ARIADNA

Awareness Raising and capacity building Increasing ADoption of EGNSS in urbaN mobility Applications and services

D3.1 – The role and challenges of GNSS for Urban Mobility & Public Transport

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[1] PU = Public | CO = Confidential, only for members of the consortium (including the Commission) | CL = Classified, information as referred to in Commission Decision 2001/844/EC

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Table of Contents

Index of tables

Index of figures

Glossary

ADAS	Advanced Driver Assistance Systems
ARIADNA	Awareness Raising and capacity building Increasing ADoption of EGNSS in urbaN mobility Applications and services
CAGR	Compound Annual Growth Rate
CAV	Connected and Autonomous Vehicle
COVID-19	Coronavirus Disease 2019
DRT	Demand Responsive Transport
EGNOS	European Geostationary Navigation Overlay System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IVS	In-vehicle Systems
MAAS	Mobility as a Service
MSP	Mobility Service Provider
OBU	On Board Unit
PAYD	Pay as You Drive
PND	Personal Navigation Devices
PTA	Public Transport Authority
PTO	Public Transport Operator
RUC	Road User Charging
WP	Work Package
ADAS	Advanced Driver Assistance Systems

1. Executive Summary

This document includes an analysis of the main trends that can impact the development of the GNSS market. The rise of Mobility as a Service (MaaS) schemes, with Public Transport being the centrepiece of urban mobility, the different services that encompass the so-called shared mobility, and the evolution of autonomous mobility are the main identified levers for the growth of GNSS technology.

With the main objective of identifying these trends and the challenges ahead, a precise methodology was defined including a survey with Public Transport Operators, Public Transport Authorities and Cites, in depth interviews with experts and desk research. This methodology allowed us to identify challenges for the GNSS market based on the industry point of view: accuracy, robustness, lack of signal availability, low frequency and battery consumption emerge as the main barriers to be overcome.

A thorough list of use cases for the usage of GNSS applications has been developed, including cases for public transport, shared mobility schemes, geofencing and fleet management.

Finally, several best practices regarding the use of GALILEO for public transport and other mobility services (shared mobility) are highlighted.

2. About ARIADNA

Urban mobility is becoming an issue of great importance in today's society due to the increasing population movements towards big cities and the exponential growth of cities in developing countries. Today, urban mobility schemes are evolving faster than ever mainly due to social, economic and technological changes. The traditional choice between walking, taking public transport or buying a car is being extended with a wide range of new flexible mobility services, such as vehicle sharing and ride-hailing.

Those shared mobility services are blurring the lines between private and public transport, with the potential of displacing car ownership but also traditional transit systems. The adoption of autonomous vehicles will only accelerate this trend. There's the need for public transport authorities, operators and industrial providers to prepare for this change and adopt the necessary tools to manage the mobility services of the future in a more flexible and efficient way.

EGNSS has the potential to enhance the quality of public transportation, by reducing operational costs, reducing traffic and providing savings in time and fuel, while fostering the development a wide range of new shared mobility services.

ARIADNA aims at supporting the adoption of EGNSS for public transport and urban mobility, by raising awareness on GALILEO and EGNOS benefits among the different stakeholders involved and supporting the introduction of new solutions provided by SMEs and start-ups. The project builds up on experience gained from previous R&D related projects and the extensive network of stakeholders that can be reached through UITP and EIT Urban Mobility networks.

3. About this document

This document, Deliverable *D3.1 "The role and challenges of GNSS for Urban Mobility & Public Transport"*, describes the main mobility trends that are impacting the GNSS market worldwide (identifying at a technological level the expected evolution of this market), analyses the main applications that GNSS devices can offer for urban mobility services (including best practices), and raises the main challenges that GNSS technologies are facing in the urban mobility area.

4. Methodology

With the objective of fulfilling the purpose of the different tasks included in this document, we have designed a complete methodology that aims to cover the different opinions, points of view and types of sources over the urban mobility market and its potential evolution, the GNSS suppliers for this market, the main services enabled by GNSS and the challenges related to geo-positioning that are still not solved.

This methodologic approach stands out by the great amount and quality of the sources that have been consulted, offering a wide vision over the topics covered.

The methodology had four steps:

4.1. Survey

A timely survey[2] was launched in order to understand the stakeholders' point of view over the role of GNSS services in the post-COVID19 recovery phase. The survey consisted of 26 questions, taking less than 10 minutes to answer and 70 responses were collected.

We obtained a wide geographical spread of responses, having participants from the following countries: Argentina, Finland, Denmark, Brazil, Spain, Estonia, Belgium, Portugal, among others. In terms of role of each participant expert, the respondents' profile was:

[2] Link to the survey http://ariadna-project.eu/ariadna-survey-gets-traction

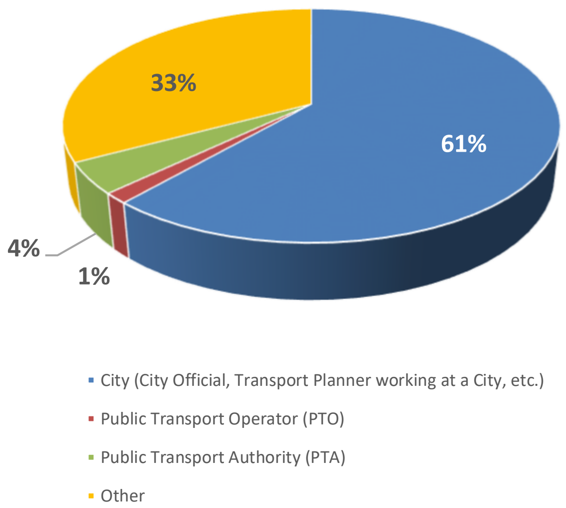


Figure 1. Respondents' profile

The questions addressed in the survey were the following:

ARIADNA Survey post-COVID19

1. Please indicate the type of stakeholder you represent: (If "Other", please indicate if Technology Provider, Consultant, Researcher, Mobility Expert, ...) *
    a. Public Transport Authority (PTA)
    b. Public Transport Operator (PTO)
    c. (Private) Mobility Service Provider (MSP)
    d. Other: ___
2. *(If PTA)* What is the name of the PTA you represent?
3. *(If PTA)* What is your geographical jurisdiction (city, region, country)?
4. *(If PTO)* What is the name of the PTO you represent?
5. *(If PTO)* What type of public transport service do you operate? (multiple answers possible) *
    a. Bus / Coach
    b. Metro / Subway / Underground
    c. Tram / Light rail
    d. Train
    e. Other: ____
6. *(If PTO)* Where do you operate your public transport service (city, region, country)?
7. *(If MSP)* What is the name of the MSP you represent?
8. *(If MSP)* What is the type of service you provide? (multiple answers possible)
    a. Bike sharing
    b. Kick scooter / e-scooter sharing
    c. Moped sharing
    d. Car sharing
    e. Car pooling
    f. Ride hailing
    g. Vehicle rental (car, motorcycle, …)

   h. Vehicle subscription (car, motorcycle, …)
   i. Other: ___

9. *(If MSP)* Where do you operate your service (city, region, country)?
10. *(If PTO, PTA, or MSP)* How many vehicles (approximately) are in your fleet? *
    a. Less than 100
    b. Between 100 and 1000
    c. Between 1000 and 2000
    d. More than 2000
11. Which Space Data are you using to PLAN or OPERATE your mobility service(s)? (multiple answers possible)
    a. Geolocation Data (GPS, Galileo, GLONASS, ...)
    b. Earth Observation Data (maps/satellite images)
    c. Other Earth Observation Data
    d. None of the above
12. Please explain briefly how do you use Geolocation Data to PLAN or OPERATE your mobility service(s):
13. Please explain briefly how do you use Earth Observation Data (please specify which) to PLAN or OPERATE your mobility service(s):
14. Do you store, and might make available Geolocation-related Datasets in your city (such as, for instance, latitude - longitude coordinates of a bus or tram fleet over a certain period)?
    a. Yes
    b. No
    c. I don't know
15. Are you using GALILEO for your Geolocation services?
    a. Yes
    b. No
    c. I don't know
16. *(If No)* Do you know what GALILEO stands for?
17. (*If No*) Could you briefly explain why aren't you using Geolocation data from GALILEO, yet? *
18. *(If I don't know)* Do you know what GALILEO stands for?
19. *(If I don't know)* Please indicate us your email, and allow us to approach you to let you know more about Galileo, Copernicus, and how ARIADNA, and the GSA can help you improve your mobility service(s)
20. The COVID-19 crisis has heavily impacted public transport ridership and mobility in general worldwide, due to the global lockdown and the need to adhere to new social distancing rules.

    [Please rate the following statements: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree]

    a. GALILEO Geolocation Data will help improve *EXISTING* mobility services during the crisis and the recovery phase
    b. GALILEO Geolocation Data will enable *NEW* mobility services and solutions to tackle the crisis and the recovery phase
    c. Earth Observation Data (maps/satellite images, other) will help improve *EXISTING* mobility services during the crisis and the recovery phase
    d. Earth Observation Data (maps/satellite images, other) will enable *NEW* mobility services and solutions to tackle the crisis and the recovery phase

21. Are you planning to modernise, or upgrade your transport solutions (e.g. infrastructure, IT systems, etc.) in order to be more efficient and sustainable, as part of your post-COVID-19 recovery plan?
    a. Yes, definitely
    b. Yes, probably
    c. Not sure
    d. No

22. What measures are you taking, or planning to take? (Multiple choice)
    a. Measures aimed at safer travel (e.g. sanitising measures, ensuring social distancing, contact tracing, etc.)
    b. Measures aimed at limiting mobility, such as reduced offer, reduced availability
    c. Updated infrastructure, such as e.g. pop-up bike-lanes, physical measures to ensure social distancing
    d. Real-time crowding information for passengers, and other IT-related measures, such as e.g. app-based
    e. solutions showing safe travel routes
    f. Economic incentives, such as to e.g. discounts to avoid concentration of passengers in rush hour
    g. Enhanced access and promotion of active travel schemes, i.e. walking, cycling
    h. Other: ___

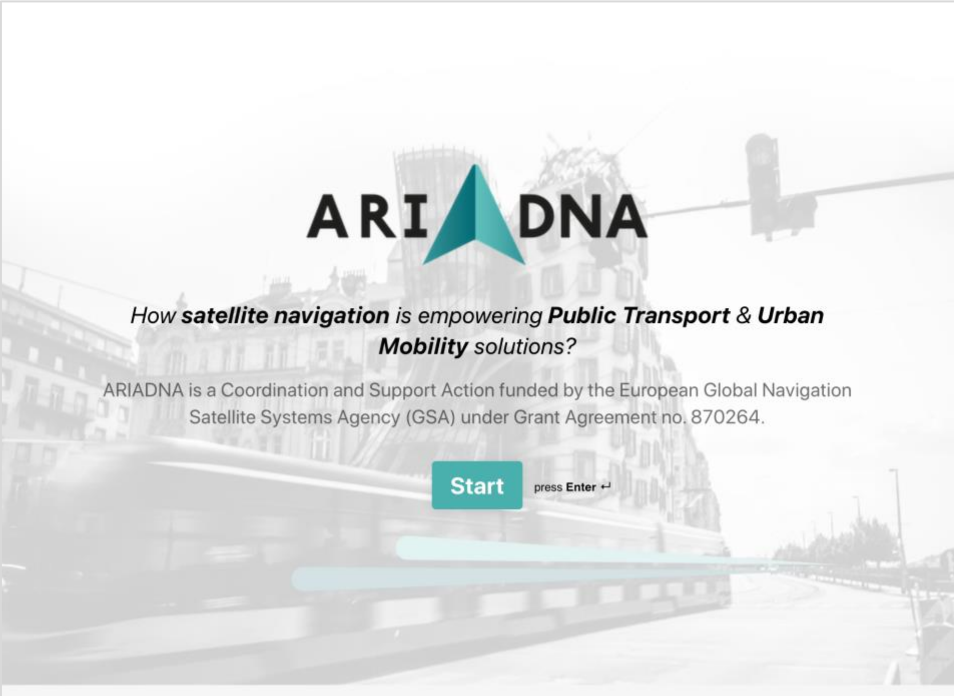
23. Please rate the following statements: (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree
    a. There is a need for sustainable transport modes to be a central pillar of the global economic recovery from the COVID-19 pandemic
    b. Space Data (Geolocation Data, Earth Observation Data) is needed, or useful, for implementing a strategy for more sustainable cities and transportation

24. Which indicators do you think can be monitored with Space Data (Geolocation Data, Earth Observation Data) as a support tool to a "go green" strategy for Cities?
    a. Emissions (e.g. COx, NOx, SOx)
    b. Location and use of different fleets (public transport, shared mobility services, etc.)
    c. Use of streets and roads
    d. Use of bike lanes
    e. Waste management efficiency
    f. Level of activity in ports, airports, public transport hubs
    g. Other: ____

25. Which support would you need from ARIADNA, and the GSA, in order to move to "go green"? In particular, regarding how to leverage Space Data.
    a. Technical Advisory Services
    b. Strategic Advisory Services
    c. Commercial Advisory Services
    d. Competitive Advisory Services
    e. All of the above
    f. None of the above

Table 1. ARIADNA Survey post-Covid-19

4.2. In-depth interviews



Aiming to understand the role of satellite navigation to empower Public Transport and Urban Mobility solutions, in-depth interviews with experts were conducted[3].

We have to highlight the role of the UITP in the completion of this task, more concretely in the distribution of the questionnaire among relevant GNSS practitioners (Public Transport Operators, Public Transport Authorities) in order to understand how they are applying GNSS in their daily operations, which are their main challenges and pains. The distribution of this questionnaire had two main targets:

- Relevant and active members at the Space4Cities Forum
- Technology and equipment GNSS suppliers, members of the IT x Public Transport group (ITxPT[4]) at the UITP

The questions addressed to the experts were the following:

Survey: How satellite navigation is empowering Public Transport & Urban Mobility solutions?

1. Tell us briefly about the services that you operate and your fleet (type of vehicles, number, average age, etc.)
2. In what ways do your services and operations make use of geolocation?

[3] Link to the interview guide: http://ariadna-project.eu/gnss-empowering-public-transport-urban-mobility
[4] https://www.itxpt.org/

3. Elaborate on how critical each of these aspects regarding geolocation are for you: a. Accuracy (difference between a receiver's measured and real position/speed/time) b. Integrity (a system's capacity to provide a threshold of confidence and, in the event of an anomaly in the positioning data, an alarm) c. Continuity (a system's ability to function without interruption) d. Availability (the percentage of time a signal fulfils the above accuracy, integrity and continuity criteria) e. Authentication (ability to provide a level of guarantee to users regarding the use of signals and data from actual Galileo satellites and not from any other source) 4. Are you facing any constraints related to geolocation? a. What type of constraints (technological, legal, financial, etc.)? b. What are they stopping you from doing? c. How would your services and operations immediately improve without any of those constraints? d. How would they improve in the long run (e.g. new functionalities/uses)? Do you have a specific roadmap or strategy revolving around geolocation? 5. Do you know what GALILEO / EGNOS is? Do you know the benefits it brings? 6. Are you aware of GALILEO being used in your operations? Have you implemented changes in your operations with the aim of benefitting from GALILEO technology? 7. If so, what was the main drive for such decision? How satisfied are you with GALILEO technology's performance? How has it improved your services and/or operations? What are you missing? 8. What part does geolocation play in public procurement processes? What requirements regarding geolocation do public tender documents include? 9. Are you aware of Earth Observation Programmes, such as Copernicus in Europe, and their applications in your field of activity? Are you using Earth observation data in any way (research, innovation projects, operations, etc.)? If not, are you aware of how it's being used or who is using it for urban mobility planning and/or service provision? 10. Please indicate the stakeholder you represent and your email (in case you want us to share with you the results of the survey)

Table 2. In-depth interviews guide

4.4. Desk Research

In order to complete the information provided by the experts, by means of the surveys and in-depth interviews, a desk research was carried out. This task was developed through the analysis of specialized reports, articles, websites and other sources of reliable information about urban mobility trends, GNSS and GALILEO, as shown in the References section.

5. Market Analysis

5.1 Mobility trends impacting on the GNSS industry

The current urban mobility trends and the introduction of innovative technologies are shaping the market transformation and its growth, leaving room for different players coming from the mobility area or the technological one.

We could highlight the most relevant mobility trends that can have an impact on the evolution of GNSS applications:

1. Mobility as a service (MaaS): although still an incipient trend in most of the regions, MaaS initiatives will play an important role over the mobility disruption in the coming years.

   Several reports highlight the great growth expected for MaaS market. Notably, a report from Verified Market Research[5] estimates that MaaS market is expected to reach 180.000 € millions by 2026, with a CAGR of 23,79% from 2019 to 2026.

   The great diversity of players that MaaS schemes require to work together (shared mobility operators, public transport operators, MaaS aggregators and City planners), stimulates an improvement of coordination activities (including sharing data) among partners, in order to provide the most reliable services for users.

   Since most of the services included in a MaaS aggregator are location-based services, the importance on having an accurate vehicle positioning (and users as well) becomes essential for being successful, so there is huge potential to leverage GALILEO here, as demonstrated in the Galileo 4 Mobility project[6]. More than that, the coordination among different services to encourage their usage in a multimodal way (instead of private transport) makes their positioning even more relevant.

2. In addition to the MaaS trend and, integrated, appear the services linked to the shared mobility (bike sharing, car sharing, scooter sharing, kick-scooter sharing, etc.). According to different reports all these services are expected to grow at a CAGR over 15% in the coming years. For instance, there were around 700.000 car-sharing users in Europe in 2011 and it is expected that at the end of 2020 there will be around 15 million[7].

   For Mobility Service Providers, the main pain point is the vehicle positioning: it is key for fleet management and surveillance, fleet rebalancing, control the boundaries of operation and even geofencing tasks. An accurate vehicle positioning is even more relevant for users as it guarantees the service and makes it reliable, so again GALILEO holds great potential to be leveraged for improved operation of such services.

   Linked to this trend, we could also stand out the Demand Responsive Transport (DRT) as an alternative to traditional collective transport. It has appeared recently targeting less populated urban and peri-urban areas aiming to be more economically efficient that usual public transport lines (bus). Positioning systems are imperative for the development of

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[5] Global Mobility as a Service; Market size, Status and Forecast to 2026. Verified Market Research (June 2019). Link: https://www.verifiedmarketresearch.com/product/mobility-as-a-service-market/

[6] http://www.galileo4mobility.eu

[7] Statista https://www.statista.com/statistics/415640/car-sharing-users-europe/

these services, since they allow the service to change the route according to latest booking and also to create virtual stops based on the location of potential passengers. Accurate geo-positioning is critical in such services, in order to reduce friction between passengers finding vehicles to pick them up, so again GALILEO can be leveraged in the navigation systems of the IoT platforms in the vehicles, and superior performance of smartphones with multi-constellation chipsets[8] must be highlighted.

DRT is one of the services with highest expected growth, with a CAGR of 50,3% from 2017 until 2030, reaching around 474.000 million euros by 2030[9].

3. The rise of autonomous mobility is another key trend that can have impact on the evolution of GNSS applications. Right now, the main services based on autonomous driving are mainly incorporated in local transport solutions, usually in the form of pilot projects, providing first/last mile connections, with vehicles up to level 4 of autonomy. Although current routes are relatively short without major issues in the road (limited slopes and roundabouts) and the average speed limit is around 15km/h, it is expected to have more and more intelligent systems with safer measures that take these vehicles to higher levels of autonomy in several years.

5.2 The GNSS industry

The GNSS market (devices and services) was valued at 139.000 € million in 2019, and is expected to reach USD 301.000 € million by 2025, with a CAGR of 14.6% during the period of 2020-2025[10].

The European market for components and receiver manufacturers accounts for 27% of total industry revenues (2017) with a growth of 2 percentual points in two years (25% -2015). The market leader in total revenues are the United States (28%) and China accounts for 10%. Depending on the market segment, the position of Europe can vary. Thus, one of the most relevant market for Europe is Road, where European manufacturing stands far above the market average (49%)[11].

Road solutions dominate by far total cumulative revenues of GNSS market, compared to other segments such as consumer solutions, agriculture or geomatics, forecasting 55,0% of total revenues for the period 2019-2029. In the Road sector there are two main applications that lead the market: In-Vehicle Systems (IVS), such as positioning and navigation information, and Personal Navigation Devices (PND). While IVS shipments are growing (more than 40 million of units in 2018) and they are expected to continue this growth with a CAGR of 6% over the next decade, PND are declining since 2009 due to the rise of IVS and growing use of smartphones for navigation. For the period 2019-2029, the GNSS applications based on insurance telematics will play an import role in the market as well.

[8] https://www.usegalileo.eu/EN/inner.html#data=smartphone

[9] Strategic Analysis of the Global Demand-Responsive Transit (DRT) Market, Forecast to 2030. Frost & Sullivan (June 2018). Link: https://store.frost.com/strategic-analysis-of-the-global-demand-responsive-transit-drt-market-forecast-to-2030.html

[10] Mordor intelligence, 2020 https://www.mordorintelligence.com/industry-reports/gnss-chip-market

[11] GNSS Market Report, 2019 https://www.gsa.europa.eu/system/files/reports/market_report_issue_6_v2.pdf

The GNSS industry can be placed at the initial stage of the road transportation and automotive value chain. Among the main global players there are four European companies coping the top positions of GNSS component and receiver manufacturers: TomTom, Hexagon, U-blox and STMicroelecronics. European companies are leading the global market with a share 48%, followed by USA with a 42%.

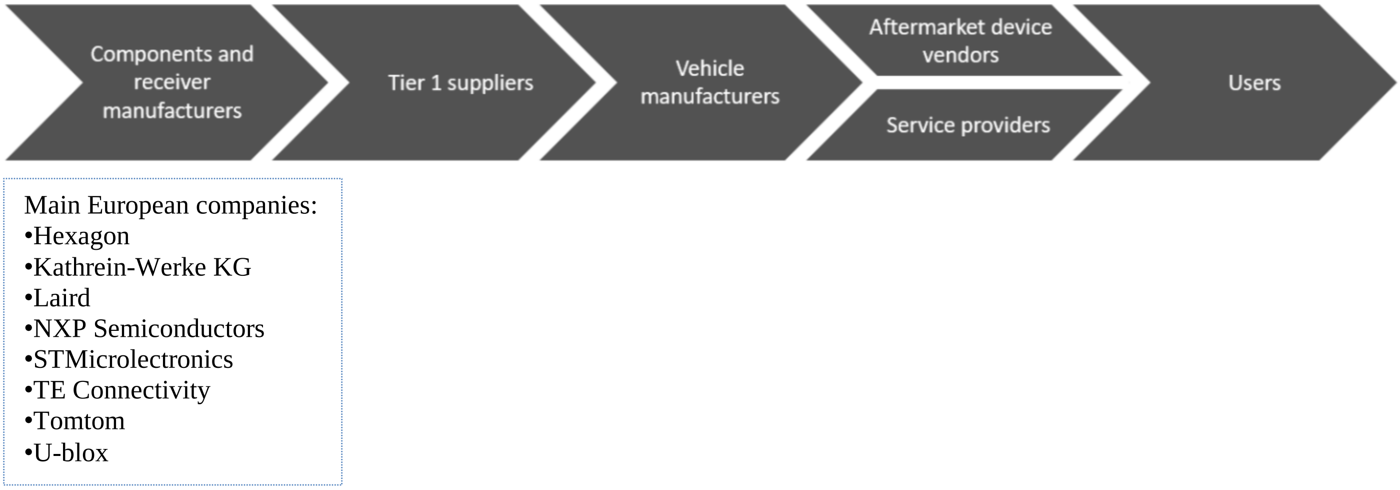


Figure 2. Road Transportation and Automotive Value Chain

5.3 The industry point of view

Based on the survey that was launched to understand the opinion of stakeholders regarding the usage of GNSS services in the post-COVID19 recovery phase, we can highlight several conclusions:

- 62% of PTA, PTO or City officials use mainly Geolocation Data (GALILEO, GPS, Glonass, etc.) to plan or operate their mobility services.
- 57% of these professionals that use Geolocation Data, states that they store and might make available Geolocation-related datasets in their cities.
- Just 14% are using GALILEO for Geolocation services, while 39% of them states that they don't know if they use Galileo.
- Among these professionals using Geolocation Data, 53% know what GALILEO stands for.
- According to COVID19 crisis and recovery phase:
    - 85% of respondents considers that Geolocation Data will help improve existing mobility services.
    - 84% of respondents thinks that Geolocation Data will enable new mobility services and solutions.
    - 79% of respondents considers that Earth Observation Data (maps/satellite images, other) will enable new mobility services and solutions.
    - 78% of respondents thinks that Earth Observation Data (maps/satellite images, other) will help improve existing mobility services and solutions.

- As a part of the post-COVID19 recovery plan, 30% of respondents are planning to modernise or upgrade their transport solutions, by a 36% that are not sure about it.
- The main measures that has been taken or planning to take are related to safer travel (77%).
- 94% considers that as a central pillar of the global economic recovery, there is a need for sustainable transport modes.
- 91% states that Space Data is needed, or useful, for implementing a strategy for more sustainable cities and transportation.
- The main indicators considered that can be monitored with Space Data to support the “go green” strategy for cities, are: Location and use of different fleets (87%), emissions (80%), use of streets and roads (74%).
- 51% of respondents states that the support needed from ARIADNA and the GSA, to “go green” and leverage Space Data should be based on: strategic advisory services, technical advisory services, commercial advisory services and competitive advisory services.

- How many vehicles (approximately) are in your fleet?

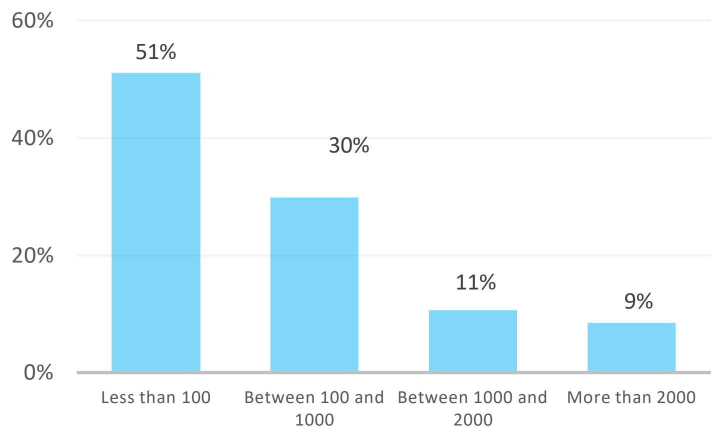


Figure 3. Number of vehicles in their fleets

- Which Space Data are you using to PLAN or OPERATE your mobility service(s)? (multiple answers possible)

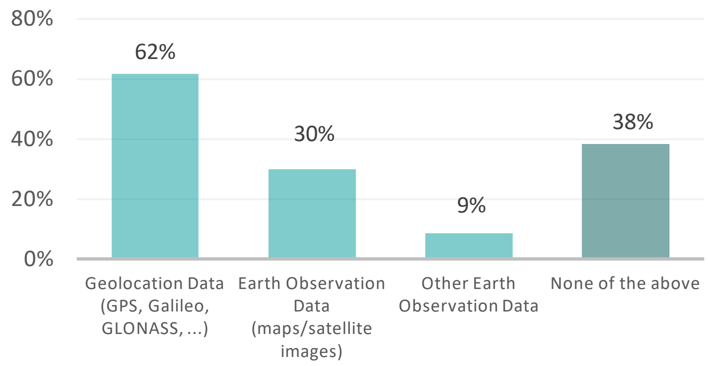


Figure 4. Space Data used

- Do you store, and might make available Geolocation-related Datasets in your city (such as, for instance, latitude - longitude coordinates of a bus or tram fleet over a certain period)?

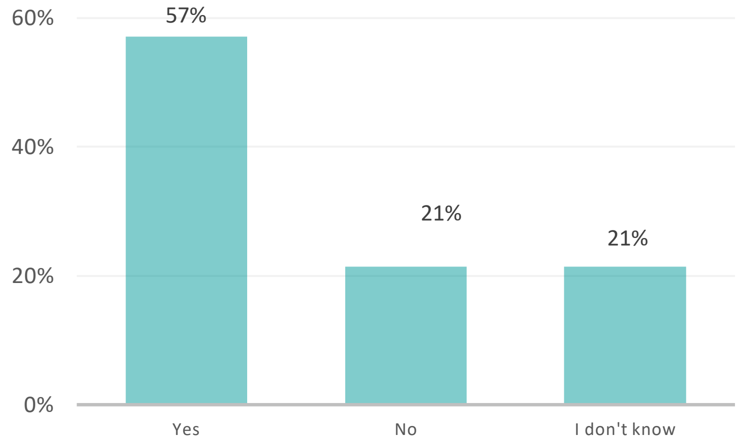


Figure 5. % Store data

- Are you using GALILEO for your Geolocation services?

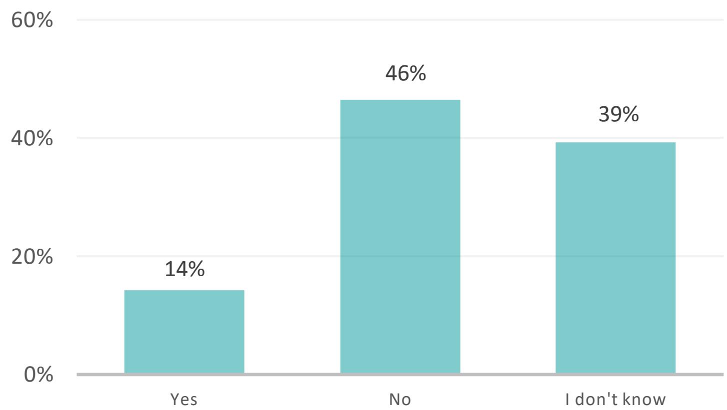


Figure 6. % Usage of GALILEO

- Do you know what GALILEO stands for?

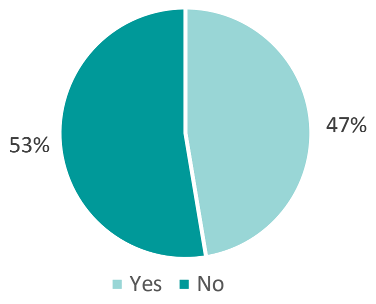


Figure 7. % Know GALILEO

- Please rate your level of agreement with the following statements:

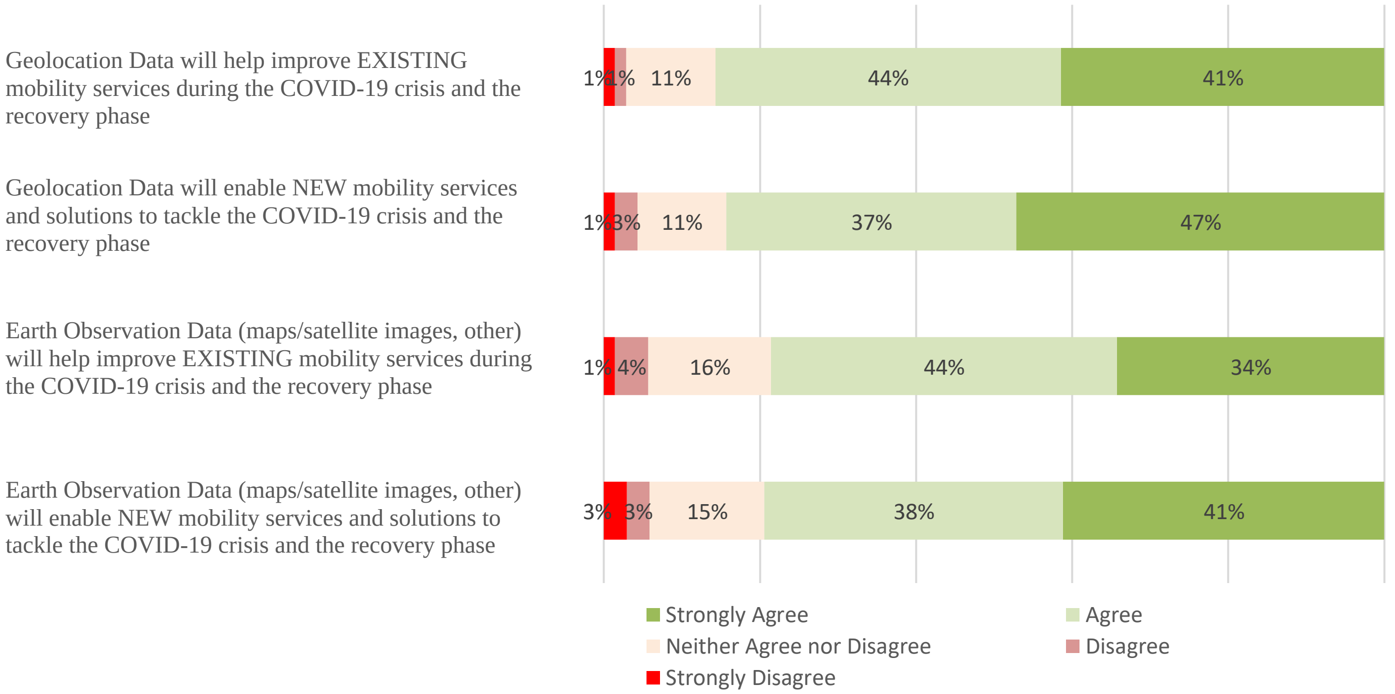


Figure 8. Usage of Earth Observation Data and Galileo

- Are you planning to modernise, or upgrade your transport solutions (e.g. infrastructure, IT systems, etc.) in order to be more efficient and sustainable, as part of your post-COVID19 recovery plan?

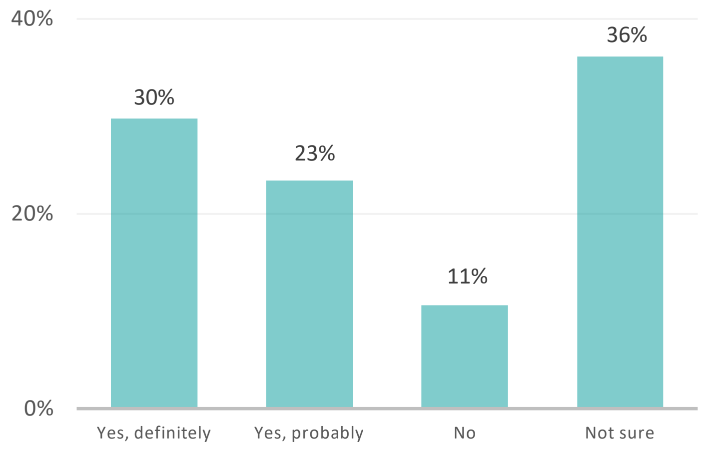


Figure 9. % Planning to modernise transport solutions.

- What measures are you taking, or planning to take? (Multiple choice)

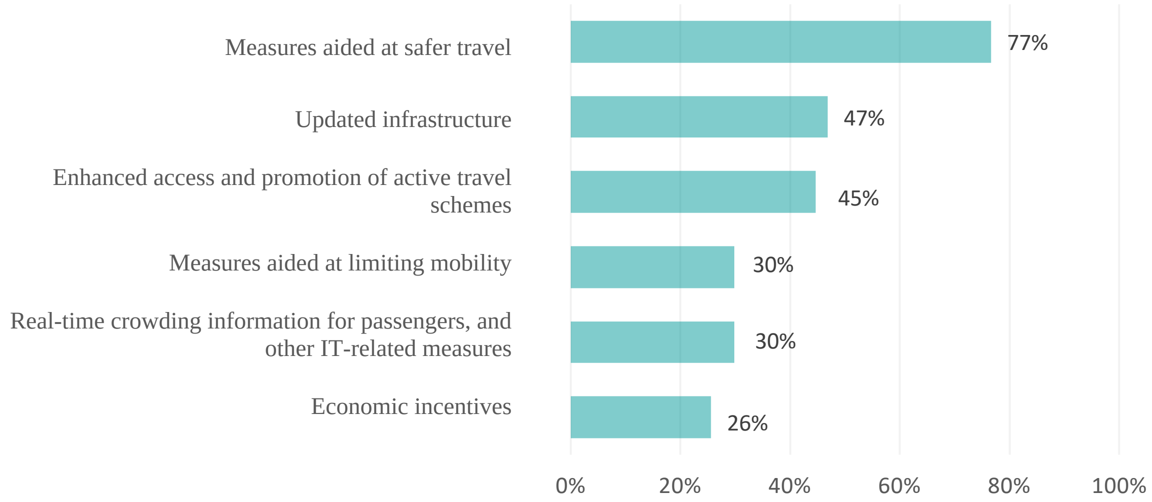


Figure 10. Measures planning to take

- Please rate your level of agreement with the following statements:

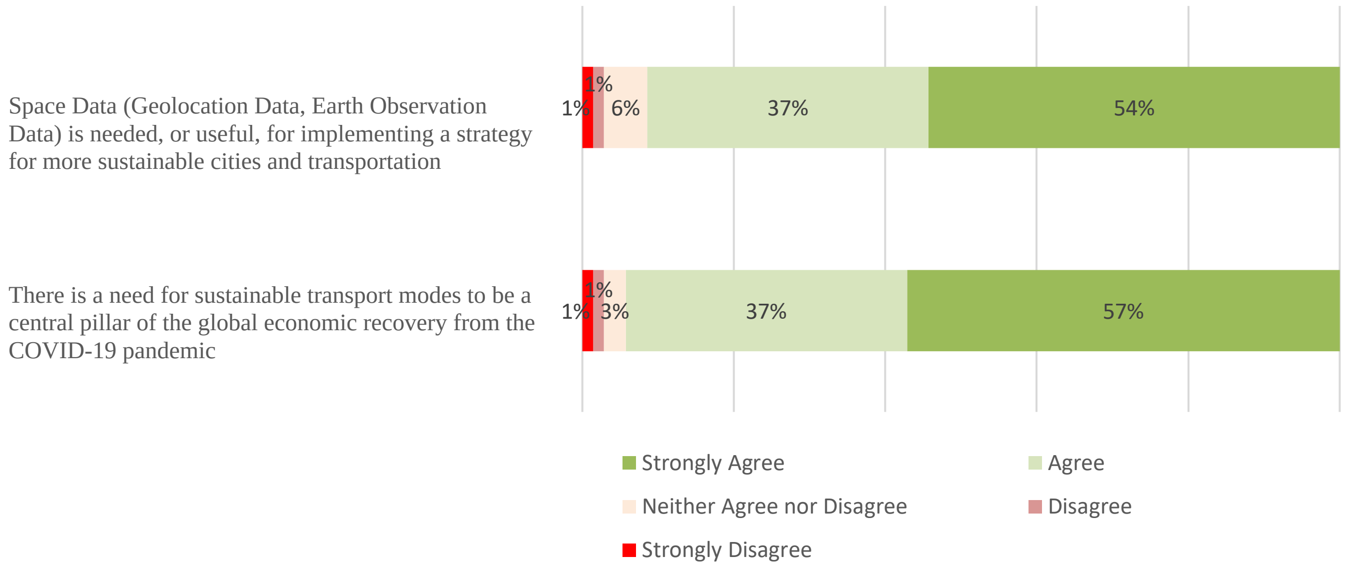


Figure 11. Level of agreement

- Which indicators do you think can be monitored with Space Data (Geolocation Data, Earth Observation Data) as a support tool to a "go green" strategy for Cities?

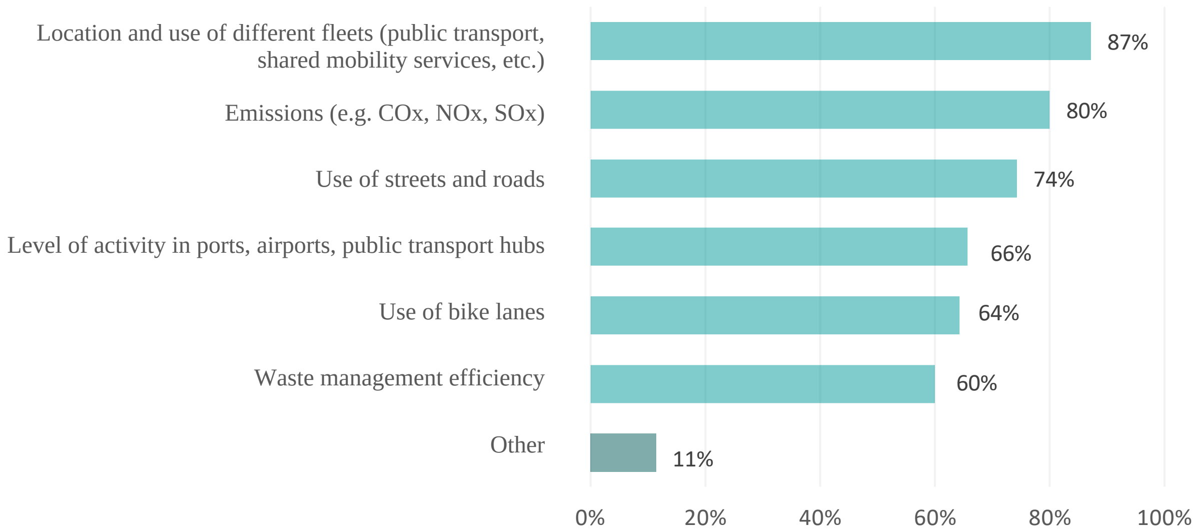


Figure 12. Indicators to be monitored

- Which support would you need from ARIADNA, and the GSA, in order to move to "go green"? In particular, regarding how to leverage Space Data

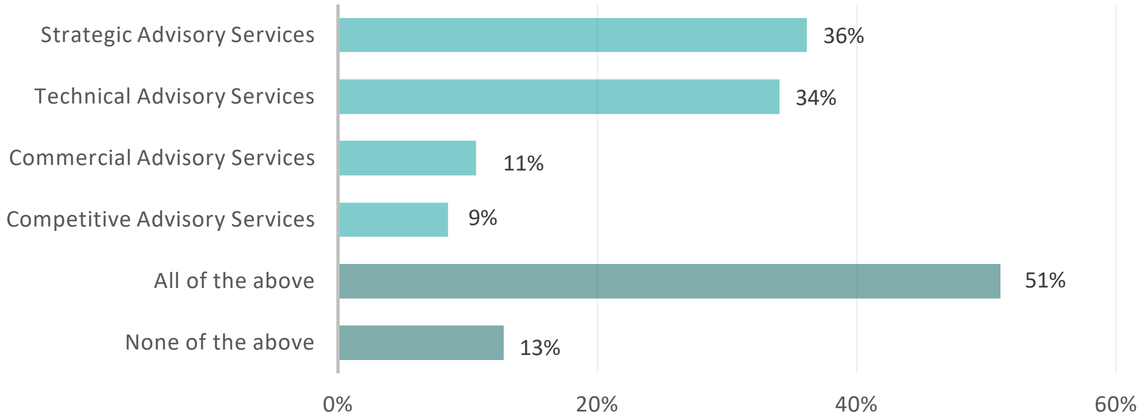


Figure 13. Support needed from ARIADNA and GSA

6. GNSS Applications (Use Cases) and Best Practices

6.1 GNSS Applications

The applications of GNSS in the area of mobility are multiple; we could define and classify them in four main areas:

1. Smart Mobility: it includes those applications which main objective is to improve the efficiency and comfort of road transport.
2. Safety-critical applications that according to the precise positioning, help in those situations that can represent a potential harm for citizens or environment (ADAS, ITS for connected vehicles).
3. Payment-critical applications which are relevant for economic purposes based on positioning data, such as those related to Road User Charging (RUC) and Pay-as-you-Drive (PAYD) systems.
4. Regulated applications that help to apply transport policies (eCall o Smart tachographs).

As the scope of ARIADNA project are the urban mobility applications and services, we will focus this part of the document on the GNSS applications based on smart mobility. The emerging whole area of smart mobility solutions can take advantage from the usage of GNSS applications in order to give citizens and operators more effectiveness and comfort in its usage. The improvements in this area are contributing to develop more reliable transport services as well as more applications that can help in the daily urban mobility trips.

The social, technological and economic changes have impact as well in the fast evolution of mobility services. Since the beginning of the last decade, the quick introduction of smartphones and its adoption among citizens in their daily life, is motivating a revolution in different aspects in the way citizens behave and, urban mobility is one of them easing the creation of new solutions and applications.

The main use cases of GNSS in the area of smart mobility have been developed in three principal fields:

1. Navigation applications: these services provide positioning information to different interested targets, such as users, drivers and fleet operators. Different devices such as Portable Navigation Devices (NPD) or in-vehicle systems (IVS) are being developed and will be relevant for the present and near-future applications:

1.1. Public transport

In recent years, public transport fleets (mainly buses) all over the world, have been incorporating GNSS receivers (OBUs – On Board Units), in order to obtain a more accurate positioning of the vehicle, allowing the route monitoring in real time[12]. The applications of these receivers and the benefits for users, drivers and fleet operators are multiple:

- Get online geolocation of buses and possibility to monitor it on map.
- Positioning of bus stops accurately.
- Get statistics about Real Time Arrival and Estimated time of Arrival. Give accurate real-time information to passengers.
- Improving user experience (know when your bus is approaching and view your bus route on the map).
- Get real time disruptions. Understand the reasons behind delays or irregular bus services (different route). Having the concrete positioning of the vehicle, the operator has the necessary information over possible difficulties in the service (traffic jam, accident, etc.)
- Give information regarding the driver behaviour and the driving quality (speeding, braking, abrupt accelerations, etc.).
- Being able to change the route in order to avoid congested areas, easing the traffic flow in the city.
- Study real-time situations aiming to develop services and routes with a more accurate schedule.
- Offer aggregate data from de different bus services to public authorities and mobility planners to understand the impact of buses and other factors in traffic patterns.
- It avoids the need to implement and maintain a sensor infrastructure (i.e. beacons) to know the vehicle positioning.
- Help the fleet administration to review the route mapping in order to optimize time and maximize vehicle utilization.
- One of the latest applications that is being developed is the so-called transit-signal priority (TSP). It is a service that enables buses to travel in a faster way by means of adjusting traffic signal along their route in real time. When the bus is approaching to an intersection, the OBU sends its positioning to a transit management centre, requesting for the traffic signal to provide a green light.

These benefits and applications are even more relevant for the services related to DRT, such as on-demand bus, which are increasingly being developed mainly in low dense areas. The possibilities that GNSS applications offer to DRT are elemental for its performance. Thus, having of the vehicle positioning, can help to improve the service performance:

- The users can track of the bus position and time of arrival on real time.
- The service operator can track the route of the bus in real time and detect if it leaves the indicated route (and even contact the driver to understand the reason) and, if necessary, notify the rest of users of the expedition.
- The operator can have a real validation over the correct route performing. This point is especially important in this type of service where the route may change.

[12] Impetus project https://www.fig.net/resources/proceedings/fig_proceedings/fig2016/ppt/ts03b/TS03B_ogundipe_8209_ppt.pdf

1.2. Shared mobility

The importance of positioning applications for the shared mobility services stands as the most relevant factor for their good performance. Either station-based services or free-floating ones, knowing an accurate position of the vehicle is the key factor for the development of shared mobility services in recent years. GNSS applications have allowed the introduction and growth of different services: car sharing, scooter sharing, kick-scooter sharing and ride hailing.

The need of knowing the position of the vehicle is similar for all of them, with slightly specific considerations:

- Car sharing:
  - Real-time geolocation for service monitoring by the technical assistance
  - Maintenance schedule based on car turnovers and kilometres travelled.
  - Reporting, statistics and mapping over the vehicle performance.
  - Accurate information about the vehicle pick up and drop off. So, the service provider is able to bill time overrun.
  - For free floating services, importance of parking accuracy because it could avoid user inconvenience and costs for the company.
  - Give information about possible warnings such as non-restitution of the car after the end of a reservation or car movement without an associated reservation.
  - Give information to the user regarding the nearest vehicle available

- Ride hailing:
  - Real-time geolocation for service monitoring by the technical assistance.
  - Maintenance schedule based on car turnovers and kilometres travelled.
  - Accelerate the pick-up of passengers by drivers.
  - Know in the most accurate way the lane of the street where is requested the pick-up.
  - Optimization of routes: determine routes and distance of trips for users and drivers for further analysis.
  - Characterize driving behaviour.

Having all these shared services plus public transport in the a developed MaaS platform will allow users to have a seamless transport, affordable and sustainable. Thus, getting an accurate positioning of all the different vehicles will enable a faster and smother transition between modes and consequently the better performance of the MaaS platform.

1.3. Micromobility Geofencing[13]

The rise of micromobility sharing services (bike-sharing, kick-scooter sharing and even scooter sharing) since 2018, filled the urban environment of bike and kick-scooter fleets due to the main benefits that this kind of mobility offers for the cities: a more safety, equity and more sustainable

[13] Geofencing https://www.govtech.com/transportation/Cities-Use-Invisible-Geofencing-to-Control-Use-of-E-Scooters.html

mobility. Before 2018, bike-sharing schemes were already successfully introduced in cities promoted in some cases by the local government, through public bike-sharing programs, pursuing the objective of encourage non-motorized mobility as an alternative to pollutant vehicles and reducing traffic congestion.

In general terms, this kind of services share the same needs in terms of geolocation than other shared services:

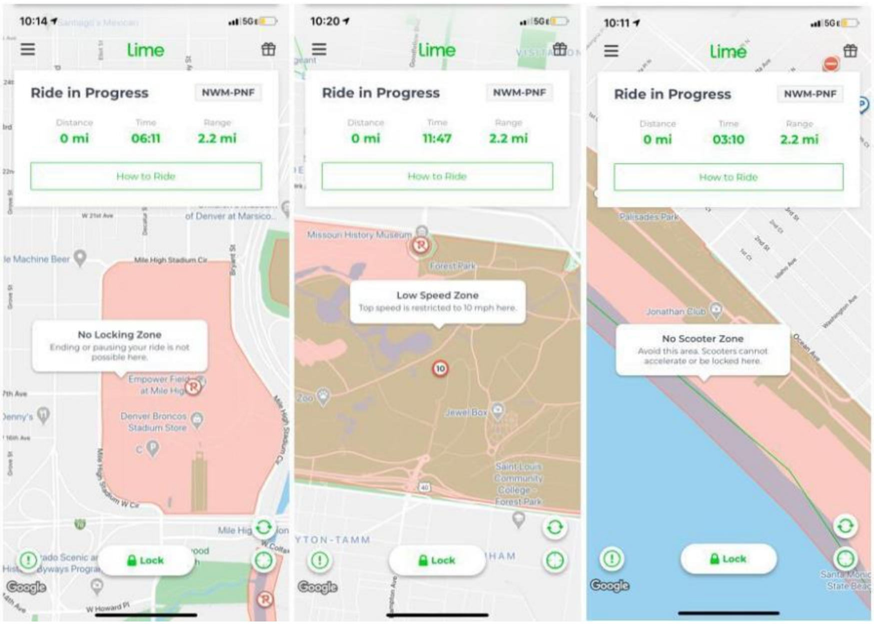
- Real-time geolocation for service monitoring by the technical assistance
- Maintenance schedule based on car turnovers and kilometres travelled.
- Reporting, statistics and mapping over the vehicle performance.
- Accurate information about the vehicle pick up and drop off. So, the service provider is able to bill time overrun.
- Give information about possible warnings such as non-restitution of the vehicle after the end of a reservation or vehicle movement without an associated reservation.
- Give information to the user regarding the nearest vehicle available
- Planning of battery swapping (if needed).

Since 2018, and the quick introduction of a new mobility vehicle (and service), the kick-scooter, its known benefits were shadowed by the issues generated by its usage. Concerns regarding safety (related to the speed these vehicles can reach), parking spaces and circulations areas, arose.

The micromobility industry is addressing these concerns by means of different types of measures, such as: educational campaigns, incentives or even photo verification. Apart from these solutions based on users' behaviour, micromobility companies are offering other alternatives to cities based on technology, such as geofencing. Geofencing could be described as the enforcement of several set of rules to a specified geography boundary. Thus, depending on the location of the vehicle, a certain rule will be applied in an automatic way: companies can limit the operational zone of the vehicle, limit the speed according to the zone the vehicle is working, or restrict the parking out of the operational limits.

In this sense, GNSS applications become essential for a good performance of these services and comply with the city policies. Location data, not only at a vehicle level, but in an aggregated way (area, city, etc.) is also valuable for cities in order to assess the micromobility services having information, for instance, over the correct allocation of vehicles to serve neighbourhoods with poor public transport connection.

However, geofencing applications have still room to improve, since they are facing two main challenges: the accuracy of positioning signals and the time-consuming communication between the vehicle and the cloud system. This second point is decisive in order to give instructions to the vehicles (according to their position) in a short time.



Source: Mes-insights.com

2. Fleet management applications: the services that GNSS offer for fleet management are based on the information over vehicle positioning that on-board units (OBU's) send to transport operators aiming to monitor the performance of their activities. Current OBU's give the possibility to transfer data in real time to the transport operator related the vehicle positioning, the route course or time of journey.

   Having these applications offers a wide variety of benefits[14] for fleet managers, such as:

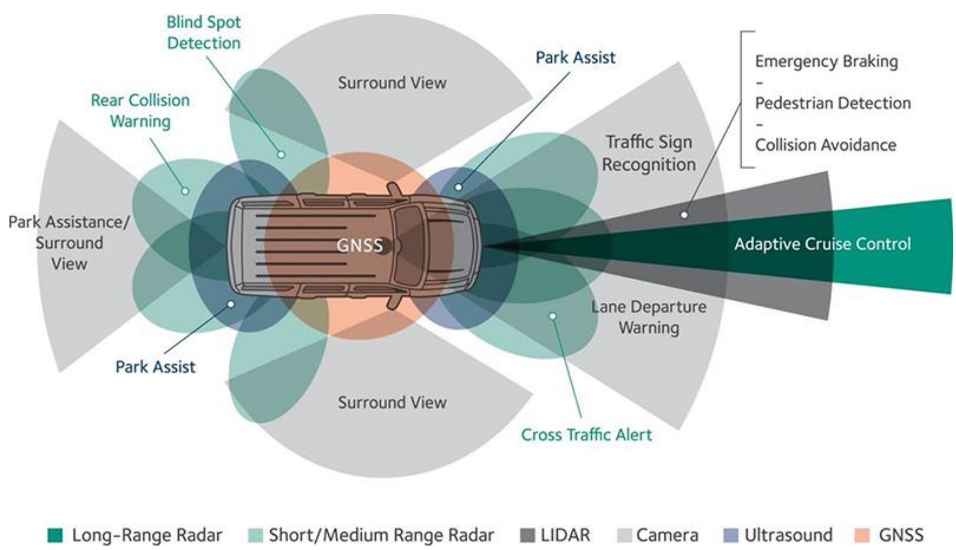
- Real time information over the vehicle positioning.
- More effectiveness in route planning. GNSS applications offer future technical improvements and R&D projects such as the creation of algorithms to predict demand of routes and identify the most popular ones.
- Faster response time overt unexpected situations.
- Short time analysis of gathered data.
- Real-time connected alarm to improve safety (drivers, charge and vehicles)
- Better control of drivers performance.

14 Arkadiusz Tyszko*, University of Warmia and Mazury in Olsztyn http://transportproblems.polsl.pl/pl/Archiwum/2007/zeszyt2/2007t2z2_02.pdf

Source: inhandnetworks.com

2.1.Connected and Autonomous Vehicle (CAV) fleet management.

Although the evolution of autonomous mobility (Levels 4-5) is still uncertain in short term, it is expected that in mid-term and long-term there will be autonomous vehicles moving through the cities in which the usage of technologies such as cameras, radar, lidar and GNSS becomes essential. The application of GNSS to perform in the most accurate and reliable way is crucial to ensure de security of car users and citizens. So, GNSS has a key role in the driverless mobility. In this sense, the accurate positioning (in lanes) and the management of dynamic data (for real time positioning) become the most relevant challenges that need to be addressed to avoid positioning errors that can affect the reliability of autonomous vehicles, in general. GNSS devices can provide high-definition 3D street maps and deliver large-scale mapping of geographic terrain.



Source: Novatel

3. Road traffic monitoring: this include all the services that collect vehicles location data by means of OBU's or other devices with the main objective to be analysed and improve traffic management. The information obtained and aggregated to other sources (road traffic sensors) allows to increase the effectiveness of traffic control, to adapt management policy to changing conditions and to predict infrastructure bottlenecks.

6.2. Best practices:

There have been selected some best practices regarding the usage of Galileo-related applications for public transport:

1. Prague tram[15]

   Prague has one of the largest tram fleets in Europe, using a 20-year system based on GPS. Encouraged by ARIADNA project partners the Prague Public Transit Company (DPP) has issued a tender for Galileo-enabled receivers to be included in Prague tramways as part of a modernization plan to increase network efficiency and improve user experience.

   By the end of 2020, the GALILEO-enabled, multifrequency and multiconstellation receivers are expected to be installed into the Prague trams, benefiting different stakeholders:

- From the end-user point of view: provide more accurate vehicle positioning data (down to 1,5 meters) to passengers.
- From the operator perspective: decrease maintenance costs; improve systems, such as automatic speed limitation over the switches.

15 Prague tram: http://ariadna-project.eu/galileo-prague-tram

Source: ariadna-project.eu

2. Madrid EMT buses[16]

EMT is the public company responsible for the network of buses in Madrid and, member of the Regional Transport Consortium, the public body in charge of planning the public transport in Madrid.

EMT has been renewing their fleet for four years and, introducing technology innovation to improve buses performance. Thus, the introduction of GALILEO receivers in the fleet of 2.050 buses is improving the accuracy of bus positioning, allowing the citizens to better plan their trips.

Other Intelligent Transport Systems are being implemented in the fleet (operational support systems, driven simulations, WiFi, Open Data, etc.) that are becoming more precise thanks to the enhanced positioning services that Galileo offers.

Source: EMT Madrid

3. Cervelló – On demand bus[17]

Funded by the EU project Galileo4Mobility, the service of an on-demand bus started at the beginning of 2020 in Cervelló, a peri-urban area close to Barcelona. This kind of areas face two main issues for urban planners and local authorities: the reduced demand of the classical bus lines and more requested public transport coverage by citizens.

In the case of Cervelló (9.054 inhabitants, with a population density of 375,7 inhab/km^2), there were 3 urban lines with just 40 trips per day with a weak public transport demand and negative balances in current bus services.

[16] EMT Madrid Bus: https://www.gsa.europa.eu/newsroom/news/emt-madrid-announces-readiness-galileo-all-metropolitan-bus-fleet

[17] Cervelló - on demand bus http://www.galileo4mobility.eu/pilot-sites/barcelona-pilot-site-2/

The AMB (Metropolitan Area of Barcelona), as a public administration responsible for bus public transport, wanted to establish a new on-demand bus service, to increase the efficiency and reach areas without access to public transport.

The service developed, which includes GALILEO receivers in each of the buses, consists in just 2 lines with flexible routing (the users have to book the trip in advanced) that connects the city centre to residential areas, with fixed and virtual stops, covering and area of more than 100 bus stops.

Source: La premsa del Baix

4. SEAT – Sharing services

SEAT recently launched in Barcelona its service of motosharing "SEAT MÓ"[18]. It includes 678 full electric scooters, model Silence SO2 L3e, through a free-floating model.

By means of this service, the users can book an e-scooter with 15 min in advance, at the most. Then, using their smartphone they can unlock the e-scooter and start the trip. The vehicles provided can just be used and park in Barcelona, in a concrete area that SEAT has defined. Due to the importance of geo-positioning for this free-floating service, they have included in each vehicle a GALILEO-enabled Astra chip.

[18] https://www.seat.es/sobre-seat/seat-mo/motosharing.html

Source: SEAT

SEAT has also included another GALILEO-enabled chip (Continental) for the fleet of 91 car for its own Corporative Car Sharing service. This service allows to employees to use cars for their labour trips (visits to suppliers, partners), with origin in SEAT Martorell factory.

5. Reby – Micromobility services[19]

Reby is a Barcelona-based micromobility company that operates in seven cities across Europe: Barcelona, Terrassa, Zaragoza, Oviedo, Milano, Napoli and Lecce. Its main service is kick-scooter sharing although they are working as well in bike-sharing schemes (Terrassa).

Reby's main goal when using GALILEO is to improve the geolocation accuracy of scooters on the street. It allows, unlike GPS, to know with the minimum possible error the position of the same. This is especially useful for ensuring good parking and avoiding clutter in the city.

Currently, Reby scooters use the Quectel EC21-E device for server connection and geolocation. This device allows them to work with GPS and GALILEO. The GPS have an approximate error of more than 10 meters with a confidence level of 95%. For this reason and in order to obtain best geolocation accuracy, all Reby scooters are configured to work with GALILEO's dual frequency open service and improve position up to 4 meters with 95% confidence.

Source: beteve.cat

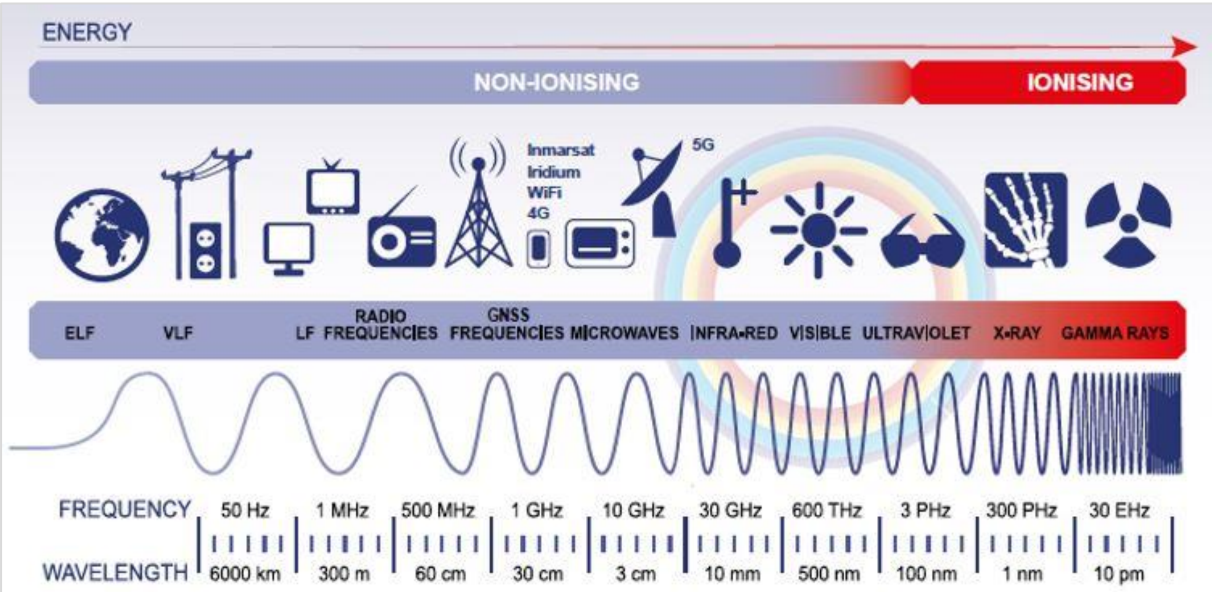
19 https://www.reby.co/

7. Challenges to overcome

Satellite navigation technologies (GNSS) offer a wide variety of opportunities for users, authorities and operators being a key enabler for most of the urban mobility services. In fact, the quick introduction of mobile technologies (smartphones) and its adoption by citizens and, its integration in the value proposal of urban mobility services, requires an increased navigation performance.

However, GNSS applications are facing several challenges[20][21], which different GNSSS constellations are trying to solve:

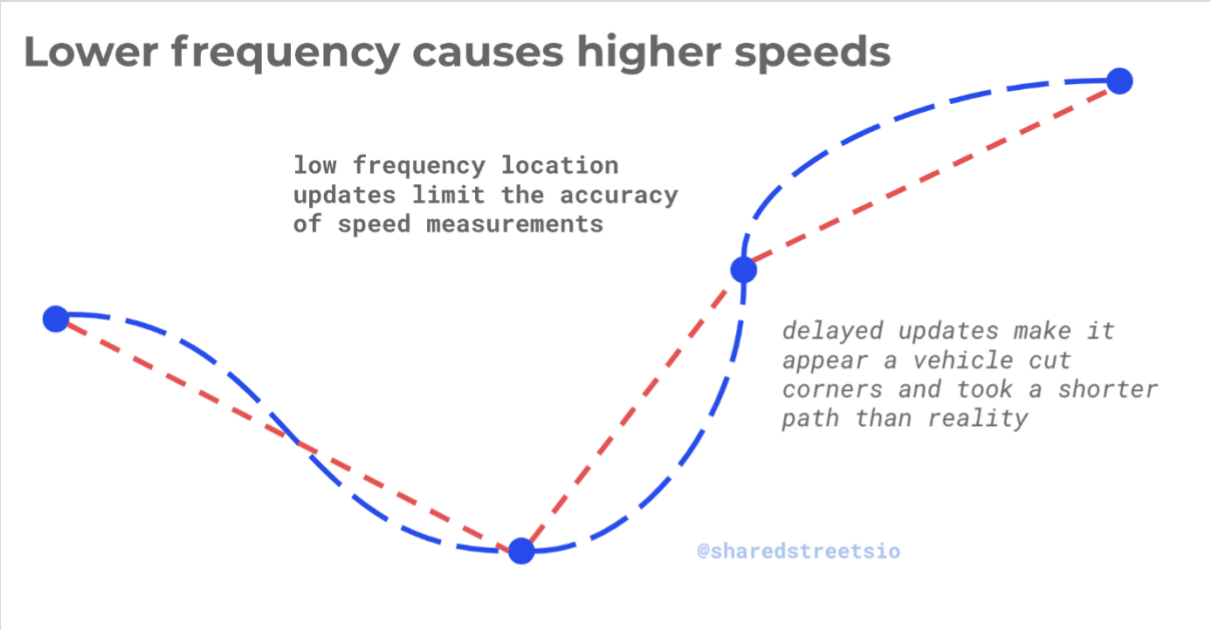
a) Accuracy: positioning errors can make difficult for users to rely on mobility services. GNSS receivers play and important role in ensuring the position of the vehicle. The requirements for location accuracy can be significantly different depending on the vehicle or the application. For instance, the accuracy required for an autonomous vehicle positioning will be more precise (safety issue) than the one needed for finding a parked scooter.
b) Lack of availability of the signal in certain urban areas, where the vast majority of these mobility services are working. This is the so-called urban canyon effect, where the visibility of satellites is reduced in urban environments with tall buildings.
c) Robustness: GNSS receivers face relevant issues regarding interferences, whether they are unintentional (radio frequency interference from cell phone towers, for instance) or intentional (jammers).



Source: septentrio.com

20 How GNSS Receivers Empower Smart Cities https://www.septentrio.com/en/insights/how-gnss-receivers-empower-smart-cities
21 Main problems of GNSS technologies https://www.researchgate.net/publication/328015392_Main_problems_of_GNSS_technologies

d) Low frequency[22]. If the location data frequency of a vehicle is low (due to the operation system, device battery level or physical barriers-buildings) then, the precision of the device (vehicle) speed estimation is reduced considerably.



Source: sharedstreets.io

e) Unaffordable battery consumption, data communication and tracking device costs

Hackathon challenges

"Hack ARIADNA"[23] is the name of the online *Hackathon* coordinated by ARIADNA project partners and Y4PT (Youth For Public Transport) and endorsed by the projects' Space 4 Cities Forum members, that took place on November 2020.

The objective of Hack ARIADNA was to find young professionals, robotics experts, tech individuals, companies or anyone interested in the call to design solutions and developing innovative applications that will help the world find better new mobility solutions through the use of EGNSS (GALILEO). The call was wide in terms of scope, focused on already existing or new solutions and on the creation of MVPs or prototypes according the proposed topics, as well.

It combined the scope of the ARIADNA project with the new challenges raised by the ongoing COVID-19 crisis. In the current COVID-19 scenario, with the implications for several areas of

22 Using Location Data for Guiding Micromobility Outcomes, 2019 https://sharedstreets.io/using-location-data-for-guiding-micromobility-outcomes/

23 http://ariadna-project.eu/hack-ariadna-2020

our life across the globe that it has (health, economy, etc.), space data and, location and navigation technologies can offer a huge potential to support the fight against the virus. For this reason, Hack ARIADNA was conceived to call for solutions to help public authorities to monitor and analyse emergency situations, to increase awareness amongst citizens about viruses like COVID-19, and further advance public transport and support healthy urban mobility.

Based on the general challenges that GNSS functionalities are facing (not just technological) and those that COVID-19 issues are adding, a timely process, ensuring the participation of all the consortium members and stakeholders, was designed in order to defined the main topics, that Hack ARIADNA should address:

a) First of all, the consortium partners participated on a brainstorming activity aiming to define and prioritize the most relevant challenges for GNSS applications, that could be addressed through GALILEO. For this brainstorming task, the needs of relevant stakeholders (PTO, PTA and MSP) were considered. From a raw list of challenges, six of them were prioritized.

Raw list of challenges
• Explore ways to count cyclists (allocate them to specific lanes and directions of ride) using EGNSS or Earth Observation Data. • Reduce friction in intermodal urban travel (MaaS), especially in areas of the city with a harsh urban canyon effect. • Accurate geofencing for shared mobility services • Geo-position signal authentication for applications involving enforcement • Modal shift and mobility stats: determine means of travel based on a mobile track • Develop a bonus on bike usage: monitoring of distance travelled by bike. It implies detecting dynamics of bike trips. • Bus O/D (Origin/Destination) matrixes to be more accurate. • Monitor the usage of public e-bike and e-scooter sharing services: O/Ds, determine if using bike lanes, characterizing riding behaviors, etc. • Urban tolling "per use", according to distance travelled and category of street (some street segments might be more expensive). • Automatic check-in and pay-on-the-go of transport services on a MaaS scheme. • COVID-19: Develop a platform automatically indicating when a route is ‘too full’ (of people walking) utilizing GALILEO technology, and providing an alternative route. • COVID-19: Use space technology to indicate crowds in PT, and on the basis of that, propose new routes and modes of transport. • Develop a solution designed to integrate existing mapping and routing services, calculating how much time would be saved if people chose cycling/shared scooters over cars or even other forms of PT, and indicating the closest shared cycling/scooter service. • COVID-19: Queue management (models) in peak hours, ensuring social distancing at bus/metro stations. • COVID-19: Fleet management systems to assure the social distancing inside the public transport. • COVID-19: Determine the percentage of occupation inside a PT Vehicle.

• COVID-19: Control of physical distance, average load on vehicles, traceability. Public transport • Providing more reliable real-time service information through the available user communication channels (apps, website…). • Enabling the operation of public transport services with autonomous vehicles. • Having better control over the correct execution of the route by every vehicle in operation. • Responding more efficiently to incidences. • Post-COVID19: making PT attractive again by ensuring user safety. Shared mobility • Making the pick-up process smoother in DRT (Demand-Responsive-Transit), ride-hailing and taxi services. • Improving logistics operations for staff moving vehicles around or swapping their batteries. • Reducing friction on the user side when locating the vehicle before the trip.

Table 3. Hackathon raw list of challenges

List of pre-selected challenges
• Let's make Public Transport attractive again (post COVID-19): Ensuring social distancing, and in consequence user safety • More Sustainable and healthy mobility: Reduce emissions, promote healthy and sustainable ways of mobility, improve the quality of life of the people living in urban areas. • Reduce friction with intermodal travel: Reduce friction when changing modes, especially in areas of the city with urban canyon effect. • Modal shift and mobility stats: Determine means of travel based on a mobile track. The use of geo-location data can automatically inform about which mode of transport the user is using (walking, cycling, bus, etc.). • Seamless travel, urban tolling "per use": according to distance travelled and category of street (some street segments might be more expensive). • Autonomous Driving (first in PT, fixed routes), autonomous last-mile delivery / logistics.

Table 4. Hackathon list of pre-selected challenges

b) Space 4 Cities Forum members, also took part in the definition and prioritization of challenges, helping to select the final two topics that were used for the Hackathon:

1. Public Transport during and post COVID-19:

Ensuring social distancing, and in consequence user safety, by:

- Queue/Crowd management at bus/metro stations, in the city centre, streets, proposing routes and modes of transport.
- Fleet management systems/models.
- Determine average load on vehicles.
- Flatten the demand curve.
- Increase resiliency (e.g. pre-book on-demand mobility services as a complement to traditional public transport).

2. More sustainable and healthy mobility:

Reduce emissions, promote healthy and sustainable mobility, improve the quality of life of people living in urban areas.

- Exploring ways to count cyclists (allocate them to specific lanes and directions of ride).
- Bonus on bike usage.
- Calculation of time (and money) saved if people chose cycling/shared e-scooters over cars, and indicate the closest share cycling/e-scooter service.
- Public e-bike and e-scooter sharing services: usage monitoring (O/Ds, riding behaviours, etc).
- Bus O/D matrices.

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