passenger port in Europe and the second largest in the world.

With respect to its transport and urban development, growth in the Attica region during the 2000-2009 period can be partly attributed to significant infrastructure investments made for the 2004 Olympic Games, the influx of the Structural Funds, but also to indigenous growth based mainly on consumption and at a lesser extent on investments triggered by low interest rates after entering the Eurozone. In this period, transport services were greatly improved with the development of the metro and tram networks and the suburban railway, the development of Attiki Odos (the major peri-urban highway) and the construction of the new Athens international airport.

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[2] *D9.1 – "The HARMONY area's orchestration, engagement plan and data collection guidelines"*, 2021, Nesterova N., Rooijen, T. van (TNO)
[3] *D9.4 – "HARMONY areas engagement activities – Second version"*, 2022, Charoniti, E., Rooijen, T. van (TNO)
[4] *D1.1 – "Review of new forms of mobility, freight distribution and their business models; gaps identification in KPIs and SUMPs"*, 2021, Angelo Martino, Francesca Fermi, Stefano Borgato, Simone Bosetti (TRT); Ioanna Pagoni, Ioannis Tsouros, Amalia Polydoropoulou (UAEGEAN)

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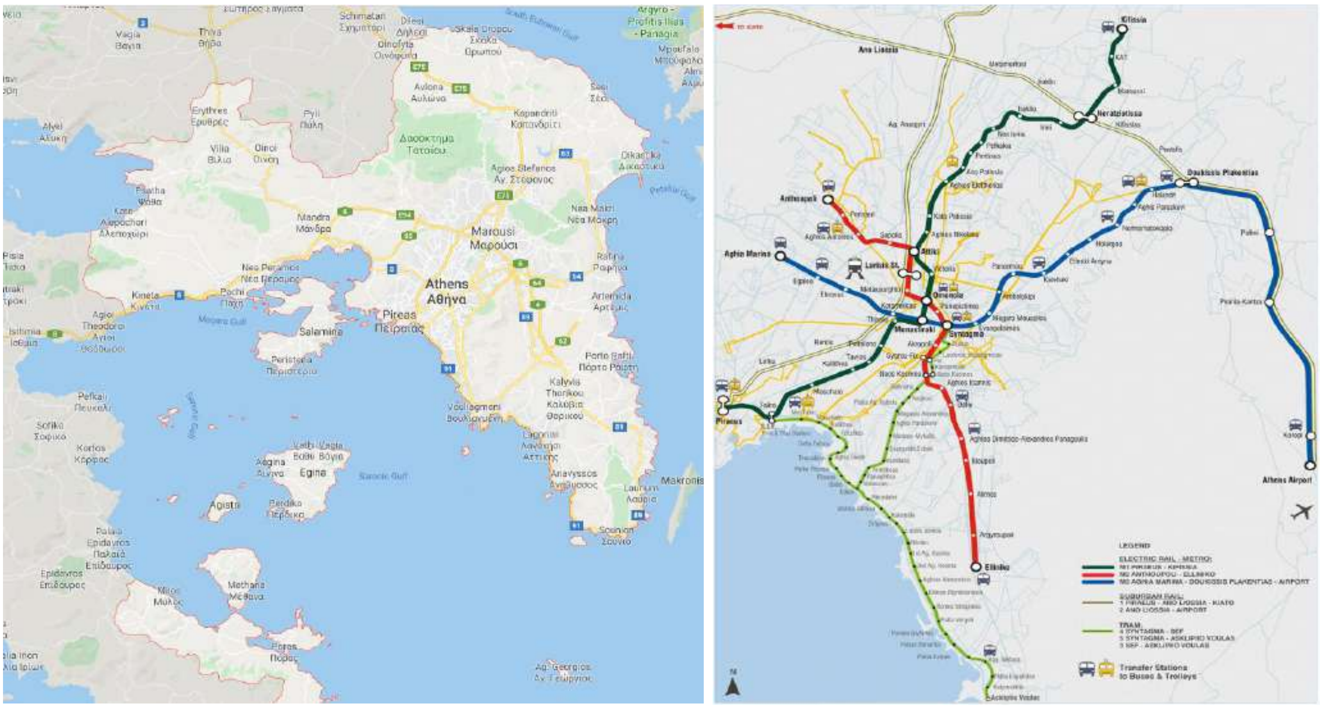

Figure 1: Attica Region and the Athens Public Transport network

Athens public transport system provides easy access to all major points of interest. Backbone of the Athens transport system - operated by Athens Public Transport Organization (OASA) - is the Athens metro; it has three lines and provides direct connection of the city centre to the city's entry points, like the Athens airport, the port of Piraeus and the Athens railway station, and the urban suburbs.

With respect to Athens' modal split, the motorized transport (cars and motor vehicles) percent stands at 53%, public transport at 37%, walking at 8%, and cycling at ~2%. Every day more than a million passengers travel and 2.5 million boardings are made using public transport. Indicatively, during 2021, the OASA Group recorded 287,23 million boardings and executed 139,47 million vehicle kilometres.

In this respect, the company's biggest competitor appears to come from the use of private cars; this use, however, at least in the pre-covid era, seemed to have decreased over the years, possibly due to the economic crisis that Greece faced. Indeed, the economic recession of the 2009-2019 considerably affected the transport sector, with a 31% decrease in passenger volumes and 21% decrease in PT mileage. Speeds were reduced in all means and public transport daily trips were also limited.

On top of the decade-long crisis, years 2020-2022 were characterized by the outbreak of the Covid-19 pandemic and the imposed social-distancing restrictions on travel and homeworking. In this light, in August 2020, the Greek Government adopted the "Emergency measures for the enhancement of public transport systems", aiming to improve the operation of the public transport systems in all cities. The act limited passenger capacity, increased the public transport systems frequency and services, contracting with transport operators, leasing of buses and hiring of new personnel.

Other types of mobility (e.g., bicycles, scooters, walking) are currently promoted as a viable alternative in the capital through the Sustainable Urban Mobility Plans (SUMPs) of Athens' municipalities. The integration of new mobility services with the traditional modes of transport such as the PT system will possibly come in the form of a MaaS system, that is likely to be developed in the near future, given the maturity of the discussions conducted between the involved stakeholders.

With private cars being the primary form of transport, Athens faces urban challenges such as traffic congestion, safety, air pollution and public health. Illegal parking and other public space violations are also common in the city centre. As a result, the Athens metropolitan area is aiming to adopt a holistic

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transportation plan focused on sustainability and environmental protection along with the integration of both private and public transportation networks and alternative mobility forms.

Finally, as far as the development and implementation of SUMPs in the greater Athens metropolitan area and its municipalities, **in 2018, actions towards the formation of SUMPs were initiated by about half of the municipalities in Attica**. Actions included in the SUMPs demand numerous transformations regarding PT management, the extension of cycling networks, the systematic upgrade of public spaces and the establishment of integrated pedestrian networks. In addition, the SUMPs aim to support the necessary shift in the stakeholders' planning mentality and priority setting.

2.1.2 HARMONY impact on mobility planning

Within the framework of the HARMONY project, **Athens conducted transport simulations, through the development of city-specific models at the strategic and operational levels**. These models take into account the city's characteristics, its needs, worldwide transportation and environmental trends as well as transport and land-use plans, currently under implementation or to be implemented over a short- or mid-term horizon.

As such, with respect to strategic-level simulations, OASA developed four models for Athens. The first one, the Athens LUTI model is an origin-constrained model, containing a journey to work sub-model. This model considers workplaces as origins and homes as destinations. The model is built for the whole Attica region, but the changes refer to only four zones. The model considers the Elliniko investment, one of the greatest land-use changes that have ever been undertaken in the city of Athens. Two scenarios were developed to assess the impact of the investment (Elliniko scenario 2030 and 2045), along with an additional base case scenario.

On the operational level, OASA investigated different scenarios that could have implications on the city's day-to-day PT operation. Three case studies have been examined in this regard:

- the electrification of PT: investigating the transition from conventional fuel buses to electric ones (based on Athens current initiative expected to be fully realized over the next years).
- the electrification of PT with micro-mobility interventions: the previous scenario is enriched with the addition of micro-mobility schemes on the network. Current urban plans devise the implementation of two major cycle paths in the city. Smaller micro-mobility interventions at the municipal level have also been proposed as part of the already adopted SUMPs.
- the operation of autonomous vehicles (AVs): examining the effect of different AV penetration rates on the network through the adjustment of the model's Volume - Delay Functions (VDFs). Although not a scenario that is expected to be realized soon in Athens (at least when considering significant penetration rates), this hypothesis is interesting as an indication of the future operation of the transport system.

From the models developed for the city of Athens and the individual case studies examined, it can be concluded that these largely relate to the scope and objectives of the SUMPs developed by each municipality of the metropolitan area. The HARMONY MS, being an all-encompassing transportation and urban planning platform and considering it covers all levels of planning (strategic, operational, tactical), can contribute to reach the SUMPs goals, with the already developed models. As such, the strategic-level models developed for Athens, and especially the Athens LUTI model, can be particularly useful in cases such as the Elliniko – Argyroupoli municipality and its SUMP, considering the huge financial investment that is currently undertaken in the specific area. The same is also valid on an operational basis. In both cases (strategic and operational planning level), **measures proposed by the municipalities' SUMPs can be modelled and tested with the HARMONY MS** to check their efficiency and efficacy on network operation, while, conversely, other actions, not currently included in the SUMPs, can possibly be tested against them. This modelling experience can **provide relevant insights** and, eventually, **result in an update of the respective SUMPs in a data-driven manner**.

Finally, in the vision of achieving a more sustainable and human-centred urban development, transportation planning can be facilitated, applied, and tested through the HARMONY MS. Different

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scenarios and mobility solutions can be performed and examined before their actual implementation. Similarly, the optimization of parameters and the integration of analytical tools can also be tested and assessed, all of which will eventually result in cost and labour savings as well as in a functionally optimal transportation system that supports and satisfies the city's needs.

2.1.3 Demonstration activities and achievements

No demonstrations with innovative mobility services or technologies were planned within the HARMONY project in the Athens metropolitan area. Instead, co-creation labs were organized and held during the whole duration of the project.

The main objective of the **co-creation lab** was to apply the HARMONY spatial and multimodal transport planning tool to model new mobility services, measures and policies as well as to evaluate and quantify their impacts in the Athens area, aiming at a sustainable and energy-efficient PT system. In the context of the co-creation labs, several local stakeholders and citizens were involved.

During the workshops, the Strategic and Tactical simulators of the HARMONY MS were applied on the updated Athens transportation model, and the co-created scenarios were tested in order to quantify their impact. Several workshops were organized to discuss the results and recommendations that could contribute to update the short-, medium-, and long-term spatial and transport planning strategy.

The main expected results from the co-creation lab were:

- to understand the stakeholders' problems, needs and points of view on different transport-related issues;
- to allow stakeholders to express their proposals and preferences with respect to these issues;
- to possibly implement some of the stakeholders' proposals in the scenarios examined as part of the project.

The **first Athens co-creation lab** took place online in **May-June 2020**. With UCL CASA and UAegean, it discussed the use cases and the influence of various mobility parameters on the land-use patterns. In particular, four modelling use cases were elaborated on: 1) the electrification of PT, 2) the operation of autonomous bus fleets, 3) the operation of Demand Responsive Transport (DRT), and 4) the application of micromobility schemes. In addition, the existing transport model (VISUM) was integrated in the HARMONY MS, with the support and collaboration from Aimsun.

The general objectives of the first co-creation lab were to provide the inputs for the strategic, tactical and operational-level transportation planning of the greater Attica region, and to assess the impact of various sustainable urban mobility solutions and services on the Athens metropolitan network. However, since the transportation services proposed in the questionnaires were innovative and had never been applied to Athens before, the most relevant goal was to collect stakeholders' insights on these services, as well as their challenges, needs and preferences.

The **second co-creation lab** was organized by OASA and took place in **October 2022**, during which **questionnaires** have been handed out and other stakeholders' engagement activities were carried out during the event.

2.2 Trikala

2.2.1 Context and background

Trikala is a medium-sized provincial city and the capital of the Thessaly region in the middle of Greece. It hosts a population of approximately 81,000 inhabitants (130,000 including the suburbs and nearby villages). The municipality of Trikala was formed in 2011 with the local government reform, which merged 8 former municipalities into municipal units.

The city hosts around 85,000 people commuting per day. The usage of private cars remains the most predominant means of transport, along with a high percentage of car ownership (approx. every

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household owns a car). The modal split pattern is, therefore, characterized by car dominance in a central area of the city, with 32,78% of people moving by car, 28,87% by scooters (2 wheels), 26,06% by foot, 10,33% by bike, and 1,96% by public transport (Trikala's SUMP, 2020). The low usage of buses highlights that PT is not attractive for the citizens of Trikala for daily trips within the city. The peak hours concerning mobility is in the early morning hours and around noon.

The private company Urban KTEL of Trikala S.A. provides a network of 26 bus lines operating on different lines across the city, of which 15 bus lines operate in the city and its centre, while 11 bus lines connect with the surrounding cities or villages. The citizens prefer to walk, cycle or drive, rather than use the PT, when it comes to distances less than 1.5 km. Moreover, the ticket's cost is comparable to the taxi fares, thus the people prefer to move by the latter, with the majority of the citizens using PT for travel distances larger than 2 km, in order to move from the suburban areas, i.e., the surrounding villages, to the city of Trikala and vice versa. It should be noted that some of the rural and peri-urban areas of Trikala are underserved.

Traffic congestion is considered one of the main problems in the city centre. The city's topography and morphological characteristics (i.e., the river and its bridges), the mixed land uses as well as the high rates of car ownership, conjointly with the citizens' preference to use private cars even when it is not necessary, cause severe traffic in the city centre. The high use rate of private cars, along with the unregulated car parking and the lack of exclusive bus lanes, cause serious traffic congestion problems, especially during peak hours, as well as many delays in the scheduled bus routes. The current location of the central bus station in the heart of the city centre seems to have a significant impact on the problem, particularly during the days when the local open-air market takes place in the same area, occupying central streets.

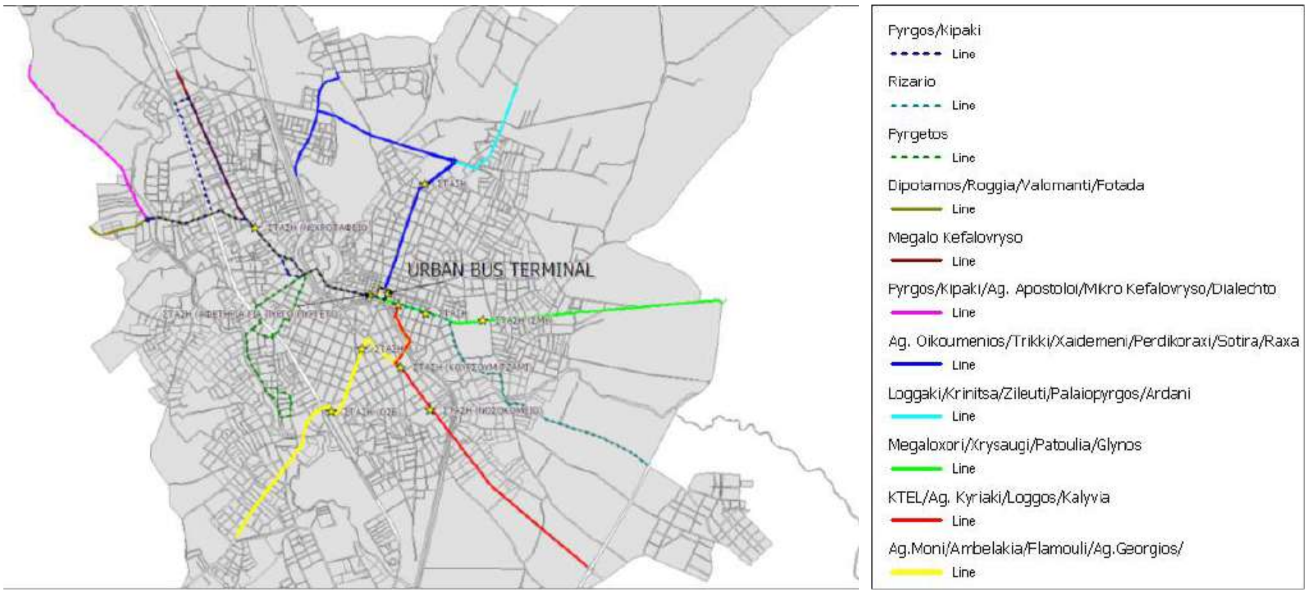

Figure 2. Urban transport network integrated with main bus stops per direction

At the local level, Trikala represents a best practice in the country, being the first **Smart City** in Greece in 2004. Since then, city authorities and their partners have a strategic orientation towards the future, using information and communication technologies to enhance the quality and performance of urban services, health and government services, and mobility, to implement policies that reduce cost and resource depletion and to promote citizens' participation. In the transport and mobility field, applications, platforms and digital tools have been developed and employed to tackle Trikala's main problems (e.g., restricted width of bidirectional arteries, irregular parking) and increase the flexibility of transport infrastructure by adapting it to the demands and needs of the citizens (e.g. efficient and seamless

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integration of different mobility services)[5]. All the innovative applications and tools developed in the Smart City context are managed through a control centre at the City Hall. The control centre is also the place where all the data are collected, monitored and analysed. More specifically, the innovative apps and services developed for urban mobility include:

- a smart parking system, which allows the identification and monitoring of designated parking spaces in the city centre,
- a traffic lights operation monitoring system, which detects any potential breakdowns, provides information about light bulbs' malfunctions, etc., and
- a smart lighting system, which supports managing the municipal street lighting.

Finally, over the last 6 years, three mobility projects have been deployed and piloted in the city of Trikala fostering innovation in mobility. The CityMobil2 project[6] demonstrated the automated transportation of six driverless EVs in the city centre, the TEAM project[7] offered mobility innovations in PT, while The MyWay project[8] offered journey planning capabilities for pedestrians and drivers offering green mobility alternatives. In addition, the **research project 'AVINT'[9]** has focused on the **integration of autonomous vehicles within the urban context through a demonstration in the city of Trikala** Greece. This is further expanded in the **SHOW[10]** project, which is the **largest and most holistic ever initiative piloting automated vehicles in urban environments**, gathering a strong partnership including 69 partners from 13 EU-countries.

2.2.2 HARMONY impact on mobility planning

Trikala's participation to the HARMONY project certainly contributed to further explore the innovative aspects of urban air mobility (UAM), particularly to respond to the need for immediate access to urgent medication through a future, remote-based UAM service. In the project context, in fact, drones have been piloted for medical logistics, delivering medicines from the city centre to the pharmacies in the surrounding rural areas, aimed to serve primarily the urgent needs of elderly and other vulnerable social groups with limited accessibility to mobility services[11].

Trikala's **SUMP** was developed in the framework of the implementation of the Financial Program of the Green Fund[12], aiming to support the services of the municipality of Trikala for the recording of the existing urban mobility situation and the problems that arise within its boundaries[13]. **The SUMP was finalized during the project and has been approved in 2020**. The SUMP aims to decongest transport networks, reduce the traffic load, strengthen the cycling network, promote walking, and reform the PT system. Among other things, it is planned to adapt the city's traffic model with appropriate traffic regulations (one-way streets, direction and intersection priority changes, etc.) in order to reduce through traffic in the city centre, and to create a complete and integrated network of accessible sidewalks for pedestrians, overpasses, safety islands, light traffic roads, etc[14]. In conjunction with the **Sustainable Urban Development Strategy**, which plans the redevelopment of several squares as well as the

[5] https://cities4people.eu/en/pilot-areas/trikala-greece/index.html
[6] http://citymobil2.eu/
[7] http://collaborative-team.eu/
[8] http://myway-project.eu/
[9] https://www.avint-project.eu/index.php/en/
[10] https://show-project.eu/
[11] https://www.eltis.org/sites/default/files/practitioner_briefing_urban_air_mobility_and_sump.pdf
[12] Financial Program of the Green Fund entitled "other environmental balance actions 2016 – Priority Axis (4) – Urban Sustainable Mobility'.
[13] https://www.trikalaerevna.gr/%CF%83%CF%87%CE%AD%CE%B4%CE%B9%CE%BF-%CE%B2%CE%B9%CF%8E%CF%83%CE%B9%CE%BC%CE%B7%CF%82-%CE%B1%CF%83%CF%84%CE%B9%CE%BA%CE%AE%CF%82-%CE%BA%CE%B9%CE%BD%CE%B7%CF%84%CE%B9%CE%BA%CF%8C%CF%84%CE%B7%CF%84%CE%B1%CF%82/
[14] *Idem*

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Lithaios riverbank in the city centre, sustainable forms of transportation, including electric mobility and automated transport, are encouraged and green transportation awareness and public engagement will raise.

Three thematic consultations took place between since 2019, on the preparation of the SUMP. During these occasions, ideas, proposals, necessities, current trends, as well as present and future scenarios have been discussed[15]. During the 3rd thematic consultation of the SUMP, the proposed measures and the methodology applied to determine them were presented as well as a detailed comparative evaluation of the interventions and a series of indicators and parameters extracted from the VISUM software.

The proposals for the SUMP are the result of a long participatory process with local stakeholders and citizens, who completed a survey on the future urban development and mobility of the city. The proposed measures are articulated in 10 main axes and three-time horizons of implementation (short-term implementation horizon: 2019-2021, medium-term: 2025, and long-term: 2030). The ten main axes of intervention are: 1) traffic management, 2) accessibility, 3) public transportation, 4) urban freight transport, 5) promotion of non-motorized means of transport, 6) parking management, 7) improvement of urban environment, 8) power consumption management, 9) adoption of new, smart solutions and technologies, and 10) informing and raising awareness among citizens.

The adoption of new, smart solutions and technologies - "Smart" applications is one of the main axes defined in the SUMP[16]. The actions envisaged to reach this goal are related to the exploitation of the existing Information and Communication Technology (ICT) infrastructures and services and to the adoption of Intelligent Transport Systems (ITS) applications in information, traffic management and introduction of innovative mobility technologies. The SUMP also proposes 8 actions, articulated in the three-time horizons of implementation. In particular, it envisages the provision of infrastructure and framework for the pilot test of distribution systems through urban air mobility technologies by 2025.

Table 1. Trikala's SUMP measures related to the adoption of new, smart solutions and technologies

Short-term implementation horizon (2021)	Medium-term implementation horizon (2025)	Long-term implementation horizon (2030)
Upgrading existing web pages with information on all means of transport and services in the Municipality	Operation of variable information signs (VMS) in real time in a representative number of public stops transportation	Creation of an application to monitor traffic in real time and provide relevant information to residents and visitors.
Creation of an electronic platform for the promotion of car-pooling	Creation of an application to control illegal parking with sensors	Resident card that will include all means of transport and services within the Municipality (controlled parking system, shared bike system, driverless public transport buses, etc.).
Establishment of a mobility body (or evolution of the existing e-trikala) for the organized planning and management of applications of intelligent transport systems	Provision of infrastructure and framework for the pilot test of distribution systems through **urban air mobility** technologies	

[15] https://trikalacity.gr/to-kykloforiko-mellon-ton-trikalon/
[16] https://svaktrikalacom.wordpress.com/2021/04/08/%CE%BC%CE%B5%CF%84%CF%81%CE%B1-%CE%B1%CF%83%CF%84%CE%B9%CE%BA%CE%B7%CF%83-%CE%BA%CE%B9%CE%BD%CE%B7%CF%84%CE%B9%CE%BA%CF%8C%CF%84%CE%B7%CF%84%CE%B1%CF%83/

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The Municipality of Trikala continues to envision a future with smart systems at the service of citizens, which will contribute to the quality of life of the residents and create new specialized employment positions in the area. In this spirit, the SUMP envisages to conduct a first feasibility study in order to ensure the provision for the development of distribution systems using Unmanned Aircraft Systems (drones) for freight transport deliveries.

The lack of an institutional framework at the European level regarding urban air mobility in urban areas makes the implementation of such systems challenging in the immediate future, however the Municipality is committed to gradually overcome the obstacles. In order for this to happen, in the context of the SUMP, the Municipality is going to proceed with the following actions:

- participation in national and European research programs on the subject for the acquisition of experience and know-how;
- creation of a strategic plan that will determine the operation of the entire urban commodity chain (e.g., arrangement of an urban distribution system); and
- gradual development of infrastructure and services after research studies.

Finally, the transport modelling activities of the HARMONY MS carried out during the project have not been used to draft the SUMP as the MS was still in progress, before the SUMP approval.

2.2.3 Demonstration activities and achievements

The main objective of the **co-creation lab** in Trikala was to foster co-creation, social embracement, and public acceptance for drones as a new mobility concept. A number of crucial stakeholders, such as local pharmaceutical warehouses and pharmacies, the National Union of Pharmacists and Union of Pharmacists in Trikala, the Medical Association of Trikala and Greece, and citizens were involved in the organization of the co-creation lab activities. The goal was to promote and boost (i) the pharmacists' acceptance in transferring medicines served using urban air mobility (UAM) services and (ii) the pharmacists' agreement on which villages should be served using drones. In addition, their input has been collected regarding the number of urgent cases per day that could be served by drones. The Medical Association of Trikala and the Medical Association of Greece provided requirements for the design of the demonstration. Furthermore, the geographical routes served by drones have been planned in conjunction with all stakeholders. The bottom-up approach of the participatory process was well structured and stakeholders collaborated smoothly; both these factors contributed to the success of the co-creation lab.

The main activities within the Trikala co-creation lab are **two events** related to the start of the drones' demonstrations, which took place over 3 months in 2022, in three different locations in the Trikala area. The aim was to launch the demonstration and start an initial dialogue with the local ecosystem on UAM. Two events took place for the first two series of flights, while there was no big event planned for the third demonstration. The majority of **workshops and conferences** took place in Larisa, a neighbourhood in Trikala. The drones were also showcased in an exhibition.

The **drone's demonstration** in the city of Trikala involved a preliminary case study focusing on a pharmacy shop that delivers medicines to elderly houses through drones, from urban to rural landscape in 5 villages just outside the city of Trikala (at an average distance of 4,5km). Eventually, an adapted case study has been formulated and carried out in September 2021, due to legislation restrictions. In order to conduct any test with air mobility systems and services, there is a long process to obtain permissions, but e-Trikala has initiated the process to obtain 3 permits for the first urban mixed traffic medical pilot demonstration with drones in Greece, focusing on a pharmacy logistic centre that delivers medicines to pharmacy stores through drones. Afterwards, each pharmacy store could deliver the medicines through ground mobility modes to elderly groups and other vulnerable social groups with limited accessibility to mobility services.

In total, 24 pilot drone flights have been conducted in three peri-urban areas of the city of Trikala, during winter 2021. Eight flights have been conducted to each one of the destinations. The landing took place

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in the pharmacy area of Leptokaria and in the football areas of Mikro Kefalovriso and of Megalo Kefalovriso.

During the flights, several data was collected and impact assessment results, in the form of various KPIs. During the whole pilot, a total distance of 170km was covered, while the total duration of the flights was 632 min (10.5h), on an average speed of 10m/s.

		
Landing in the pharmacy area of Leptokaria	*Landing in the football area of Mikro Kefalovriso*	*Landing in the football area of Megalo Kefalovriso*

Figure 3. Drone demonstrations in Trikala

In terms of **challenges** faced during the demo, the general lockdown because of the Covid-19 pandemic has been an essential barrier given that trips between different regions and physical meetings with stakeholders were not allowed. This has been a bottleneck for the potential operator and drone provider as well as for engagement activities. For this reason, meetings and workshops have taken place virtually. In addition, the restrictions have contributed to low participation in stakeholder engagement activities/co-creation labs and surveys as well as a multi-phased authorization process by the Greek Civil Aviation Authority (CAA) was needed. Also, safety challenges in urban and public areas, the need for traffic models and cybersecurity have been identified and highlighted as lessons learnt. An additional challenge was to limit the municipality, users and stakeholders' scepticism in relation to drones. Also to be reported were the absence of technological equipment and investment and lacking U-space monitoring tools and methods.

As per the **deviations from the initial demo plan**, legal restrictions did not allow for door-to-door medical delivery to elderly people, but rather to the pharmacy stores (as mentioned before). The procurement process has been challenging and urban air flights are not allowed in central areas of the city. Furthermore, the demo incrred in changes in the equipment and timeline. The drone was not provided by GriffAviation, but by a local company, ALTUS S.A. Technical requirements and relevant permitting processes had to follow the authorization process by the Greek CAA. All these obstacles delayed the demo from summer 2020 to winter 2021.

In addition, **quantitative data** deriving from **online surveys** has been collected before and after the pilot demonstration, while **questionnaires** were distributed to elderly people and pharmacists to understand the public acceptance of drones as a new mobility service.

Finally, given the success of the pilot, the Municipality of Trikala is planning a workshop with students to show how drones work, present the project, and receive feedback from the youth. In the future, the city aims to continue piloting drones in order to further convince local stakeholders to use it and develop cross-sectoral interactions. The local police has also shown interest in drones to grant safety and enable monitoring. This was not the purpose of the HARMONY demo (being in this case last-mile delivery/urban logistics); nonetheless, safety monitoring is indeed a possible application for drones to be further explored. The city of Trikala aims, in fact, to widen the use of drones, collect more data on last-mile deliveries and evaluate more deeply the impacts (technical and economical), and counter the

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disruptive impacts. A UAM service that could be developed from the experiences of the HARMONY pilot has the potential to improve the everyday life of citizens by decreasing the delivery time, reducing operational costs and operating in a safer way promoting social distancing if needed, like in the context of the COVID-19 lockdowns.

The municipality is also evaluating to launch a contact point (a municipal incubator) to inform citizens and stakeholders on drones' application and to foster the market by promoting investments locally and nationally (e.g., start-ups). The GiSeMi HUB, a joint initiative of the Municipality of Trikala and e-Trikala SA, has already bought drones and delivered 50 training courses and free certifications for companies to use drones.

2.3 Turin

2.3.1 Context and background

The Turin Functional Urban Area (FUA) is located in the Northern-West of Italy, in the Piedmont region, where it extends for almost 7000 km^2. **Turin is the capital city of both Piedmont and the Metropolitan City, placed on the western side of the Po River, and it develops westward through its first and second hinterland areas along the Susa Valley, up to the Alpine arch defining the border with France**.

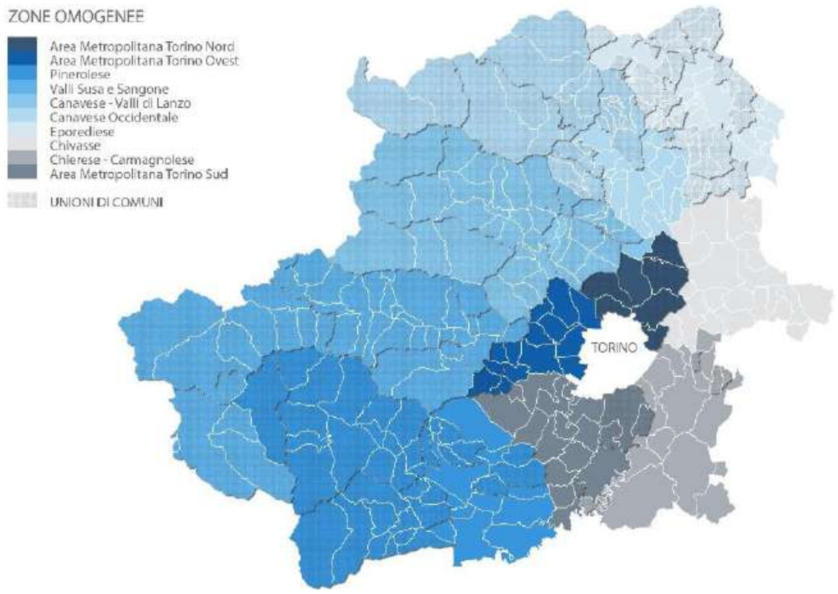

Figure 4. Turin Functional Urban Area (FUA)

Thanks to its adjacent location to France and proximity to Milan and Genoa, it plays a crucial role as a strategic crossing point for people and goods transfer between Italy and France. Because of these reasons, many highways and railways transport are connected to the Turin city, and many others are ongoing projects (for example the HST (high speed train) that will connect Turin to Lyon.

However, the city of Turin is also a significant attractive area itself for the neighbouring and further territories: it is a university town[17], appealing to people from the whole country and from abroad, and serving every year more than 110.000 students[18]. The touristic industry has always been noteworthy in

[17] http://ustat.miur.it/dati/didattica/italia/atenei-statali/torino
[18] http://ustat.miur.it/dati/didattica/italia/atenei-statali/torino-politecnico

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the city, about 3,6 million people visit the city every year[19] (ISTAT, 2019), and the trend was increasing before the pandemic period. The city offers many museums and events, while the hinterland is characterized by many Savoy Residences and castles, while during the winter season the ski resorts are the main touristic attraction.

Regarding the manufacturing field, several big companies are located in this area, mainly in the automotive sector, such as FCA (previous FIAT) and CNH-Iveco.

In terms of transport supply, the main traffic circulation for the city need is regulated by the freeway developing from south to the north lining the west side of the city, starting from which highways branch out toward the main destinations.

On the public side, a single line underground connects the south closest hinterland, the centre and the west closest hinterland of the city. The rest of the city is served by both busses and trams, often driving on reserved lanes. For longest trips, public service and private bus companies are available for every main destination within the metropolitan area. Concurrently, dedicated train lines by SFM provide connection to the whole metropolitan area.

During recent years, also many vehicle-sharing companies have settled in Turin, increasing the mobility offer inside the city and in the main hinterland municipalities: these includes car-sharing (LeasysGO, Enjoy, ShareNow), scooter-sharing (MiMoto, Bird, BIT Mobility, Bolt, Circ, Dott, Helbiz, Lime, Link, Tier, Voi), bike-sharing (Mobike, Helbiz, Tobike).

Turin is also equipped with an airport, the Caselle International Airport, located in the north of the city, well-connected with the city by means of dedicated busses from and to the main train stations and closest airports (for example Milan’s ones).

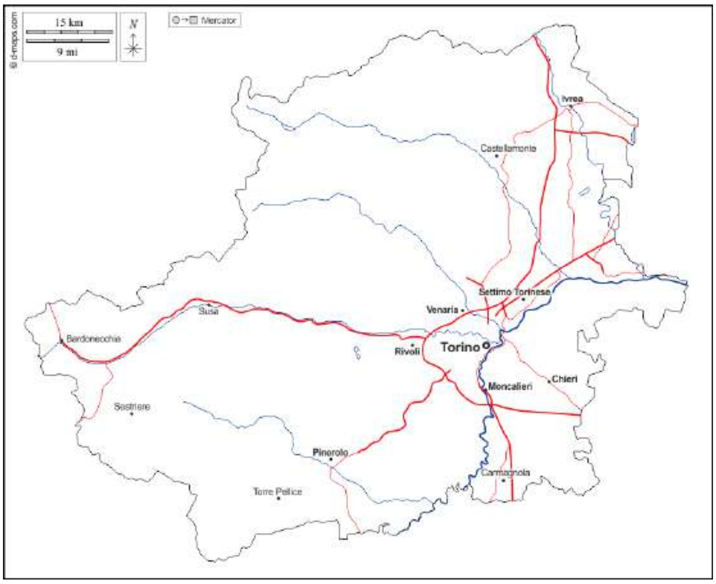

Figure 5. Turin’s road network

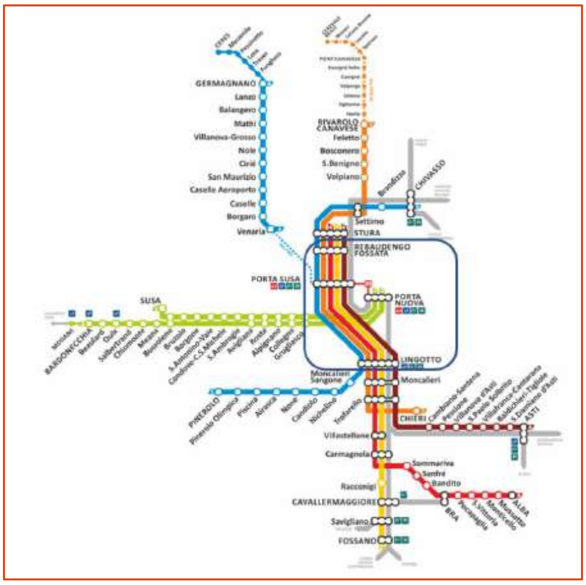

Figure 6. Turin’s transport network

Turin is the first Italian city to develop an experiment on self-driving and connected vehicles in an urban setting. In fact, the Memorandum of Understanding (MoU) signed on 30 March 2018, in implementation of the D.M. (MIT) 70/2018 "Smart Roads", between the City of Turin, FCA Group, GM Global Propulsion Systems srl, ANFIA, 5T srl, Polytechnic University of Turin, University of Turin, Fondazione Torino Wireless, TIM SpA, Open Fiber SpA , Italdesign Giugiaro SpA, Unione Industriale di Torino, FEV Italia and Unipol, a first phase of development of vehicle-to-infrastructure (V2I) technological solutions was

[19] https://www.istat.it/it/files//2020/12/C19.pdf

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launched, aimed at receiving data from moving vehicles, in order to monitor and assist self-driving cars in a complicated and unpredictable context such as the urban one.

This experimentation is supported, in particular, by the Traffic and Urban Mobility Centre, managed by 5T, equipped with sensors and devices aimed at monitoring and controlling traffic and road flows with information services that are always updated in real-time[20]. The perspective of the automation of road vehicle driving appears promising, in the medium-long term, with reference not only to individual motorized mobility, but also to collective transport services, which will be able to largely benefit from the economy and flexibility generated by new technologies in operating the network.

2.3.2 HARMONY impact on mobility planning

The **Metropolitan City of Turin's SUMP** was adopted by the Metropolitan Area's Council in August 2021 and then **approved in July 2022**[21], aiming to foster technological innovation towards the future challenges of electric mobility and autonomous driving. As part of the SUMP, three other sectoral plans are being drafted: the Cycling plan, the Accessibility and Intermodality plan, and the Logistics plan.

Within the framework of the HARMONY project, several modelling activities have been carried out. The study area of the model was Turin's FUA, composed by the city of Turin and other 87 municipalities of the first and second belt, for a total of about 1,74 M inhabitants.

Several use-cases have been defined, considering the Territorial Strategies of the Metropolitan City of Turin's SUMP. The territorial impact generated by the new public transport infrastructure and land use changes have been simulated, as well as the new MaaS mobility paradigm on the Turin FUA, with particular reference to its integration with Metropolitan Railway System (SFM). The particular impact of remote working, the reduction of trips for work and study, and the change of travel patterns during the day have also been tested. Finally, tests also covered the introduction of Urban Vehicles Access Regulation (UVAR) measures, namely the introduction of the limited traffic zone (LTZ) in Turin city centre, its consequent traffic calming in Turin and in the first belt as well as the implementation of low-emission zones (LEZs) in several municipalities of the Turin FUA.

The modelling activities produced the following results: the provision of secondary data and access to existing models, and 2) the collection of passenger primary data and recruitment of individuals via the Moby App survey to understand the levels of social acceptance of new mobility services and technologies. As for the provision of secondary data, the Municipality of Turin developed a specific data warehouse collecting data from available open data access sources. As it was the case in other cities, some administrative processes were slowed-down due to the Covid-19 pandemic restrictions and a delay was experienced with respect to the original plan for data with restricted access. Access to the existing VISUM models was provided after several meetings and agreements with 5T and GTT (owners of the network models for private cars and public transport). As for the passenger primary data collection and recruitment of individuals via the Moby App survey to understand the levels of social acceptance of new mobility services and technologies, this activity was postponed due to COVID-19 pandemic (originally planned in late 2020) to spring 2022.

Finally, the **HARMONY project contributed to update the metropolitan SUMP and integrate a few objectives and measures regarding innovative mobility technologies**, such as the intensification of electric vehicles and sharing mobility, the electrification of public transport, and piloting of autonomous vehicles[22]. In particular, the City of Turin pursues the objective of rebalancing the demand for mobility between individual and collective modes, in order to reduce congestion and increase accessibility. The pilot project developed within the Project was focused on the territorial impacts generated by the new transport infrastructures (such as the M2 line) and by the new MaaS mobility paradigm, with particular reference to its integration with the Metropolitan Railway Service.

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[20] https://www.5t.torino.it/
[21] http://www.cittametropolitana.torino.it/cms/trasporti-mobilita-sostenibile/pums/pums-elaborati-di-piano
[22] http://www.cittametropolitana.torino.it/cms/risorse/trasporti-mobilita-sostenibile/dwd/pums/RapportoFIN.pdf

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In this respect, it was envisaged to use the **HARMONY MS** to simulate specific strategies and scenarios of the metropolitan SUMP, involving stakeholders in their development and integrating the actions emerging from the co-creation labs, for example in terms of shared taxi services, e-scooters, and motorcycles. The SUMP adopted the results of the finalized activities.

2.3.3 Demonstration activities and achievements

Within the framework of the HARMONY project, **co-creation labs** were set up and developed, together with citizens and stakeholders, focusing on the territorial impacts generated by the new PT infrastructure and the new MaaS mobility paradigm in Turin's FUA, with reference to its integration with the Metropolitan Railway System (SFM). As mentioned before, the purpose was to analyse Turin mobility in the wider context of the city's emerging trends and vision for the future, and to explore the potential opportunities offered by the MaaS mobility paradigm from various points of view.

The Municipality of Turin, in collaboration with other stakeholders, organized co-creation and stakeholders' engagement activities. **Several interviews and focus groups took place in November-December 2020**, aiming at finding synergies with other local projects and involving stakeholders related to the MaaS paradigm in Turin. Another **workshop** managed by the Urban Lab (AUCM), with about 30 participants, took place in **December 2020**, during which it was discussed the application of modelling tools, also in respect to the SUMP. A list of over 60 stakeholders from different organizations was prepared (including local authorities, public transport providers, universities, NGOs, associations, sharing mobility companies, foundations, etc.) and organised according to the topics and their expertise (MaaS, Autonomous vehicles, cycling plans, micro-mobility, electric mobility, etc.).

In addition, a **survey** was conducted through the Moby App. The tender to hire a company to recruit individuals was published in August 2021, and the assignment to the company occurred at the end of September 2021. The requirements were the following: 1) users had to be selected within Turin's FUA, including 88 municipalities; 2) the minimum of participants was 500, this sample was defined by macro-zone, gender, age, employment, and car ownership; and 3) each user had to track and validate 4-7 days of trips, and answer at least 2 stated preference questionnaires (out of 4, investing mobility habits).

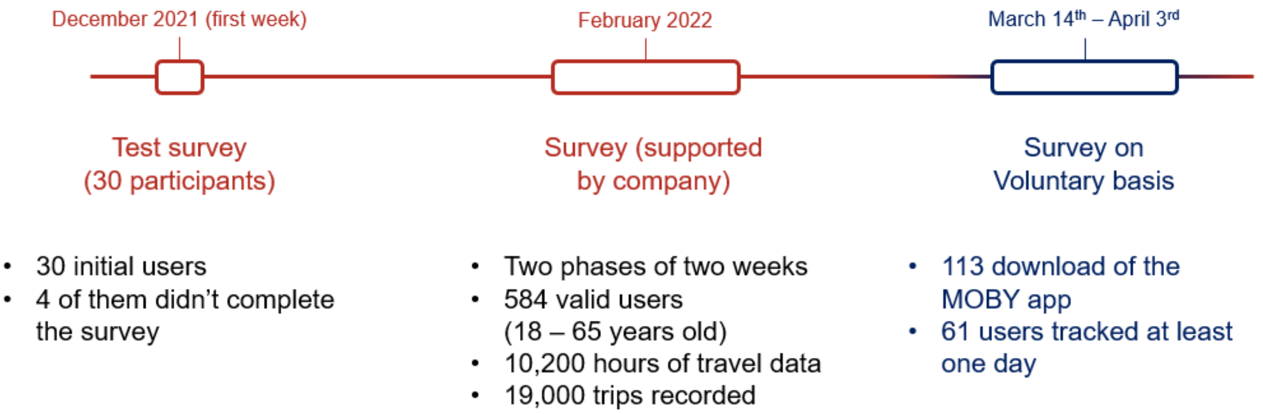

Figure 7. Turin survey timeline

The collected data on passengers' mobility trends was analysed. The elaboration of the data aimed to support modelling applications; in particular, the demographic forecasting model, the agent-based model, the VISUM network model and the different use-cases.

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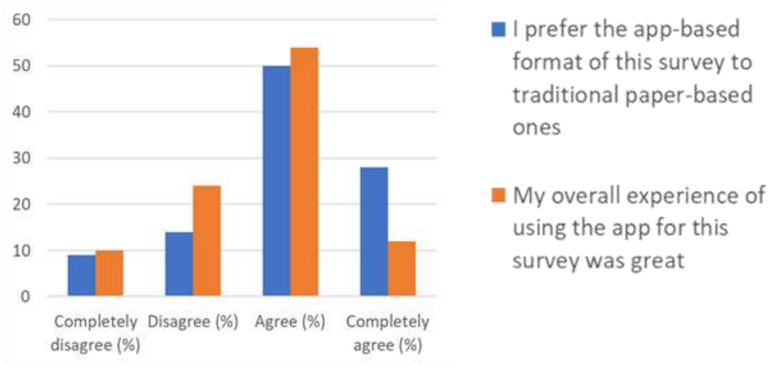

Figure 8. Turin survey - feedback

A **workshop** on the survey results and **on HARMONY MS application** took place in November in Turin. This was an occasion to also participate to a panel to discuss with institutions, experts, and professionals. During the workshop, the HARMONY MS was presented and shown its application for the case of Turin. It was also shown **the Moby App survey for modelling**, as well as selected use-cases simulations and their results. Data was collected and elaborated to support modelling applications. It was tested the linkage of the Turin VISUM model with large scale model – TRUST model (multimodal European network model). The airport connection service was also tested, including and improved rail connection to the airport.

2.4 Upper Silesian-Zaglebie Metropolis GZM

2.4.1 Context and background

The Upper Silesian-Zaglebie Metropolis (Gornoslasko-Zaglebiowska Metropolia, GZM) is an association of 41 cities and communes with 2.3 million inhabitants, located in Upper Silesia and Zagłębie in Poland. It is **the largest Polish metropolitan area and an economic centre**, being a trade and service midpoint with a significant share of production activity.

GZM is situated on the main national and international routes, both road and rail ones, at the crossroads of two TEN-T corridors. In the northern part of the Metropolis, there is the international airport of Katowice-Pyrzowice.

GZM endeavours to design, implement and test innovative urban mobility concepts, linking densely populated urban centres (e.g., Katowice) with extensive public transport systems and shared services and sparsely populated suburban and regional areas, which are mainly accessible by car. Due to the region's high economic activity, a rapid transition to regional and urban transport and environmental sustainability is a priority in the conurbation.

The PT system in GZM, managed by the Metropolitan Transport Authority (ZTM), is the largest in Poland in terms of area served and number of transport lines. The Metropolitan Railway is the backbone of the entire PT system. The Metropolitan Railway project envisages the development of 220 km of railway in four steps, between 2019-2039. In further development stages, light rail is to be built and a monorail solution is to be considered, e.g., connecting Pyrzowice International Airport with Katowice and Sosnowiec. The development of the network assumes the addition of new passenger stops. GZM is also part of the "Kolej+" (Rail+) program, which will further contribute to the improvement of the existing rail connections between communes and the city of Katowice.

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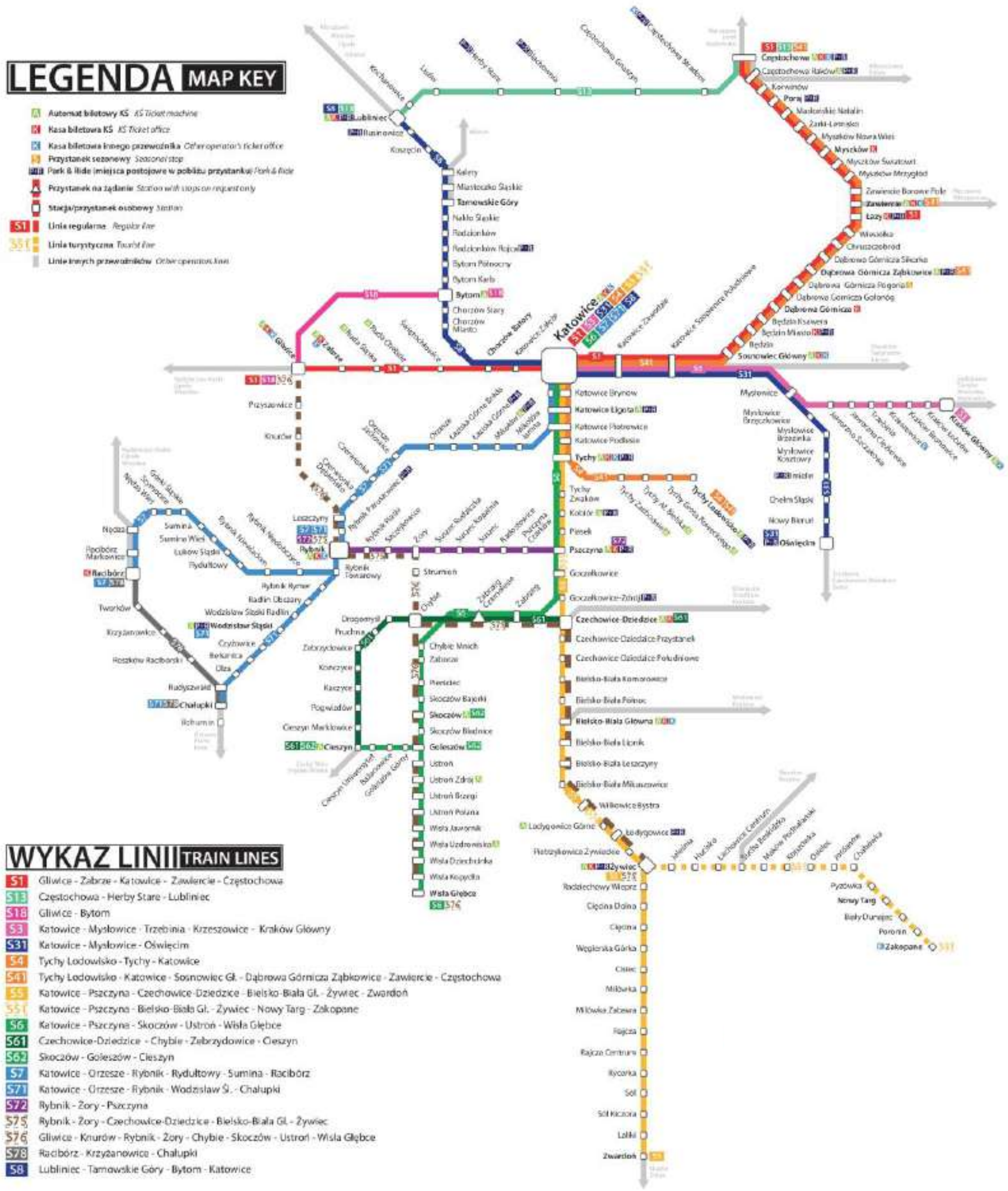

Figure 9. Rail network in GZM

GZM's PT network is also composed by approximately 434 bus lines, 8 trolleybus lines, and 31 tram lines. The bus fleet serving the bus transport network consists of ~1500 vehicles, with diesel-powered buses being the most numerous and a few low-emission vehicles (e.g., hybrid, electric). Vehicles using alternative fuels represent a small but growing percentage of the total number of vehicles (11.78%).

Being a post-industrialised metropolitan area (with a relevant presence of coal mines), GZM is highly congested, recording elevated levels of air pollution. To tackle these challenges, the metropolitan area is increasingly investing in the development of electric mobility, with the purchase of 20 hydrogen buses that are now being tested. Another 32 new electric buses are expected to operate soon in GZM, 16 plug-in chargers and 11 pantograph chargers to be implemented.

The Act on Electromobility and Alternative Fuels requires local authorities with a population of more than 50,000 inhabitants to have a share of zero-emission buses in the fleet of vehicles used to provide public transport service at 30% from 2028.

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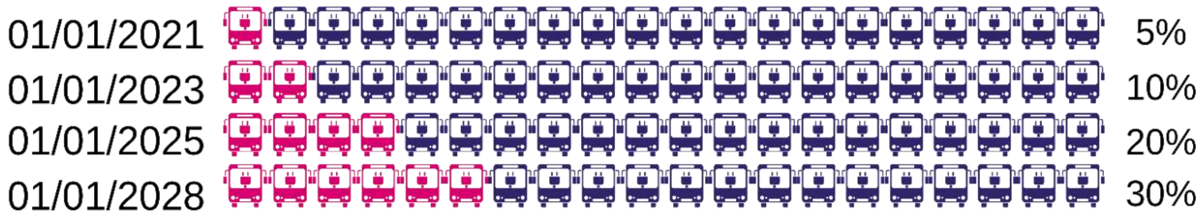

Figure 10. Progression on the share of zero-emission public transport buses in GZM

In addition, GZM is planning to implement the Metropolitan Bike System which aims to ensure seamless movement in conjunction with PT systems within the framework of tariff integration and the use of interchanges (implementation of the MaaS concept), support movement between municipalities of GZM, and favour the recreational use of bikes in connection with metropolitan attractions and amenities (e.g., parks, tourist attractions). At the moment, GZM reports a lack of public cycling, coordinated and integrated with other transport modes within the whole metropolitan area. Some GZM communes have already developed their own bicycle systems (e.g., Katowice), which, however, require to be further integrated with other transport modes.

The planned metropolitan bike sharing system will also act as a complement to other modes of active mobility, e.g. e-scooters, creating a common mobility "ecosystem". In the designed system, the bicycle will serve urbanised areas, located at a distance of 12-20 km. Due to the parallel development of inter-municipal cycling infrastructure, priority will be given to the implementation of the system in municipalities linked by already planned cycling lanes.

Overall, the largest share of transport is represented by the use of private cars (64,7%), then PT (busses, trams) (23,5%), bikes (4,5%), combination of several modes (1,3%), other (6%) (Polish national data, 2021). The metro is not a transport mean in GZM as the territory lays on a huge area of coal mines. At the same time, the use of e-scooters and bikes is progressively increasing.

The table below shows the share of non-walking trips of inhabitants grouped by modes of transport[23].

Table 2. Modal split in GZM

Transport mode	Modal share
Public transport	23,5%
Car	64,7%
Bike	4,5%
Combination of several modes	1,3%
Other	6,0%

Finally, GZM is involved in a number of hydrogen technology market initiatives. It is a member of the European Alliance for Clean Hydrogen, under the Sectoral Agreement for the Development of the Hydrogen Economy in Poland, and it participates to the work of the Hydrogen Technology Committee of the Polish Alternative Fuels Association.

[23] Transport Study of the Central Sub-region of the Silesian Voivodeship, Report 10, Stage 74.

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2.4.2 HARMONY impact on mobility planning

GZM's SUMP is currently under development and is expected to be adopted by mid-2023. Thanks to HARMONY's project and to the close collaboration with the UCL MaaS Lab, **the integration of drones and UAM into the mobility sector was added as one of the objectives in the SUMP draft**. The aim is to treat drones as part of mobility services (2035-2050) to decongest cities and decrease air pollution, using these innovative technologies to optimize last-mile deliveries.

In particular, HARMONY helped identify the possible use of drones in the context of GZM. Drones could be used as a public service: 1) for environmental protection, e.g., to monitor waste, water resources, coal mines dumps, and fires, and 2) for medical purposes and deliveries between hospitals and laboratories. This last option could also help overcome the problem of poor infrastructure and traffic congestion, while supporting the development of sustainable mobility.

As for the HARMONY Model Suite, transfer results from the **HARMONY MS application** are aimed to assist the local authority in planning the metropolitan-wide transport, introducing new forms of mobility and updating their SUMP. To this end, a UAM Workshop with crucial stakeholders was carried out in December 2020, as an input for a broader survey. The workshop was named "Flying taxis? Drones as a component of modern urban mobility". Another achieved result are the two main use cases, chosen in the initial survey, discussed in groups: one group focused on the support that drones could give to save lives, e.g., in water rescue and other places difficult to access, while the second group focused on drones for passenger transport, e.g., flying taxis and air ambulances.

2.4.3 Demonstration activities and achievements

The main objective of the **co-creation lab** is to have a citizen-driven approach to the process of SUMP creation, with a focus on the social acceptance of UAM use cases. Citizens and stakeholders were involved to investigate UAM requirements in terms of spatial and transport planning and new mobility services.

In the HARMONY project context, **GZM was not expected to conduct any physical demonstration**. Nevertheless, stakeholders were involved regarding drones and public acceptance, aiming to increase theirs, local authorities and citizens' awareness of the topic. Differently from other cities that started with technological demonstrations, in this case, GZM started first from engaging stakeholders and analysing public acceptance of innovative technologies.

Despite the lack of a physical demonstration, **co-creation activities were crucial**. In 2021, during the Covid-19 pandemic, an online presentation was held by the UCL MaaS Lab on drones, named "Flying taxis: are we ready?". The was a first attempt to involve GZM's stakeholders introducing them the concept of drones in cities. Secondly, a few workshops (hybrid events) were organized in June 2022 during the **World Urban Forum**, discussing about the public acceptance of drones and the status quo. In this occasion, discussions focused on the use of drones for medical purpose, which is well accepted, while their use for deliveries of other items is still not that convincing to people. Younger generations provided positive feedback on the possible introduction and development of drones. Finally, in 2022, GZM supported the UCL MaaS Lab with a **drone delivery game** aiming to analyse people's preferences for to use of drones. In this instance, GZM provided a number of indicators that helped respondents make their decision. A thousand answers to the survey were collected.

A **survey on the public acceptance of drones** was also distributed to over 400 stakeholders, in 2021, with a strong cooperation between UCL and GZM in developing and translating the survey content into Polish. Results have been reported for a conference paper "Factors affecting preferences for drone delivery services" (IATBR, 2022). The aim was to understand citizens' preferences for UAM services, and drone deliveries when the citizens are bystanders or recipients of the drone services.

Once again, from preliminary results of the survey, **it appeared that citizens prefer drone services for medicines deliveries, while they are less favourable to their use for surveillance or for delivering other items: such as clothes, illegal items, or mail**. Higher noise, unregistered drones or unlicensed operators have negative impacts on preferences. Rural areas or villages are the most preferred delivery areas. The drone survey results are fully report in HARMONY deliverable D3.4[24].

In the coming future, GZM aims to pilot drones and to educate public officials in drones, regarding GDPR issues, how to use them, technological and legal aspects, to increase the possibility of implementing use cases, and to involve them for medical use.

GZM co-creation activities highlighted several challenges. Firstly, it was crucial to adopt different communication languages with each group in order to ensure the involvement of stakeholders and particularly of public officials, who at the early stage of UAM implementation were not that prepared on the topic. As drones are not on the market yet, it was hard for them to imagine and plan the infrastructure needed, the amount of budget to allocate in order to develop drones, how they work, and so on. Local authorities were particularly interested into practical questions, such as those related to the budget. In a second stage, GZM engaged with hospitals, which are getting increasingly convinced by the benefits of using drones for medical deliveries. In particular, they were more favourable when drones were presented by city officials that were also in favour of their use. Increasing the awareness on the new mobility technologies was crucial to encourage stakeholders to consider drones implementation.

Other relevant concerns, particularly for citizens, were **privacy, safety, and (the new kind of) noise that drones produce**. Monitoring and drones flying near residential buildings are also a concern. Last but not least, the pandemic was also reported as a challenge to development of the co-creation activities. However, this was also considered as an opportunity, especially in terms of social distancing which helped reduce the need of moving with public transport, and, in these circumstances, drones were used to disinfect benches.

To conclude, GZM **co-creation activities helped understand that the most acceptable function for drones is the one for medical transport deliveries**. It is of crucial importance to involve and convince first and foremost local authorities and public officials as this is a huge advantage to make pilots and involve other stakeholders (e.g., NGOs, hospitals). Finally, local authorities are key also to introduce UAM into the SUMP.

2.5 Rotterdam

2.5.1 Context and background

Rotterdam is located in the province of South Holland in the Netherlands, at the mouth of the Nieuve Maas channel leading into the Rhine-Meuse-Scheldt delta at the North Sea. **It is a port city, the second largest after Amsterdam, and the largest port in Europe, being a major logistic and economic centre**. The Rhine, Meuse and Scheldt give waterway access into the heart of Western Europe, including the highly industrialized Ruhr. The extensive distribution system including rail, roads, and waterways have earned Rotterdam the nicknames "Gateway to Europe" and "Gateway to the World". However, in the recent years port-related employment has been decreasing and a shift towards high-level functions due to mechanization and automation has been observed.

The municipality of Rotterdam occupies an area of about 325 km^2 and is home to 640,000 inhabitants, about 25% of the population of the Rotterdam-The Hague metropolitan area (which is home to around 4 million people). Nonetheless, from the expected demographic trends, it appears that people are increasingly moving from Rotterdam to elsewhere in the Netherlands.

The City of Rotterdam faces several challenges which are comparable to many large and growing cities in Europe, such as the growth and densification of the city, air pollution, noise, climate change, need for greener and more attractive environment, and more inclusiveness.

In terms of transport infrastructures, Rotterdam offers connections by international, national, regional and local public transport (PT) systems, and the Dutch motorway network. At the urban level, PT

[24] *D3.4 – "HARMONY data: statistical and spatiotemporal analyses"*, 2022, Ioannis Tsouros (UAEGEAN)

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services include an extensive metro network of about 78 km, operated by 5 lines, a tram network of about 93 km, offering 13 lines, 55 city bus lines of 430 km, and a waterbus network of 7 lines.

Figure 11. Rotterdam metro network).

Source: https://bestanden.ret.nl/user_upload/Documenten/PDF/Kaarten_en_plattegronden/RET_metrolijnenkaart.pdf

According to the Netherlands Mobility Survey (MON), about 49% of trips are made by cars, 17% by public transport and the residual 34% with active modes (16% by bike and 18% walking). In the future, it is expected a reduction in car traffic within the Ring (highway around Rotterdam), while an increase in the city centre. In 10 years, bicycle traffic has increased by 29%.

The figure below shows the decrease in the use of the private car in the city centre (in orange).

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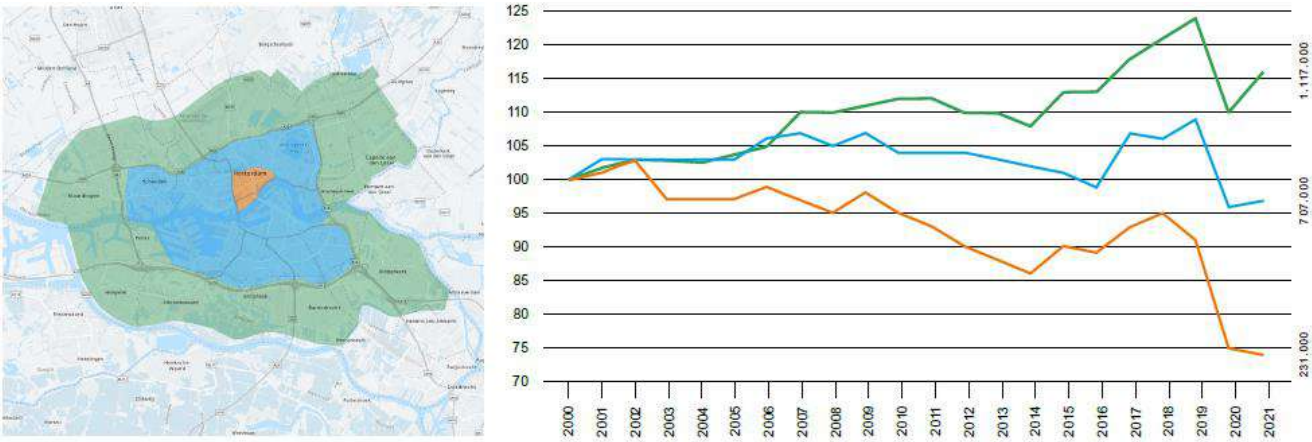

Figure 12. Number of car flows in Rotterdam

The number of shared cars and electric charging are rapidly increasing. The logistics in the city is also changing and Rotterdammers are increasingly appreciating the benefits of e-bikes.

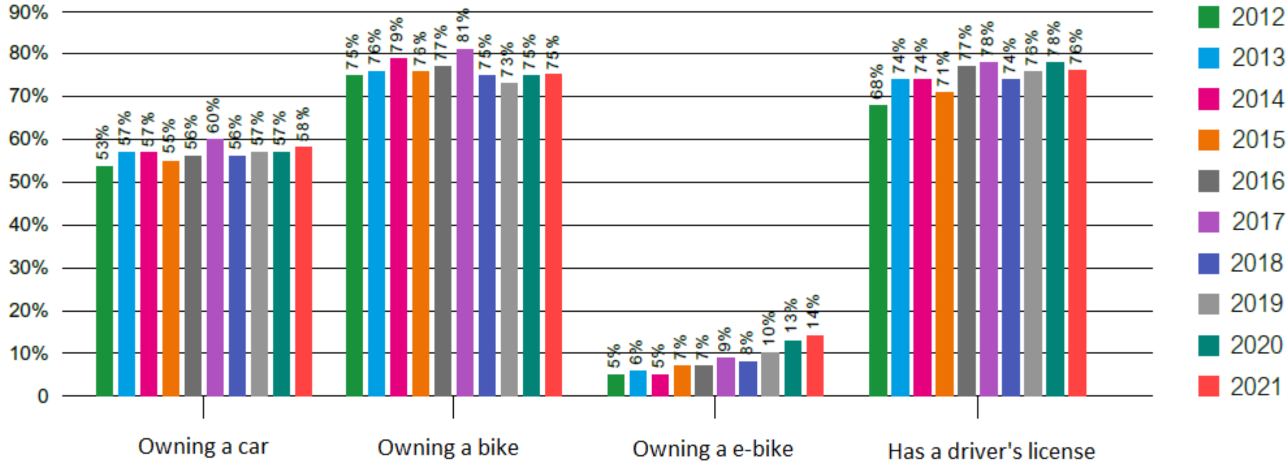

Figure 13. Car, bike and e-bike ownership (2012-2021)

2.5.2 HARMONY impact on mobility planning

In 2018, the public transport plan[25] and the cycling plan[26] were approved in 2018. At metropolitan level, the Roadmap Next Economy strategy and action program[27] was approved in 2016 and aims to foster the smart digital economy, provide smart energy, boost the circular economy, and favour the transition to a new economy and inclusive society. Specifically in the field of freight transport and city logistics, a policy document (2019) established the roadmap to a **Zero Emission City Logistics (ZECL)** zone in the city centre by 2025[28].

25 https://mrdh.nl/system/files/vergaderstukken_/6.2.%20bijlage%202%20Openbaar%20vervoer%20als%20drager%20van%20de%20stad_OV-visie%20Rotterdam%202040_definitieveversie%20januari%202018.03%28klein%29_0.pdf

26 https://www.rotterdam.nl/wonen-leven/fietsstad/Fietskoers-2025.pdf

27 https://mrdh.nl/system/files/projectbestanden/engels/Roadmap%20Next%20Economy%20in%20brief.pdf

28 https://www.rotterdam.nl/wonen-leven/stappenplan-zero-emissie/Stappenplan-ZES.pdf

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As part of the Roadmap ZECL, Rotterdam formalised a **covenant**[29] in collaboration with various logistics organisations. The signatories committed themselves to actions that contribute to the achievement of the ZECL. The covenant monitors the implementation of the actions until 2030.

In 2017, the city of Rotterdam approved the **SUMP**[30], aiming to improve sustainable freight transport. The logistics section of the Rotterdam Mobility Approach (a kind of implementation programme for the SUMP) has been derived from the simulation results (this was published in February 2020)[31].

The development of a more sophisticated simulation tool for analysis is part of the SUMP process, in which HARMONY results will take their place as far as automated transport is concerned. The current SUMP was developed starting from a dialogue with the departments of public health and economics. Ambitions in these fields have been translated into implications for the urban traffic system (e.g., traffic safety and efficiency). In this respect, 4 scenarios were analysed and compared, and a traffic modelling system was developed assessing the degree of the developed ambitions.

The city also approved in 2017 the **Rotterdam Urban Traffic Plan 2017-2030+**, a long-term mobility strategy aiming to improve the accessibility of the city (also reported in the current SUMP)[32].

As **Rotterdam opted for a pilot of autonomous transport of goods, the traffic modelling developed in the HARMONY context focused on city logistics and contributes to an improvement of the current traffic model in terms of representing transport of goods**. To this end, the Tactical Freight Simulator (TFS) was developed and use cases were formulated, taking into account ZECL zones, planning of logistic commercial spaces, micro-hubs and crowd shipping. Data was collected from stakeholders and analysed to improve both the TFS, the use cases and the design of the pilot (through questionnaires). Therefore, the use cases carried out with the TSF yielded information which was used to formulate and/or focus the flanking policies, identifying which stakeholders need what kind of support to make the transition required by the introduction of the ZECL zone.

In addition, letters were sent to all owners of commercial logistic vehicles registered in Rotterdam affected by the introduction of the ZECL, to promote awareness and offer support in making the required transition (over 200 responses were received). Secondary data was taken from transport models' output, from external sources at national level and from organisations representing importers, dealers, and retailers, focusing on their members and clients' attitude towards the transition to ZE vehicles and specific local sources.

Furthermore, as keeping the input data for the simulation up to date requires considerable effort, the HARMONY MS seems to be a suitable tool.

2.5.3 Demonstration activities and achievements

The main objective of the **co-creation lab is to understand the potential impacts emerging from the integration of AVs into the local mobility system, specifically the urban freight transport component**. In order to reach this goal, several stakeholders were involved in the organization of the co-creation labs. In addition, the Tactical Freight Simulator (TFS) of the HARMONY MS was applied for several use cases for Rotterdam to identify the impacts of the AVs on the city transport network.

Several meetings and activities with key stakeholders were organized. There have been discussions regarding the goals of a ZEZ that the city of Rotterdam plans to implement by 2025. A **co-creation workshop** and a consultation meeting took place as part of the Rotterdam co-creation lab activities. The co-creation workshop, organized by the municipality of Rotterdam, aimed to inform stakeholders

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29 https://logistiek010.nl/app/uploads/2022/03/Covenant-Zero-Emission-City-Logistics-Rotterdam.pdf
30 www.rotterdam.nl/wonen-leven/stedelijk-verkeersplan/Stedelijk-Verkeersplan-Rotterdam-20170123.pdf
31 https://backend-dvg.rotterdam.nl/media/1077?download=1
32 http://tda-mobility.org/wp-content/uploads/2018/11/Rotterdam_Urban-Traffic_Plan.pdf

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on the city's draft policy on charging infrastructure, to receive feedback, demonstrate how the city uses the simulation tool for policy development and call upon the stakeholders to set up initiatives to gain experience with (joint) use and exploitation of heavy-duty charging facilities.

Primary data for the TFS was gathered in close partnership with TU Delft, while actions on GPS devices, questionnaires and gaming activities were also carried out. In addition, questionnaires for SMEs (specifically those using delivery vans) were sent out in 2022 and results provided insights to improve the TFS input. The (domestic) waste transport module for the TFS was developed and, in line with the city's strategy on circularity (Zero Waste by 2040), **the city logistics component was integrated in the simulation tool**. The development and application of simulators was also carried out in cooperation with Hogeschool Rotterdam, promoting the application of the TFS and OFS. Furthermore, the Ecostars database was used and analysed, in collaboration with model developers and the municipality which participated in a discussion on the calibration and validation of the simulator input describing the behaviour of the logistical agents. Finally, the city of Rotterdam attended the "LEAD Futureshop: Hyperconnected city" of the EU-project LEAD in Delft-The Hague, in March 2022.

As for the **demo**, a **physical pilot with a delivery robot for freight transport** was deployed. **ROSIE freight autonomous vehicle/robot** had already been tested in the Erasmus University Campus at the end of 2021 (as part of another project). In the context of the HARMONY project, ROSIE focused on last-mile delivery and the impact of innovative technologies in multiple traffic situations. Between August-November 2022, many tests were carried out in the Future Mobility Park (in the western part of the city) and one on public roads. The trial was conducted with one robot, ROSIE, a small sustainable vehicle.

Figure 14. The robot ROSIE

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The **major challenges encountered are related to the legal framework and the strict rules that need to be followed when testing AVs**. In order to conduct any test with AVs, there is a long process to obtain permissions. In addition, it is not clear yet whether AVs are publicly accepted, and, as of today, most AVs are not economically viable yet: they are costly for logistics providers, although they are expected to become cheaper. Finally, **from a technical standpoint**, ROSIE is limited in its speed, hardly detects obstacles, and is still not very efficient. In other words, at this stage, the added value of ROSIE is still hard to be defined.

Following the trial, a couple of key policy recommendations can be presented: 1) to get a better view of rules from operators and municipal departments, and to improve coordination among stakeholders, 2) to clarify functions or the role of delivery robots within the city.

2.6 Oxfordshire

2.6.3 Context and background

Oxfordshire is home to around 666,000 people, an increase of over 10% in the past decade. The county is divided into five district council areas, with a quarter of the county's residents living in Oxford city. It is home to nearly 30,000 businesses, providing over 380,000 jobs. It sits on the busy road and rail transport corridor between the south coast ports, the Midlands and the north and enjoys easy links to London and West Midlands. The county is the second more rural area at the UK's Southeast, with a combination of urban (both historic and modern), peri-urban, highways and rural locations.

Car ownership and usage is high outside Oxford with 87% of households owing a car, compared to only 67% in Oxford[33]. There is a good network of bus/rail services linking the county's main towns with Oxford. Despite variable quality of cycling networks within Oxford, around 25% of the resident's cycle to work, though the split is much lesser in other parts of the county. OCC is committed to increase the active travel and public transport use at the county[34].

Planning authorities have assessed a need for 100,000 new homes to support 85,000 new jobs, a scenario that will provide a major challenge to Oxfordshire's transport system which has resulted in the Oxfordshire Growth deal, to be delivered by 2030[35]. The potential impact of housing and jobs growth on the county's transport networks, considering committed transport infrastructure, has been forecasted using a strategic transport model. The model shows many junctions over capacity in 2031, and severe delays on many routes, especially the A34, A40, A338 and A4074.

[33] https://webarchive.nationalarchives.gov.uk/ukgwa/20151013223839/http:/www.ons.gov.uk/ons/rel/census/2011-census/detailed-characteristics-on-travel-to-work-and-car-or-van-availability-for-local-authorities-in-england-and-wales/index.html

[34] https://www.gov.uk/government/statistics/walking-and-cycling-statistics-england-2020/walking-and-cycling-statistics-england-2020

[35] https://www.oxford.gov.uk/info/20283/oxfordshire_growth_board/1236/oxfordshire_housing_and_growth_deal

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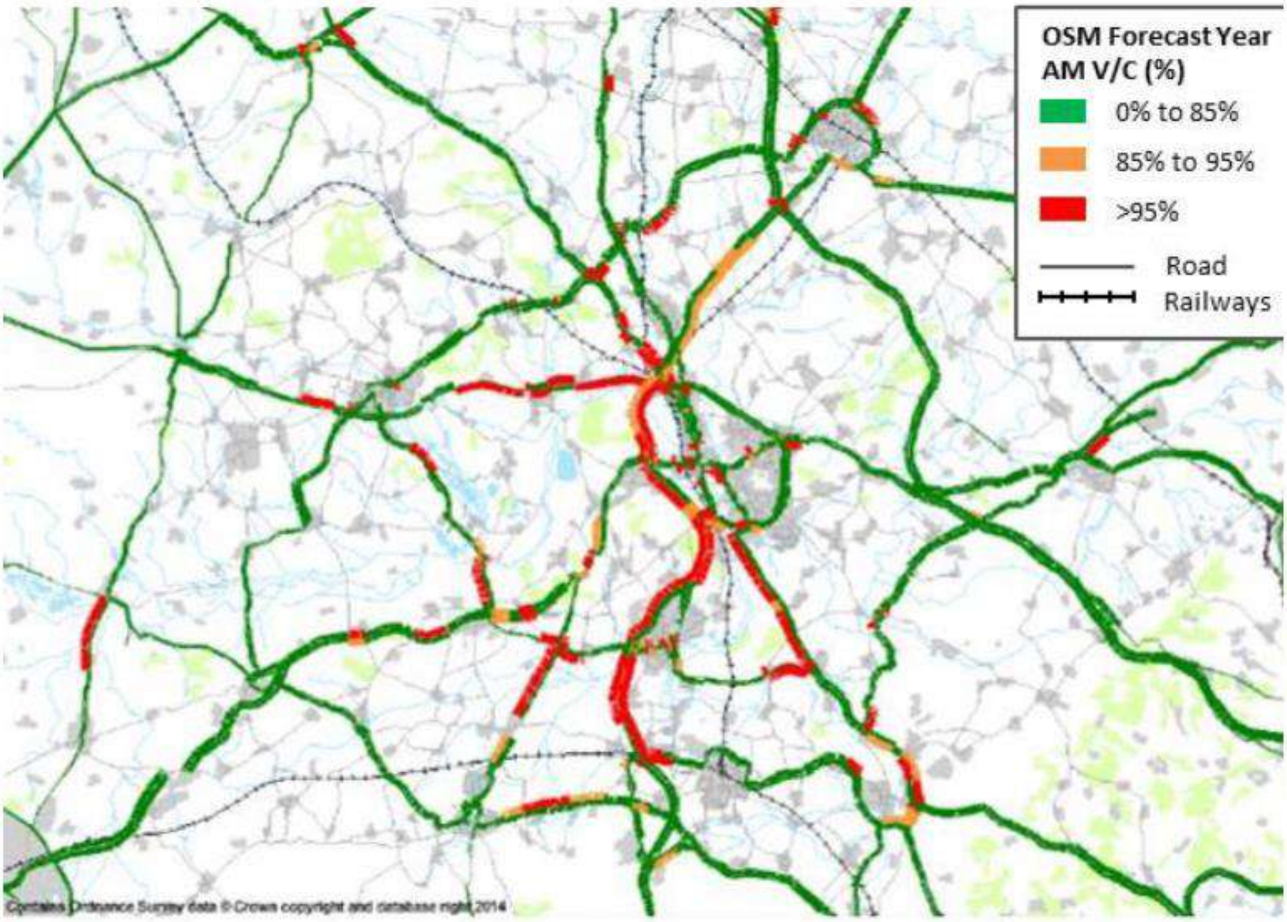

Figure 15. Highway network in the morning peak in 2031 with no intervention

Volume of traffic in relation to road capacity (85% to 95% = at capacity, 95% plus = over capacity)

Oxfordshire County Council (OCC) aims to: 1) foster job creation, housing, sustainable growth and economic vitality; 2) reduce overall emissions, enhance air quality and support the transition to a carbon neutral economy; and 3) protect and enhance the quality of life (including public health, safety, and well-being) inclusively. These objectives are consistent with the three overarching goals highlighted at the OCC corporate plan "Thriving People, Thriving Communities, Thriving Economy[36]".

2.6.2 HARMONY impact on mobility planning

In July 2022, OCC adopted the **Local Transport and Connectivity Plan**[37] which, among others, also sets policies for Connected and Autonomous Vehicles (CAVs)[38] and Unmanned and Autonomous Vehicles (UAVs)[39] aiming to ensure new infrastructure is futureproofed for use by connected vehicles. As for UAVs, OCC aims to: (a) embed futureproofing for UAV usage into infrastructure delivery and maintenance programmes and into relevant guidance for development design, including new UAV-

[36] https://www.oxfordshire.gov.uk/sites/default/files/file/about-council/CorporatePlan2020.pdf
[37] https://www.oxfordshire.gov.uk/sites/default/files/file/roads-and-transport-connecting-oxfordshire/LocalTransportandConnectivityPlan.pdf
[38] CAVs are vehicles equipped to exchange information with surrounding environment and can operate in a mode which is not being controlled by an individual (Automated and Electric Vehicles Act 2018).
[39] UAVs are remote-controlled aircrafts or small aerial devices which do not have an on-board pilot.

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specific infrastructure, where appropriate, through the **Innovation Framework**[40]; (b) assess the potential impact of UAV activity on residents and communities; (c) seek to ensure oversight of UAV use in the county, including via reviewing data requirements to facilitate future integration of UAV oversight with traffic management control systems; and (d) review data with a view to opening up data, such as mapping data, which will facilitate beneficial use of UAVs.

The main purpose is to encourage developers and planners to consider innovation within planning and development, integrating Innovation Plans, Supplementary Planning Documents (SPDs) and Local Plans for new developments, including residential, commercial, workplace, mixed use and infrastructure development. Innovation should also be considered within the developer funding process, to ensure sufficient funding is secured to futureproof infrastructure impacted by development. In assessing Health Impact Assessments submitted by developers, OCC aims also to ensure that innovation improves health equality.

Within this context, **the participation to the HARMONY project contributed to acquire knowledge which also led to participating in other innovative projects directly linked to knowledge gained from HARMONY**. For instance, OCC took part to the SKYway project, which tests automated drones on superhighways connecting multiple local authorities and aiming to make UAS flights easily manageable and progressively reduce costs for all subsequent flights[41]. Similarly, OCC was granted national funding for the development of the AirTrek project. As part of the Regulators' Pioneer Fund (launched in 2021), regulators and local authorities could apply for grants of up to £200,000 for projects that would help create a UK regulatory environment that encourages business innovation and growth[42].

The **HARMONY Model Suite (MS) was used to evaluate the impact that innovative technologies will have in the innovation space**. The multimodal approach to transport and logistics innovation adopted in the trial allowed OCC to look at future developments and to create a blueprint for new developments in the form of suggestions to developers and transport planners. This allowed OCC to future proof ongoing and upcoming developments which will in turn create a more cost effective and future proof county.

Finally, the collection of primary data started in April 2022. In September 2022, around 800 users and 6000 verified trips were reported. The collection of secondary datasets for modelling purposes also went smoothly. Key use cases were identified, based on the **analysis of the current SUMP in Oxfordshire**, using inputs from upcoming planning documents. Three primary use cases were defined on: 1) housing development, 2) AV Mobility as a Service (Demand Responsive Transport - DRT); and 3) Active Travel (initially the third use-case was supposed to focus on Zero-Emission Zones (ZEZs), which, however, changed due to variation in priorities after the pandemic).

2.6.3 Demonstration activities and achievements

The main objective of the **co-creation lab was to contribute to the demonstration of urban air mobility (UAM) solutions in the UK and use HARMONY modelling activities to further support to the development of regional spatial and transport planning strategies**. In particular, the co-creation lab aimed to: (a) integrate HARMONY project recommendations on new UAM technologies into the regional spatial and transport planning strategies; (b) carry out drone demonstration and evaluate the feasibility and viability of this urban mobility solution; and (c) carry out AVs demonstration and to evaluate the feasibility and viability of this urban mobility solution (initially planned, eventually changed in EV demonstration).

[40]https://mycouncil.oxfordshire.gov.uk/%28S%28111temanaulowwi3xfkizm45%29%29/documents/s57568/CA_OCT1921R10%20-%20Annex%204%20-%20LTCP%20Innovation%20Framework%20Draft.pdf
[41] https://www.bbc.com/news/technology-62177614
[42]https://www.gov.uk/government/publications/projects-selected-for-the-regulators-pioneer-fund/projects-selected-for-the-regulators-pioneer-fund

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As for the **co-creation activities**, two important workshops were organized. The first one aiming to explain the capabilities of the HARMONY MS and understand how it can work together with existing internal models, in order to help identify gaps in models being built within the OCC, that could potentially be filled by HARMONY. The second one involved internal planners at OCC interested in understanding more about the LUTI model being developed by UCL CASA; a detailed demonstration of the model and provision of potential use cases were given. All stakeholders (OCC, UCL, AIRBUS, GRIFF) participated to the on-site demonstration at Milton Park. Multiple discussions took place on use cases for UAV and CAV trials. UAV and CAV partners were involved discuss freight trials: to help identify use cases and zone of operation; Creation of template (along with UCL) to help manage the demonstrations. In addition, the Civil Aviation Authority (CAA) was consulted on regulatory approval application process.

A **drone and electric van (EV) trial** showcasing integrated freight delivery at a business park in Oxfordshire (Milton Park) was conducted in the end of August 2022. The purpose was to explore stand-alone trials of drones to hasten deliveries (especially in a medical use case) and also the integration with an EV to demonstrate parallelisation of new mobility freight delivery mechanisms. Support was provided by University College London (UCL), RUAS, Airbus through its Unmanned Traffic Management (UTM) platform, and other consortium partners. The HARMONY overall objective was to demonstrate electric vehicles (EVs) and drones in real-life conditions integrating them with traditional PT modes to understand the requirements, reactions and barriers and collect real-world data. The pioneering combination of technologies used throughout these demonstrations are the first of their kind, looking to advance mobility sustainability by reducing emissions, congestion and noise levels. The trials at Milton Park, which included the use of an electric van provided by OCC and the delivery of a defibrillator, successfully highlighted that the mobility technologies tested enabled increased efficiency and speed of freight delivery. In particular, Oxfordshire has one of the most sophisticated road traffic control centres in the UK and Milton Park was selected as the ideal location for the trials as it could offer a safe and controlled environment for innovative exercises.

The demo faced several **challenges**, including the restrictions on UAV trials based on flight paths, especially over railway lines and for the medical use case. In particular, the weight of drone along with payload needed to be within certain regulatory limits, and flying a drone over a railway line required additional permission. For this reason, RUAS (drone provider) had to consult with the CAA which gave the permission to conduct the pilot. Second, there were data storage concerns due to Information Governance for Brexit. Third, conducting physical meetings for co-creation workshop with planners and the Urban Traffic Management Centre as well as the demonstrations at Milton Park have been tough to organize due to Covid-19 restrictions. There was also the concern that a lot of the data from traffic management and other sources might be less meaningful because of the lockdown period.

The drone and EV trial was conducted on Sunday, 21st August 2022. The following use-cases were performed:

- drone + EV combined trial;
- parcel delivery;
- gift delivery;
- tools delivery;
- medical equipment delivery.

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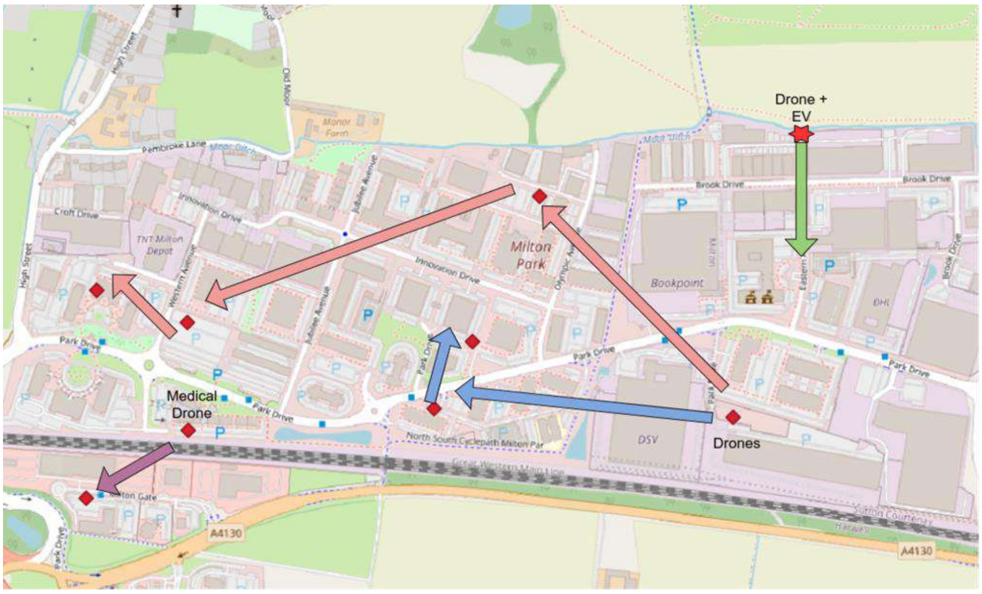

Figure 16. Drone + EV trials itinerary


Figure 17. Drone and EV trials in Milton Park

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3 Lessons learned from the HARMONY demonstrations

This chapter presents the lessons learned from the HARMONY demonstrations. In particular, **co-creation labs were organized in all 6 cities/metropolitan areas, in 5 different countries**. All co-creation labs included a set of activities aiming to contribute to the further development of the innovative approaches to the mobility services on the local level, as well as to contribute to the HARMONY modelling activities. Next to it, **three of the co-creation labs carried out physical demonstrations of the drones and/or autonomous vehicles**.

During the whole duration of the HARMONY project, the **Covid-19 pandemic** has obviously been a real challenge for the implementation of co-creation lab activities (meetings, workshops, conferences, etc.) as well as for physical demonstrations. The restrictions and social distancing measures, most of the time, caused delays in performing the demonstrations and in data collection, and limited the number of occasions for stakeholders to engage, who overcame the obstacle by meeting online.

The **bottom-up approach of the participatory process and well-structured co-creation labs worked smoothly, despite all the difficulties**. This was the case of Trikala for instance. HARMONY also evaluated the COVID-19 risk mitigation measures and the impact of the pandemic in short and mid-term planning policy and decision-making. The detailed results of Turin's data collection on passenger travel behaviour, GZM's survey on drones and the COVID-19 impact survey have been reported in D3.4.

In addition to co-creation labs, the metropolitan areas gained experience and acquired knowledge on their mobility trends and future expectations from surveys and from the application of transport modelling tools. In particular, the application of the HARMONY MS has been beneficial to the update of transport policies and of SUMPs in some metropolitan areas, as described in Chapter 2. Although not all cities/metropolitan areas performed physical demonstrations, all six of them used and applied the **HARMONY MS**. Specific guidelines on modelling tools have been developed in the ***HARMONY Guidelines on Modelling Tools for Sustainable Urban Mobility Plans in the New Mobility Era*** **(reported in Annex).**

For instance, Athens used the HARMONY MS and is planning to use this modelling tool to test and assess measures and solutions adopted in the municipal SUMPs before their implementation as well as to evaluate and quantify their impacts in the Athens area. Similarly, Turin simulated specific strategies and scenarios of the metropolitan SUMP on the HARMONY MS, involving stakeholders in their development and integrating the actions emerging from the co-creation labs, for example in terms of shared taxi services, e-scooters, and motorcycles. Turin's SUMP adopted the results of the finalized activities. Also, GZM is aiming to transfer results from the HARMONY MS application in order to assist the local authority in planning the metropolitan-wide transport, introducing new forms of mobility and updating their SUMP.

As for the **physical demonstrations**, HARMONY aimed at demonstrating electric autonomous vehicles (AVs) and drones in real-life conditions integrating them with the traditional transport modes to understand the requirements, reactions, barriers and collect real-world data. AVs and drones data were combined with socio-cultural, economic, spatial, and environmental data to derive thorough information to feed regional SUMPs.

The main lessons learned, challenges and success factors deriving from the three performed physical demonstrations are presented in the paragraphs below.

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3.1 Drones

Drones, known as UAVs or UAS (Unmanned Aerial Vehicles/Systems), can be used for several purposes: military, delivery, emergency rescue, agriculture, in outer space, wildlife and historical conservation, medicine, photography, etc. Their use in urban spaces is quite new and this should be addressed by European, national and local authorities to understand how they can be used, what are their benefits, challenges, and how to regulate them. The HARMONY project, along with other European projects, supported this process.

In this spirit, the European Union Aviation Safety Agency (EASA) conducted a study on the societal acceptance of Urban Air Mobility in Europe[43] (2021), which reports that new technologies such as the enhancement of battery technologies and electric propulsion as well as major investments made into start-ups are enabling the development of UAM. Thus, UAM – defined as an air transportation system for passengers and cargo in and around urban environments – may be deployed in Europe within the next 5 years, offering the potential for greener and faster mobility solutions.

Citizens' and future UAM users' confidence and acceptance will be critical to success. The study examined the attitudes, expectations and concerns of EU citizens with respect to UAM and revealed interesting insights, some unexpected. The results show that EU citizens are calling for active and pre-emptive measures from competent authorities. In addition to mitigating risks related to safety, security, noise and environmental impact, these measures are expected to ensure that UAM will be a common benefit to all of society by offering affordable, integrated and complementary mobility. By providing transparent and timely information and guidance, the authorities at all levels – local, national and European – have the chance to consolidate public acceptance of UAM.

As described in Chapter 2, in the **HARMONY case-studies, drones were tested in Trikala and Oxfordshire; the first for medical delivery purposes and the second for multiple purposes: parcel, gift, tools, and medical equipment delivery**.

The purpose of the drone demo in **Oxfordshire** was to explore stand-alone trials of drones to hasten deliveries (especially in a medical use case) to demonstrate new mobility freight delivery mechanisms could work in parallel, jointly. The overall objective was to pilot drones in real-life conditions integrating them with traditional PT modes to understand the requirements, reactions and barriers and collect real-world data, looking to advance mobility sustainability by reducing emissions and congestion. The trials at Milton Park, which included the delivery of a defibrillator, successfully highlighted that the mobility technologies tested enabled increased efficiency and speed of freight delivery. In the case of Oxfordshire, the initially planned passenger transport demonstration was not performed due to time constraints; therefore, the demo focused only on freight.

Trikala's drone demo aimed at delivering medicines from a pharmacy logistic centre to pharmacy stores. Afterwards, each pharmacy store could deliver the medicines through ground mobility modes to elderly groups and other vulnerable social groups with limited accessibility to mobility services.

The scope of Oxfordshire's demo was broader compared to the one in Trikala, which was aimed at testing emergency deliveries through drones.

Nonetheless, both physical demonstrations with drones, in Oxfordshire and in Trikala, faced several **challenges**, including legal restrictions to test drones in urban spaces and a long authorization process to proceed with the demo; privacy, cybersecurity and data storage concerns, and the general restrictions and delays caused by the pandemic (that sometimes even contributed to the change of the drone provider, as it was in the case of Trikala). A common issue amongst projects dealing with UAV's is uncertainty around how to engage with other stakeholders and the number of underlying variables present when scoping a potential project[44].

[43] https://www.easa.europa.eu/sites/default/files/dfu/uam-full-report.pdf

[44] https://www.gov.uk/government/publications/projects-selected-for-the-regulators-pioneer-fund/projects-selected-for-the-regulators-pioneer-fund#fn:2

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Table 3 illustrates all challenges faced in HARMONY's physical demonstrations with drones.

Table 3. Common and individual challenges in HARMONY drone demonstrations case-studies

Challenges	Trikala	Oxfordshire
Restrictions on UAV trials based on flight paths (especially over railway lines, in the UK, or in central areas of the city in Greece), purposes (e.g., medical delivery), weight, payload within certain regulatory limits, etc. For instance, door-to-door deliveries with drones are not allowed in Greece.	X	X
A long and multi-phased **authorization process** for the drone provider (on technical requirements) to obtain the permission by the national Civil Aviation Authority (CAA) was needed to perform the drone demonstration.	X	X
New **safety** risks to the urban environment, as the impact from the probability of crashes or collisions (even with the highest standards of airworthiness) increases in a densely populated air space. Safety challenges in urban and public areas highlighted the need for traffic models.	X	
Privacy, cybersecurity and data storage concerns (in the UK, due to Information Governance for Brexit).	X	X
Absence of technological equipment and investment and lacking U-space monitoring tools and methods. A regulatory framework like the U-space is based on a highly evolved technological infrastructure which is presumably costly to set up, manage, and to be accessed and utilised by UAM service providers.	X	
The municipality, users and stakeholders' **scepticism** in relation to drones.	X	
The **pandemic** and the **general lockdown** have been an essential barrier limiting physical meetings, stakeholders' participation to co-creation lab activities, including surveys, as well as to physical demonstrations. This has also been a bottleneck for the potential operator and drone provider (Trikala). There was also the concern that a lot of the data from traffic management and other sources might be less meaningful because of the lockdown period (Oxfordshire).	X	X

The drone trials in Oxfordshire and Trikala also highlighted some insightful **success factors** in drones used for delivery, including a decrease in delivery time, since no traffic congestion is confronted in the third dimension and the route is optimized to straight line, when possible.

In addition, in Trikala's demo, no errors were noted during the testing phase, hence no time for error fixing was needed. As per the Oxfordshire's demo, other success factors were the sophisticated road traffic control centre, a safe and controlled environment for innovative exercises, the preparation of contingency plans for demo locations, and the identification of multiple partners from other projects that could provide complementary and supplementary benefits.

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Table 4. Success factors in HARMONY drone demonstrations case-studies

Success factors	Trikala	Oxfordshire
Presence of a sophisticated road traffic control centre		X
Existence of safe and controlled environment for innovative exercises		X
No errors were noted during the testing phase, hence no time for error fixing was needed	X	
Prepare contingency plans for locations of demonstrations		X
Identify multiple partners from other projects that can provide complementary and supplementary benefits		X
Decrease in delivery time, since no traffic congestion is confronted in the third dimension and the route is optimized to straight line, when possible	X	X

The lessons learned and success factors identified in the drone demonstrations carried out in Trikala and Oxfordshire confirm some of the challenges and success factors identified in the EASA's study (2021) mentioned above.

In the spirit of informing citizens, increasing awareness and better understanding people's thoughts on UAM, the HARMONY cities/metropolitan areas conducted **surveys on UAM**. For instance, GZM organized co-creation activities with local stakeholders specifically focused on drones, aiming to analyse the public acceptance of drones on its territory. Interestingly, GZM feedback on drones are aligned with the responses received in Rotterdam and Oxfordshire surveys, meaning that **the most acceptable function of drones** in GZM is the one **for medical transport deliveries**.

Finally, it is important to note that in Oxfordshire one of the drone trials was combined with an electric van (originally planned with an AV). This physical demonstration aimed at testing the multimodal efficiency of drone + EV and demonstrating parallelisation of new mobility freight delivery mechanisms, in order to reduce emissions, congestion and noise levels. The demo successfully highlighted that the mobility technologies tested enabled increased efficiency and speed of freight delivery.

3.2 Autonomous Vehicles (AVs)

As per the autonomous vehicles (AVs), the metropolitan area that tested this new mobility technology is the city of **Rotterdam**.

The demo with the AV **ROSIE**, already described in detail in section Demonstration activities and achievements, was one of the first trials in the Netherlands. The purpose of the demo was to contribute to answer some learning questions, mainly related to the improvement of urban freight transport, the functions, role and impacts of self-driving robots, and whether they can provide insights to traffic modelling, energy consumptions, and so on.

ROSIE was tested in multiple traffic situations with cyclists, pedestrians, obstacles (static/moving), crossing intersections, roundabouts, respecting traffic lights. The communication between ROSIE and intelligent traffic light (ITL) was also set up and tested multiple times, using the ITL to cross a complex intersection safely. Then, ROSIE was tested on unpaved roads, on multiple slope degrees, in rainy and slippery conditions.

In addition, the energy consumption of ROSIE was calculated per delivered unit compared to an electric delivery van. On average, ROSIE consumes 7,1 times less energy than the average delivery van when

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they have the same volume capacity and on average drive the same distance per hour[45]. Hence, it can be said that ROSIE is more efficient.

Nonetheless, the AV demonstration carried out in Rotterdam encountered the following **challenges**. In addition to the pandemic restrictions, which limited and delayed the physical demonstration, in order to conduct any test with AVs, there is a long process to obtain permissions. The legal framework establishes strict rules that needed to be followed to conduct the demo of ROSIE in the Future Mobility Park (area dedicated to innovative physical demos).

From a technical standpoint, ROSIE is limited in its speed, it can detect obstacles, but it encounters difficulties when the obstacle is at a shorter distance, which limits its efficiency. In other words, at this stage, the added value of ROSIE is still hard to be defined. Technical challenges in its development contributed to delays in its physical demonstration. Finally, it is still not clear yet whether AVs are publicly accepted given that, as of today, most AVs are not economically viable yet: they are costly for logistics providers, although they are expected to become cheaper in the near future.

As for the **factors** that contributed to **successfully demonstrate** the autonomous robot, it is crucial to mention that the robot ROSIE had already been tested in the Erasmus University Campus at the end of 2021 (as part of another project). Furthermore, an alternative plan was set up in a short amount of time on self-driving delivery vehicles for last mile logistics. 169 drives of ROSIE were completed, reporting consistent results among multiple testings. From a technical standpoint, before testing on public roads is possible, the area or areas where the AV was driven were mapped in ROSIE and a begin and end location were included in the map. The mapped route was driven once without any interventions before the testing.

Table 5. Challenges and success factors in HARMONY AV demonstration case-study

Challenges	Success factors
The **pandemic** and the **general lockdown** have been an essential barrier limiting and delaying physical meetings, stakeholders' participation to co-creation lab activities, including surveys, as well as to physical demonstrations with AVs.	**Carry out multiple tests** and choose autonomous vehicles that have **already been tested before** in other locations and different situations
A long and multi-phased **authorization process** to obtain the permission to conduct a demonstration with an AV	**Set up alternative plans** in case of difficulties (alternatives to the initially defined plan)
Technical challenges in terms of AVs' speed and efficiency in detecting obstacles	**Record all results** from all tests and **assess the consistency of these results**
Scepticism and **uncertainty about AVs public acceptance**	**Map the area/areas where the AV will be driven** for testing
AVs are still **very expensive** to be used by logistics providers for last mile delivery purposes	**Drive the mapped route without any interventions before testing the AV**

Finally, a number of KPIs (showed in the Table 6) were measured dividedly within the questions and results were evaluated on them.

[45] The energy consumption data derived from the above-mentioned tests was then compared with the energy consumption of three electric delivery vans. The comparison was done taking into account the duration of each test and the volumes of the robot and vans for parcels.

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Table 6. KPIs to evaluate ROSIE's performance

KPIs	Description
Continuity	number of stops during the traffic situation
Deviation time	number of seconds before the robot has physically changed its path
Distance until ITL	number of meters the robot has until passing the ITL
Dealing with a slope or curb	robot drives a slope or curb successfully without any problems
Duration of overtaking	number of seconds that overtaking by the robot has taken place
Reaction time for colour change	number of (milli)seconds before ROSIE stops when the ITL light switches
Robot speed	km/h of the robot during intervention

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4 Conclusions and policy recommendations for the new mobility era

The HARMONY project has delivered a wealth of knowledge on transport modelling applications and new technologies and mobility services. It was able to test these in 6 metropolitan areas, which often led to test results shaping the local SUMP.

No passenger transport demonstration was performed in the end, due to time constraints. Therefore, the demos mentioned above and in the policy recommendations below focus only on **freight**.

For both **autonomous vehicles and urban air mobility**, cities had to address a range of challenges, such as safety, security, privacy, environment and noise.

Interestingly, it turned out that in the context of pandemics, drones can be an asset: the pandemic was considered as an opportunity for urban air mobility, especially in terms of social distancing which helped reduce the need of moving with public transport, and, in these circumstances, drones were used to disinfect surfaces (public benches, etc.).

Nowadays, cities have a toolbox of options at their disposal to help them advance urban mobility. An increasing number of European cities happily take on a leading role in testing and regulating the use of new mobility services, including autonomous vehicles and urban air mobility – with the hope that these types of mobility will be a reality in Europe in a close future.

For this to happen, current rules governing these new technologies need to evolve – this is where cooperation with regulatory bodies at national level is crucial. For drones for instance, airspace is an exclusive competence of the State, but it will have implications at the regional and local levels. The current regulation in European countries is very restrictive and prohibits flights in the urban environment. However, new European legislation more appropriate to current needs is expected, which foresees various use cases and will establish a set of requirements for carrying out flights. Along with national governments, urban air mobility in the EU is governed by the European Union Aviation Safety Agency (EASA). In June 2022, the agency published guidelines[46] for the operation of air taxis in cities – the first comprehensive proposal by a global aviation body. Flight platforms developed in cities will therefore have to adapt to the new technical regulations, and drones used in trials will need to undergo aeronautical certification tests.

At the end of the day, it is up to both cities and companies to put these new technologies into real-world use, and develop them into usable services so that all can benefit.

Based on the learnings from the HARMONY project, the following chapters propose a set of policy recommendations on drones, autonomous vehicles, as well as on innovative sustainable urban mobility planning.

4.1 Policy recommendations on drones

Urban air mobility, especially drones, is opening a new chapter for aviation but also for urban networks and services. In case of urban freight, point-to-point air connections can help to optimise the efficiency of surface transport, streamline and complement logistic chains, while saving time and reducing pressure on urban infrastructures.

Research and innovation help drones and urban air mobility to become not only more safe and secure, quiet and green but also more accessible, affordable and acceptable by the public. A growing number of collaborative research and innovation projects, such as HARMONY, are addressing drones for transport applications and urban air mobility. HARMONY pilots on drones took place in Trikala and

[46] https://www.easa.europa.eu/en/newsroom-and-events/press-releases/easa-publishes-worlds-first-rules-operation-air-taxis-cities

Oxfordshire. They have been developing new know-how and tested innovative solutions that help to make transport safer, more resilient and more environmentally friendly.

As demonstrated in Trikala, urban mobility could be useful for the bypass of some routes for medical supply delivery for urgent and time-critical cases. What can be claimed is that handling the transferring of crucial goods (such as medicines) by air, decreases the delivery time, since no traffic congestion is confronted in the third dimension and the route is optimized to a straight line if possible.

In Trikala, the local police has also shown interest in drones to grant safety and enable monitoring. This was not the purpose of the HARMONY demo (being in this case last-mile delivery/urban logistics); nonetheless, safety monitoring is indeed a possible application for drones to be further explored. With that in mind, Trikala plans to widen the use of drones, collect more data on last-mile deliveries and evaluate more deeply the impacts (technical and economical), and counter the disruptive impacts. An urban air mobility service could be developed from the experiences of the HARMONY pilot. It has the potential to improve the everyday life of citizens by decreasing the delivery time, reducing operational costs and operating in a safer way promoting social distancing if needed, like in the context of the COVID-19 lockdowns.

The emergence of these innovative technologies can appear to be disruptive in the eyes of cities and their citizens. However, if planned and designed adequately, technological advances and new mobility services are making it possible for citizens to cross town ever more efficiently and safely. There is a need for local authorities to engage with new developments in order to remain competitive and enable industry growth, while also not compromising safety. That is where these key recommendations from HARMONY are trying to help:

- ✓ **Cities and citizens' needs:** Identify your local needs to determine the specific use of drones: in the case of GZM, two uses were considered: 1) for environmental protection, e.g., to monitor waste, water resources, coal mines dumps, and fires, and 2) for medical purposes and deliveries between hospitals and laboratories. The second option was the successful one: it helped to overcome the problem of poor infrastructure and traffic congestion, while supporting the development of sustainable mobility. Conduct a feasibility study if necessary.

- ✓ **Stakeholder engagement:** First start to engage stakeholders and analyse public acceptance of innovative technologies. Only then, proceed with technological demonstrations. Develop a survey to understand citizens' preferences for urban air mobility services and drone deliveries, use drone delivery games aiming to analyse people's preferences for to use of drones, etc. Set up a contact point (a municipal incubator) to inform citizens and stakeholders on drones' application and to foster the market by promoting investments locally and nationally (e.g., start-ups).

- ✓ **Co-creation:** It is important to foster co-creation for the use of drones to be successful. in Trikala, a number of crucial stakeholders, such as local pharmaceutical warehouses and pharmacies, the National Union of Pharmacists and Union of Pharmacists in Trikala, the Medical Association of Trikala and Greece, and citizens were involved in the organisation of the co-creation lab activities. The geographical routes served by drones in Trikala have been planned in conjunction with all stakeholders. The bottom-up approach of the participatory process was well structured and stakeholders collaborated smoothly; both these factors contributed to the success of the co-creation lab.

- ✓ **Drones' function:** As part of HARMONY, it appeared that the most acceptable function for drones is the one for medical transport deliveries; while the least favourable use corresponds to surveillance or for delivering other items such as clothes, illegal items, or mail.

- ✓ **Geographical scope:** Rural areas or villages appeared to be the most preferred delivery areas as part of the project.

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- ✓ **Combination of new technologies:** Go one step further with integrated freight delivery which combines electric vehicles (EVs) and drones in real-life conditions. Oxfordshire conducted a drone and electric van trial showcasing integrated freight delivery. The purpose was to explore the integration with an EV to demonstrate parallelisation of new mobility freight delivery mechanisms. The pioneering combination of technologies used throughout these demonstrations were the first of their kind, looking to advance mobility sustainability by reducing emissions, congestion and noise levels. The trials successfully highlighted that the mobility technologies tested enabled increased efficiency and speed of freight delivery.

- ✓ **Inclusion of urban air mobility into SUMPs**: Introduce urban air mobility such as drones into your SUMP. Thanks to HARMONY and to the close collaboration with the UCL MaaS Lab, the integration of drones and urban air mobility into the mobility sector of GZM was added as one of the objectives in the SUMP draft. The aim is to treat drones as part of mobility services (2035-2050) to decongest cities and decrease air pollution, using these innovative technologies to optimize last-mile deliveries. Similarly, Oxfordshire integrated HARMONY project recommendations on urban air mobility technologies into the regional spatial and transport planning strategies.

- ✓ **Urban air mobility commission:** Like in Trikala, establish a mobility body at city level for the organised planning and management of applications of intelligent transport systems. Nominate an local manager for Intelligent Transport Systems and/or an urban air mobility committee.

- ✓ **Legal compliance:** Cooperate with the Civil Aviation Authority to ease authorisation processes for urban air mobility, and focus on legal compliance to reduce the risk and barriers in deploying new innovative technologies rapidly for the public good.

- ✓ **Infrastructure:** Proceed with a gradual development of infrastructure and services after research studies.

- ✓ **Know-how acquisition:** Deliver training courses to local staff: the GiSeMi HUB, a joint initiative of the Municipality of Trikala and e-Trikala SA, bought drones and delivered 50 training courses and free certifications for companies to use drones. In the future, GZM also aims to pilot drones and to educate public officials in drones with a focus on GDPR issues, how to use them, technological and legal aspects, to increase the possibility of implementing use cases, and to involve them for medical use. Participate in national and European research programmes on urban air mobility to ensure the provision for the development of distribution systems using drones for freight transport deliveries.

- ✓ **Cooperation with similar projects:** Find synergies with other local, regional or national projects related to urban air mobility (including local authorities, public transport providers, universities, NGOs, associations, foundations, etc.).

4.2 Policy recommendations on autonomous vehicles

Last-mile deliveries are one of the hardest of the whole freight transport chain. But there is a lot of room to innovate and to try and make things better, for instance with autonomous vehicles (AVs). AVs could very well be one of the technological advancements that will usher in cleaner, quieter and healthier cities that provide a better quality of life to all residents and reduce our environmental impact.

AVs represent more than just self-driving cars: they are part of a broader shift away from congestion, pollution, and shrinking urban space. They represent an avenue to open up new possibilities for society, individuals and our environment. AVs are part of the palette of solutions that cities have for more efficient and sustainable city logistics.

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As part of HARMONY, AVs have only been tested in Rotterdam via Rosie 2.0, which demonstrated that the use of robots could potentially cut costs for urban freight deliveries. At the same time, with both the move towards AVs and increased uptake of home deliveries, curbside space is likely to become significantly more valuable, with a need for drop-off space and idling locations.

AVs, when used in freight scenarios and shared-vehicles (rather than private-ownership), also have the potential to free up road space, due to more efficient driving and convoying options. When paired with a move towards micromobility and UAVs and the impetus to create modal shift away from single occupancy vehicle usage taking some vehicles off the roads, infrastructure needs are likely to shift and allow for greater and more equitable space allocation towards active and sustainable modes of transport.

Key policy recommendations to cities wishing to take up AVs for freight and passenger transport are as follows:

- ✓ **Regulatory readiness:** Get an overview of the rules from operators and municipal departments and cooperate with the national level for an adaption of national legal frameworks.
- ✓ **Technology readiness:** Cooperate with companies to ensure that the technology meets your specific local needs: clarify functions or the role of AVs within the city and tailor them to your needs.
- ✓ **Business case:** Ensure that AVs are economically viable, especially for logistics providers.
- ✓ **Public acceptance:** AVs need to be publicly accepted, which requires stakeholder engagement and co-creation.
- ✓ **Coordination with stakeholders:** Understand citizens' needs, preferences, and gain their acceptance.
- ✓ **Efficiency:** For AVs to have an added value, they need to be more efficient than other vehicles – both in terms of energy efficiency, but also space efficiency, etc.
- ✓ **Infrastructure:** Ensure the provision of sufficient and strategic drop-off space and idling locations.

4.3 Policy recommendations on innovative sustainable urban mobility planning

As previously mentioned, the seamless integration of AVs, drones or other innovative mobility services into the transport system happen during the planning process. This has been tested in the 6 metropolitan areas part of the HARMONY project.

HARMONY's impacts on planning have been detailed in chapter 2. They highlight the importance of a **bottom-up approach e.g. with co-creation labs.** In addition to co-creation labs, the metropolitan areas gained experience and acquired knowledge on their mobility trends and future expectations from the **application of transport modelling tools, but also from surveys and workshops**.

In particular, the application of the HARMONY MS has been beneficial to the **update of transport policies and of SUMPs in some metropolitan areas.**

For instance, **Athens conducted transport simulations, through the development of city-specific models at the strategic and operational levels**. Athens is planning to use the HARMONY modelling tool to further test and assess measures and solutions adopted in the municipal SUMPs before their implementation, as well as to evaluate and quantify their impacts in the Athens area.

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Similarly, **HARMONY helped with the simulation of specific strategies and scenarios of the metropolitan SUMP in Turin**, involving stakeholders in their development and integrating the actions emerging from the co-creation labs. In **Turin, the HARMONY project contributed to update the metropolitan SUMP and integrated a few objectives and measures regarding innovative mobility technologies**, such as the intensification of electric vehicles and sharing mobility, the electrification of public transport, and piloting of autonomous vehicles.

Trikala's SUMP was finalised during the project and has been approved in 2020. **Following the project, the adoption of new, smart solutions and technologies - "Smart" applications is one of the main axes defined in the SUMP of Trikala's SUMP.**

GZM's SUMP is still under development until mid-2023. GZM is aiming to apply the results from the HARMONY MS in order to assist the local authority in planning the metropolitan-wide transport, introducing new forms of mobility and updating its SUMP. The HARMONY project contributed to **the integration of drones and UAM as one of the objectives of GZM's SUMP**. The aim is to treat drones as part of mobility services (2035-2050) to decongest cities and decrease air pollution, using these innovative technologies to optimize last-mile deliveries.

In **Rotterdam**, the development of a **more sophisticated simulation tool for analysis is part of the SUMP process**, in which HARMONY results will take their place as far as automated transport is concerned.

In **Oxfordshire**, the **HARMONY MS was used to evaluate the impact that innovative technologies will have in the innovation space**. HARMONY enabled Oxfordshire to create a blueprint for new developments in the form of suggestions to developers and transport planners.

Based on the individual case studies examined, it can be concluded that that the HARMONY MS can contribute to reach the SUMPs goals, with the already developed models. In most cases, measures proposed by the municipalities' SUMPs can be modelled and tested with the HARMONY MS to check their efficiency and efficacy on network operation, while, conversely, other actions, not currently included in the SUMPs, can possibly be tested against them. The modelling experience can provide relevant insights and, eventually, result in an update of the respective SUMPs in a data-driven manner.

Overall, planning and implementing new mobility services and technologies can still appear to be challenging due to the **lack of institutional frameworks and existing infrastructure**. However, many HARMONY cities are committed to gradually overcome the obstacles.

HARMONY policy recommendations for planning at the strategic level include:

- ✓ **Transport modelling at the service of SUMPs**: Transport modelling can help local authorities in planning the metropolitan-wide transport, introducing new forms of mobility and updating their SUMP. Modelling can also encourage planners and developers to consider innovation within planning and development, e.g. integrating Innovation Plans, Supplementary Planning Documents (SPDs) and Local Plans for new developments.

- ✓ **Inclusion of new technologies and mobility services into SUMPs:** Cities should include the application of smart technologies into their SUMP in the form of "Innovation Frameworks", Intelligent Transport Systems (ITS) applications in information, traffic management, etc.

- ✓ **Regulatory framework and infrastructure:** SUMPs should also envisage the provision of regulatory frameworks and infrastructure for pilot tests of new technologies.

- ✓ **Institutional framework:** Cities could envisage to establish a mobility body at city level to organise the planning and management of applications of new technologies and mobility services. Like Trikala, they could appoint a local manager for Intelligent Transport Systems and/or on urban air mobility.

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- ✓ **Investments:** SUMPs should also ensure that investment for innovation, including new technologies and mobility services, is sufficient.
- ✓ **Bottom-up approach:** Successful SUMPs are the result of a long participatory process with local stakeholders and citizens, including co-creation labs as a success factor.
- ✓ **Quality of life and jobs:** New mobility services and technologies can contribute to the quality of life of the residents and create new specialised employment positions in cities.
- ✓ **Savings:** New technologies and mobility services can eventually result in cost and labour savings as well as in a functionally optimal transportation system that supports and satisfies the city's needs.
- ✓ **First positive step:** Cities who tested new technologies as part of the project continue to envision a future with smart systems at the service of citizens.
- ✓ **Knowledge acquisition:** To compensate obstacles such as the lack of institutional frameworks and infrastructure, cities should acquire experience and know-how by participating in national and European research programmes on the subject.

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Annex: Modelling tools for Sustainable Urban Mobility Plans in the new mobility era

These guidelines are aimed at providing local planning authorities guidance on transport modelling applications in their Sustainable Urban Mobility Plan (SUMP) implementation process. They build on the concept of SUMP, as outlined by the European Commission's Urban Mobility Package[47] and described in detail in the European SUMP Guidelines 2.0 (second edition)[48].

As mentioned in the SUMP Guidelines, *a transport model can be used to generate reliable and consistent input to the SUMP process, specifically in certain planning stages such as scenario development, measure appraisal and selection, and monitoring. Modelling results help to predict the impact of different combinations of policies and measures, taking into account the complex interactions and potential reinforcing or rebound effects, thereby helping to define the most effective integrated packages. Beyond their use to define the baseline scenario, they also enable regular monitoring of changes in the transport system during the implementation phase to assess whether you are on track or if you need to react and adapt your actions*.

These guidelines will help public authority planners and practitioners from various levels of government (from local/city level to regional, national and European), with a broad variation in their level of expertise in relation to mobility and planning, **to answer to the following questions**:

- What transport models are?
- What transport models can do?
- What are their challenges and limits?
- Is a transport model really needed to draft a SUMP?
- What kind of model should be used?
- What are the development steps of a model? When such steps are to be taken within the SUMP planning cycle?
- What are the roles and responsibilities when developing a transport model to support a SUMP?

Transport models are simplified representations of transport supply, transport demand and their interaction in a given context (e.g., mobility within a city). However, the purpose of building transport models is not to create simple versions of existing conditions: transport models are built to simulate the effect of modifications of such existing conditions.

Mobility, as well as the wider social, economic, demographic context, is continuously changing. Change makers are background conditions (e.g., demographic trends, economic growth); behavioural adaptations (e.g., preference for sustainable solutions) and policy interventions. Some of these sources of change correspond to modifications of some elements of transport models: input variables or parameters. Therefore, by changing input variables and parameters, alternative conditions can be simulated and the resulting effect on mobility can be estimated. In a nutshell, **transport models allow to do experiments, anticipate the effect of exogenous trends and assess policy measures**.

However, **transport models cannot do everything**. Their responses are necessarily affected by the explanatory power of the theory underlying algorithms and parameters, by the quality of data, by the amount of time and resources that are devoted to their development. Transport models are not one-fits-for-all solutions providing estimations on everything, but useful tools which should be built and used for the specific purposes they are capable to handle being aware that they cannot invent solid responses out of limited knowledge.

47 Annex 1 of COM (2013) 91.

48 Rupprecht Consult (editor), Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan, Second Edition, 2019.

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A **transport model is not necessarily the only method to estimate the impact of policy measures and support the development of a SUMP**. Alternative, simpler, methods are realistic options in case of simple context, which are common in smaller towns and cities, where, furthermore, data, time and resources are often limited. **In more complex contexts, without a transport model, only rough and often qualitative indicators can be estimated**. So, in those contexts, the conditions where a model is not applied are also conditions where planning is quite poor. This conclusion does not mean that using a transport model ensures that the plan will be a high quality one. Models are tools and the results depend ultimately on how they are used rather than on their theoretical potential.

Assuming that the application of a transport model is considered the appropriate way to proceed, the following step is **selecting the type of model**. There are different types of transport models, more or less articulated, with different capabilities. One may wonder which type of model is the most appropriate for supporting a SUMP. Again, the answer depends on case by case. Considering some aspects can help to choose.

Are transport models useful tools for developing SUMPs? Yes, they are. Are there some types of transport model more useful than others to support the development of SUMPs? Yes, there are.

The answers to these to questions are undisputable. Nevertheless, they do not bring to a unique recommendation, because **specific circumstances matter**. Building transport models is not a quick and cheap task, it requires expertise and the availability of data. When the mobility context is reasonably simple and the content of the planning is necessarily simple as well, a transport model is not necessarily required. When resources, time, expertise, and data is poor or lacking, developing a transport model is simply unfeasible.

Transport models are not crystal balls opening a sight on the actual future. They are tools based on simplified representations of conditions, options, behaviours. They depend on information and cannot transform poor data into reliable forecasts. Using transport models means doing an effort to get estimations. And estimations inherently include some degree of uncertainty. Notwithstanding, it should be clearly understood that, whenever the planning context is articulated, any alternative to models can only provide coarser, more uncertain estimations than those of models or even only vague qualitative considerations. There is nothing less demanding than models but providing the same, or even better, results of models when the object of the analysis is complex.

Developing a model is a process requiring skills, data, time and resources. These guidelines provides a closer glance to this process and describe the **five main phases**: design, data collection and elaboration, implementation, calibration, application.

As it comes to **roles and responsibilities**, transport models are developed by experts (**modellers**) holding the required knowledge and experience as well as the necessary specialised software. Nevertheless, especially when the transport model is developed for a local administration to support an urban mobility plan, other actors play a role. One actor is the **local authority**, which ultimately should be the owner of the model and holds the political responsibility for the content of the SUMP. Another actor is the **planner team**, which is the technical arm of the local authority regarding the definition of the content of the SUMP. A third actor consists **of stakeholders**: transport operators (e.g. the providers of urban and non-urban public transport, car-sharing companies, etc.), specific categories of citizens like cyclists, disabled people, retailers and so on. Stakeholders can be involved in the definition of the SUMP in one form or another as they represent interests that can be affected by the plan.

The main actions and elements essential for implementing transport modelling as part of **the phases of the SUMP cycle** are finally introduced. We identify crucial aspects and recommend concrete actions to the general guideline cycle, to encourage urban planners to better integrate transport modelling in their SUMPs.

The document has been drafted within the **Harmony project** (www.harmony-h2020.eu), within the WP8 (Process assessment, SUMPs recommendations and roadmaps) activities, and takes advantage from the project achievements related to the development of the Harmony Model Suite and its application to case studies in Rotterdam (NL), Oxfordshire (UK), Turin (IT), Athens (GR).

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