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Smart Mobility: Analysis of State-of-the-art and emerging technologies

MASTER'S DEGREE THESIS IN
MECHANICAL ENGINEERING

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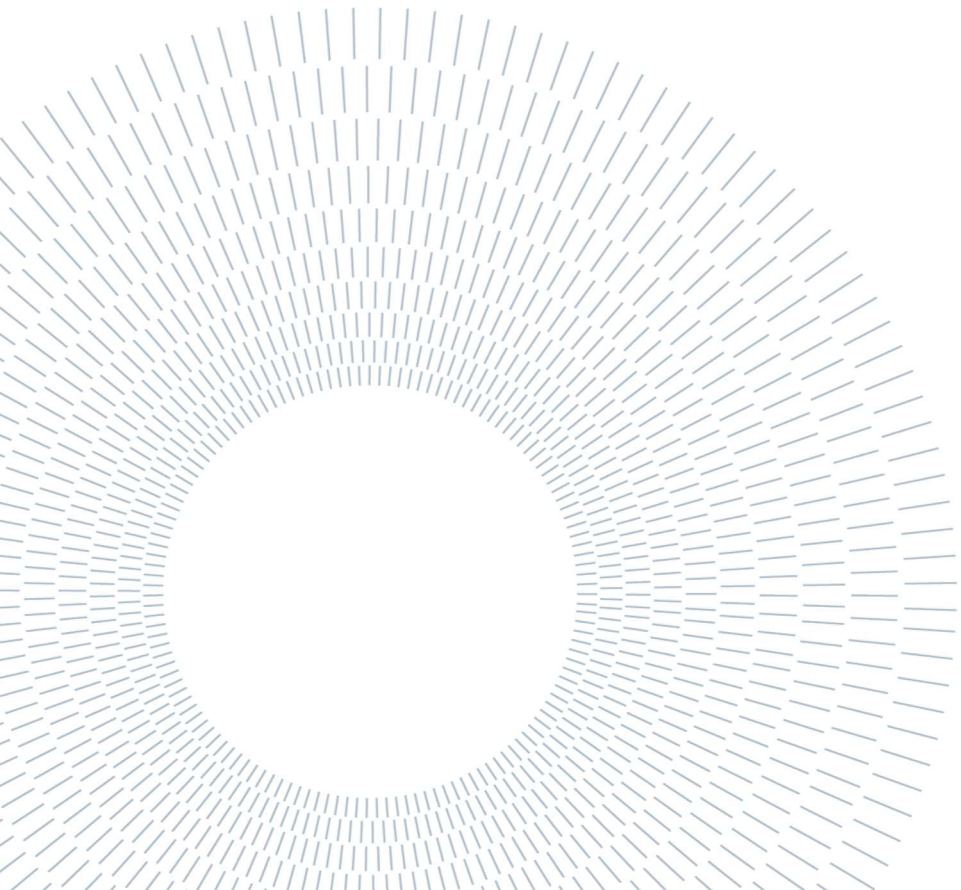

Abstract

The concept of Smart Mobility refers to the evolution of mobility towards a quality model, sustainable and environmentally friendly, which is why it is the subject of research for both the public administration and the private sector. Nowadays, society is experiencing significant changes in the mobility patterns of population, especially in the urban cores, as a consequence of the introduction of new regulations and a stronger environmental awareness. This thesis aims to investigate the state-of-the-art and the most remarkable trends in the Smart Mobility development, considering the different fields of application and involved technologies.

In order to achieve these objectives a database of Smart Mobility projects was created. This database gave a perspective of the current scenario and provided useful data for performing the corresponding analysis. The research methodology started with a review of the literature to better understand the context of the thesis. This was followed by an analysis of secondary sources that were utilized for identifying the projects of the database.

As a result, this thesis will provide an overview of the state-of-the-art of Smart Mobility. Thus, there will be obtained some patterns about the trends in terms of application areas, smart technologies, geographical data, etc. Moreover, a specific analysis will be made for the technologies adopted in the different fields of Smart Mobility, crossing different data about the found projects.

Keywords: Smart Mobility; Mobility; Smart City; State-of-the-art; Database; Communication technologies.

Abstract in lingua italiana

Il concetto di Smart Mobility fa riferimento all'evoluzione della mobilità verso un modello di qualità, sostenibile ed ecologico, motivo per cui è oggetto di ricerca sia per la pubblica amministrazione che per il settore privato. Oggi la società sta vivendo importanti cambiamenti nei modelli di mobilità della popolazione, soprattutto nei centri urbani, come conseguenza dell'introduzione di nuove normative e di una maggiore consapevolezza ambientale. Questa tesi si propone di indagare lo stato dell'arte e le tendenze più notevoli nello sviluppo della Smart Mobility, considerando i diversi campi di applicazione e le tecnologie coinvolte.

Per raggiungere questi obiettivi è stato creato un database di progetti di Smart Mobility. Questo database ha fornito una prospettiva dello scenario attuale e ha fornito dati utili per eseguire l'analisi corrispondente. La metodologia di ricerca è iniziata con una revisione della letteratura per comprendere meglio il contesto della tesi. Questa è stata seguita da un'analisi delle fonti secondarie che sono state utilizzate per identificare i progetti della banca dati.

Di conseguenza, questa tesi fornirà una panoramica dello stato dell'arte della Smart Mobility. Si otterranno così alcuni pattern circa le tendenze in termini di aree applicative, tecnologie intelligenti, dati geografici, ecc. Verrà inoltre effettuata un'analisi specifica per le tecnologie adottate nei diversi ambiti della Smart Mobility, incrociando diversi dati sui progetti trovati.

Parole chiave: Mobilità intelligente; Mobilità; Città intelligente; All'avanguardia; Tecnologie della comunicazione; Database.

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Premise

According to the telecommunications company Verizon, Smart Mobility is an intelligent transport and mobility network. Specifically, it is the connection between different elements of technology and mobility, a rethinking of the transport infrastructure that citizens use in their day to day and in their businesses. In this sense, it not only includes the use of traditional motor vehicles, electric vehicles, and public transportation systems, but also completely new modes of transport like on-demand ride sharing services and carsharing programs. Changes in consumer behaviour are leading into a decline in private car ownership coupled with the rise of completely new mobility options are rapidly changing the way people are getting around. Concerns around pollution, traffic congestion, loss of productivity and, of course, money, have made this idea gain importance in recent years in the fleet industry. [1]

In this sense, the idea behind Smart Mobility is to reinvent mobility in order to present new mobility models that are sustainable, environmentally friendly and efficient. In this way, it is intended to give rise to a mobility system more convenient for both the environment and the user, in the form of an individual or a company.

For this purpose, Smart Mobility plans to reduce traffic congestion and air and noise pollution while increasing safety, increasing the speed with which transport demands are satisfied and reducing the costs associated with different modes of transport. [2]

In a scenario where technology is growing at an exponential rate unprecedented in history, the impact of technological advances cannot be quantified. In this sense, citizens, administrations, and business owners have in their hands the ability to take or not the risks of implementing this type of technology within their daily operations, and it is in this aspect that this project aims to act, responding to the interest presented by the various entities in relation to the new paradigm of mobility.

The concept of Smart Mobility is closely linked to that of Smart City, as it is one of the parts that composes it. In this sense, according to *RideAmigos*, the Smart City movement is gaining traction worldwide and has opened up a new world of possibilities to forward-thinking municipal planners. It also defines that, despite not having a single definition of Smart City, the factor that makes a city "Smart" is the fact of integrating information and communication technologies (ICTs) into their municipal infrastructure to improve the efficiency and performance of municipal services while reducing waste, pollution, and resource consumption. In essence, they use connected systems and programs to keep the city moving and working effectively. [3]

Objectives of the research

Having described the importance of the term Smart Mobility in how society interprets and will interpret transport in the future, it should be noted that its expansion is advancing by leaps and bounds. It is in this sense, in which the need to carry out an analysis of the technologies that are being developed is detected to estimate to what extent and in which sectors Smart Mobility is evolving.

It should be borne in mind that the transition process towards Smart Mobility models is progressive, so that, although the growth is rapid, the implementations carried out today are within a first-time development phase, which will require constant evolution to resemble the ideal models.

In this way, certain questions are presented that will be the object of the development and that are intended to be answered with the research carried out:

"What is the current state-of-the art of Smart Mobility?"

"What are the trends in Smart Mobility developments in terms of adoption of technologies for the different application environments?"

To carry out the analysis that responds to the research questions posed correctly, it is necessary to establish, in advance, a methodology and a research strategy that allows an accurate analysis of Smart Mobility in the current mobility ecosystem.

Methodology

This section describes the guidelines on which the research process will be based, so information about the tool used, the literature search and the procedural criteria used are detailed in the following points.

Database development

First, the tool on which all the performed analysis has been developed is defined, and it is an extensive database where a wide variety of information is collected on different projects related to Smart Mobility. Its use is key to be able to carry out a data analysis that provides a statistical vision of the state-of-the-art in mobility.

In this way, the database collects a wide variety of data that is intended to be used to extract data on mobility trends for both public administration and private sector.

In Table 1 it can be seen an extract of the database that is the main tool for data collection on which to base the research. In general, various information has been specified in the database for the definition and identification of projects.

Specifically, within this database it can be found general information about the proposal, such as the name of the initiative, a description of the proposal, the year of launch and its state of development. In addition, there are several parameters related to geographic information and the application area of the projects, so that their sector and origin can be determined. Likewise, it includes specific information on the communication technologies used, as well as other technologies of interest for the analysis.

The identification and determination of these parameters for the various projects allows to have a correct traceability of these, and gives rise to the characterization of the data, in such a way that a statistical analysis can be carried out to extract useful information.

Table 1. Extract from the database used to perform the research object of this project

Initiative name	Partner Name	Description	Geographic area	Initiative nation	Region/ city	Company type	Application area (main)	Application area (secondary)	Launch year	Progress	Communication technology (main)	Communication protocol (main)	Communication technology (secondary)	Communication protocol (secondary)	Other technologies 1	Other technologies 2	Other technologies 3
Apollo Vehicles for Walmart	Udelv, Baidu & Walmart	Self-driving vans for last mile delivery of refrigerated supermarket products	North America	United States	Arizona	Established company	Logistics	Autonomous vehicle deliveries	2021	Preliminary analysis	Cellular network	5G	C-V2X		Autonomous driving		
curbFlow	DC's Department of Transportation (DDOT) & curbFlow	Curb parking was removed at nine locations where commercial deliveries often result in double parking, and drivers could reserve loading zone time online either on-demand or in advance	North America	United States	Washington	Partnership (private sector & public administration)	Traffic management	Parking management	2019	Pilot	Wired technologies	Optical fiber	Smartphone app		Camera	Microwave detection	
SENTINEL	ANAS, Takius, ENEA and Consorzio Train	Installation of intelligent sensors capable of measuring weight and speed of vehicles in transit on bridges or other structures. With this data it will therefore be possible to organize targeted maintenance interventions more accurately.	Europe	Italy	Genoa	Public administration	Smart Road	Road management	2021	Executive	Wired technologies	Optical fiber			Presence sensors		
SensTraffic	Sensys Networks	SensTraffic is a traffic management solution that allows optimizing the traffic at intersections by making use of the different sensors and technologies of the company. It has already been implemented in the city of Berlin	Europe	Germany	Berlin	Established company	Traffic management	Intersections priority management	2020	Executive	Wireless technologies	IEEE 802.15.4			Artificial intelligence	Radar	
X-Bus	Huawei	Huawei is developing a self driving bus that works paralelly with V2I technology in a 2.5 mile road in Wuxi, China. This road has established a network of connected radar, camera, and sensor systems.	Asia	China	Wuxi	Established company	Traffic management	Public transport	2021	Pilot	DSRC	C-ITS	C-V2X		Autonomous driving	Radar	Camera
Bercman Smart Pedestrian Crosswalk	Bercman	This smart crosswalk is composed of two regular traffic signals with a lot of different sensors and cameras that allow having different functions. It is able to detect pedestrians and notify its presence to the drivers. Moreover it is able to detect and notify infractions of the drivers. It also has V2X protocol for future functions.	Europe	Finland	Helsinki	Startup	Traffic management	Analytics	2020	Pilot	DSRC	C-ITS	C-V2X		Artificial intelligence	Camera	
Sitraffic Fusion	Siemens, Transport of London	Sitraffic Fusion is an adaptative traffic control system that takes data from different connected vehicles in order to adapt traffic to the user needs. This system is also designed to provide a control on air quality in the cities.	Europe	United Kingdom	London	Established company	Green technologies	Environmental parameters monitoring	2020	Pilot	Wireless technologies	802.11p WLAN	V2I		Autonomous driving		
P3Mobility Smart Intersection	P3Mobility	P3Mobility is a company that provides smart intersection systems by using smart traffic signals which manage different priority levels depending on the traffic that can be analysed with AI. Moreover it is compatible with V2I communications. They are testing the product on more than 20 intersections on the city of Ann Arbor.	North America	United States	Michigan	Startup	Traffic management	Intersections priority management	2021	Pilot	DSRC	ITS-G5	V2I		Artificial intelligence	Radar	
TransAID (Transition Areas for Infrastructure-assisted Driving)	TransAID	This European project works on the integrations of automated vehicles and connected automated vehicles to the infrastructure. They try to anticipate to the problems of this kind of vehicles in different challenging scenarios in order to prevent those problmes and to have a more stable and integrated system.They also work for a standard in this kind of technologies.	Europe	Germany	Cologne	Startup	Smart Road	Connected roads	2018	Executive	Wireless technologies	IEEE 802.11p / ITS-G5	C-V2X	LTE-V	Autonomous driving		
ICT4CART	ICT4CART	They work for the developement of infrastructure for Connected Transport (ICT) platform which benefits the transition to automoated transport. Moreover, their objective is to use the information that automated and connected vehicles take from the road in order to have an extra infromation source. Their solutions are being tested in four different countries.	Europe	Greece	Athens	Startup	Software and platforms	Connected vehicles	2018	Pilot	DSRC	ITS-G5	C-V2X	LTE / 5G	ITS (Intelligent Transport Systems)	Data analytics	
5G Mobility testbed	LMT	The Latvian network operator LMT has set up a 5G mobility testbed in order to test and verify their 5G networks in specific mobility scenarios, this way, the potential of the new 5G technology can be verified. They have performed tests where a car was remotely driven thorugh a 5G network.	Europe	Latvia	Riga	Established company	Smart Road	Connected roads	2021	Pilot	Cellular network	5G			Autonomous driving		

Literature framework

To achieve the objectives of the project, previously translated into two research questions, the database must be used as a tool for exploiting information. At this point, the determination of what information to exploit and why, therefore, a selection criterion is established in this section, as well as the different sources used, comes into play.

First, the search has begun by the analysis of articles and current news within the mobility sector that have allowed to establish the context of the project, as well as to expand the level of knowledge in the field and understand its complexity while the most relevant application areas are determined. This very first analysis allowed structuring the basic ideas of the research.

Next, the various parameters and characteristics to be analyzed were established, specifically related to communication technologies, main application areas, other technologies of interest, typology of the project, among others.

This way, the literature search was able to focus on the determination of the advances and initiatives made in the field of Smart Mobility. This information accompanied the entire process of analysis of the state-of-art and allowed to complete the content of the database.

Regarding the sources, a large part of the projects analyzed have been obtained from search engines specializing in the field of research. The main sources consulted have been, specifically:

1. *Google Scholar:* This web search engine is focused on scholar literature and includes multidisciplinary information, so its utilization is almost essential for the realization of research work or to analyze the state-of-the art of various sectors.

2. *ResearchGate:* This search engine collects a database of scientifically and medically based information. On this website it can be found articles from academic journals and e-books useful to perform any research work.

Likewise, much of the information has been obtained from secondary sources, such as mobility-specialized websites or news portals of a technological nature. In this area, the SmartCitiesWorld, IntelligentTransport or SmartCitiesDive websites stand out, as they provide current news related to the latest notable advances in the field.

In addition, the searches carried out have been based on the use of a series of keywords that have allowed to find the results obtained, among them stands out: "Smart Mobility", "Smart City", "Mobility technologies", "Smart Road", "Mobility innovation" and "Smart transportation".

Procedure criteria

In this sense, it has been determined that, given the nature of the research, the analysis of the literature should focus on the search for the most outstanding developments by both private sector and public administration.

Specifically, it has been considered that the analysis of the projects in which resources are being invested is the most reliable indicator of the evolution that the different application areas of Smart Mobility are presenting. It should be noted that the criterion used is based on the selection of projects and not solutions, that is, it is an essential requirement that the information entered within the database has associated a practical application in process of execution, or simply planned for more evolved phases of the project.

Likewise, some of the Smart Mobility projects found have been discarded for not having a sufficiently innovative technological base. In this sense, a criterion has been used that is based on including only projects that provide a novelty at a technological level or that, at least, fulfill a Smart Mobility function in an unprecedented place or application.

Moreover, it has been required that the projects incorporated into the database were strictly related to Smart Mobility and not only to Smart Car or autonomous vehicles specifically.

State-of-the-art analysis

After sampling 135 different projects through the database, the project proceeded with a statistical analysis of the information that would allow obtaining a global view of the current scenario of Smart Mobility. Specifically, the study focused on determining the State-of-the-art of related initiatives and evaluating the adoption of technologies and their specific application. In this sense, Chapter 2 focuses on evaluating the State-of-the-art of Smart Mobility,

First, with reference to the State-of-the-art of Smart Mobility initiatives, an analysis of the most outstanding projects for each of the application areas has been carried out. Thus, it has been possible to obtain an indicative vision of the characteristics of the initiatives presented for each of the categories of application area, as well as to differentiate the most innovative and ambitious proposals of each of the areas.

Next, the analysis of the State-of-the-art has proceeded through an analysis of the information collected in the database. In this way, a significantly greater presence of projects framed within the application area of traffic management has been distinguished, which has comprised 37% of the total sample. Likewise, it has been determined that there is a fairly balanced distribution of initiatives according to the type of company between the established companies (46%), startups (32%) and public sector (22%), which is usually concentrated, for other application areas, mainly in the established companies. From this first analysis it was also possible to distinguish an exponential growth in the number of initiatives, since there was an increase in initiatives in 2021 of 70.7% compared to 2020.

Emerging technologies

Once the state-of-the-art analysis was concluded, the line of analysis focused on the study of the most relevant emerging technologies in the sector, which, specifically, was divided into communication technologies and other alternative technologies. Specifically, this section summarizes the results obtained in the analysis carried out in Chapter 33 that includes the study of the various technologies adopted.

In this way, the analysis was able to extract, in the first place, an important weight in terms of Smartphone application, GPS and V2X technologies, forming part of 46, 38

and 34 projects, respectively. These communication technologies were distinguished based mainly on 5G protocols and, to a lesser extent, on ITS protocols. Secondly, the analysis of other technologies was able to distinguish a remarkable presence of artificial intelligence and autonomous driving technologies, in a total of 26 and 24 initiatives, respectively.

In addition, in relation to the various technologies analyzed, it has been possible to distinguish a remarkable combined presence of communication technologies and other artificial intelligence technologies together with cloud platforms and autonomous driving together with GPS. This result agrees with the differentiated result where artificial intelligence and autonomous driving technologies have a superior presence over the rest.

Conclusions

After having proceeded with the analysis of the initiatives included in the database, the research project concludes with Chapter 4 where the conclusions obtained from the realization of the study are detailed, thus being able to determine the patterns and trends that follow the Smart Mobility initiatives analyzed, as well as present a much more accurate perspective on the trend and the future path that the mobility paradigm will take.

In this sense, with respect to the State-of-the-art it has been possible to determine that the mobility sector is of great relevance for all parties involved, since there is interest in research and development in this sector by public administrations, established companies and startups. In addition, in this sense it should be noted that the initiatives and, in general, the paradigm of the Smart City (in which Smart Mobility is included) has a very wide acceptance by citizens, who are the end user of most initiatives.

At the same time, it has been possible to determine that the area of application that arouses the greatest interest among the involved roles is traffic management, and this result makes sense considering the large number of possibilities and intrinsic advantages presented by advances in this area, especially in the urban cores of cities with a large number of inhabitants.

Likewise, it can be determined that the interest in Smart Mobility is growing, because among the 135 projects introduced in the database it has been possible to distinguish an exponential behavior, where year after year, it is easier to distinguish a greater number of Smart Mobility initiatives.

On the other hand, in terms of the adoption of technologies, it has been possible to determine that, broadly speaking, communication technologies focus on the use of smartphone applications, considering the large amount of information that these devices can provide about most citizens, and their excellent ability to interact with the user to facilitate the services offered by some of these initiatives. In this sense, it has also been possible to distinguish that this technology has gone in many projects accompanied by location by means of GPS.

In this area, it has also been possible to distinguish a high presence of initiatives focused on communications between vehicles (V2X), which is one of the pillars on which the paradigm of mobility is based, communication between different users and devices, in line with trends towards the IoT (Internet of Things).

In addition, it has been possible to distinguish the presence in a remarkable part of the projects of artificial intelligence technologies and autonomous driving. This result is consistent considering the technological nature of the initiatives that, focused on optimization, require complex machine learning algorithms, as well as fully autonomous vehicles that increase safety and operate with greater efficiency than conventional vehicles.

In this way, the present project has concluded allowing to offer a much broader and more precise vision of the situation of Smart Mobility, differentiating the patterns and trends presented by the developments made in recent years, in order to determine the path that the sector will take in the future.

1. Chapter 1: Smart Mobility

This chapter introduces the topic on which the analysis carried out in the thesis is based. In this sense, the concept of Smart Mobility is defined and introduced within the historical context of mobility in general. In addition, this Chapter determines the different application environments that encompass the broad concept of Smart Mobility and the different roles involved in the emerging projects related to this concept.

1.1 Definition of Smart Mobility

The concept of Smart Mobility arises as a response to the need to evolve through technology towards personal mobility models where aspects such as the reduction of environmental impact, sustainability and efficiency are prioritized. Taking into account these premises, Smart Mobility is mainly focused on public transport, redefining urban mobility and its infrastructure to give rise to the transport network of the future. In this way, the private vehicle for individual use is in the background.

This mobility model was born as a response to an increase in population in urban centres, giving rise to greater traffic on the roads of cities and thus generating a mobility problem, as well as an environmental problem.

In this way, Smart Mobility can be presented in a variety of ways in your practice, such as car sharing, using public transport, walking, cycling, driving an electric scooter, etc. Thus, the different projects focused on Smart Mobility seek to promote this type of mobility through various technologies that increase its efficiency and sustainability, making it more attractive for the user.

It is worth mentioning the advantages that this mobility paradigm presents, and among them it should be highlighted the following:

- **Safety**: The fact of being mainly focused on public transport, implies that Smart Mobility provides a great advantage in terms of safety, as the fatalities and injuries associated with traffic accidents are drastically reduced.

- **Pollution reduction**: One of the main concerns of the current population is environmental care, and this can be seen reflected in mobility, as it is intended to reduce to the maximum the use of cars with thermal engines, betting on collective means of transport or electric vehicles, in such a way that pollution levels in cities are significantly reduced.

- **Integration**: As this paradigm aims to provide mobility solutions to every Mobility necessity that anyone can present, it is completely integrated into the geography, in such a way that it has a transport network completely communicated in an efficient and effective way.

- **Less time consumption**: Another of the main objectives of Smart Mobility is to obtain a highly efficient transport system, so that routes in general can be completed in a significantly shorter amount of time. In this aspect, intermodal mobility comes into play in a way routes are designed to include various means of transport in an optimized way, in order to reach any destination as fast as possible.

- **Flexibility**: The mobility system proposed in the Smart Mobility models aims to integrate all modes of transport under a common framework, so that users can choose each alternative according to their needs. In this sense, Smart Mobility tries to respond to the havoc created from traffic not by building more roads but instead, by extending the coverage and the service of more sustainable means of transport.

- **Convenience**: In this sense, Smart Mobility has a substantial advantage as all its developments are closely related to mobile platforms through smartphone applications, in such a way that its interaction with the user is simple and comfortable.

- **Connectivity**: Smart Mobility focuses on increasing the level of connectivity not only through smartphone applications, but through various communication technologies, in which communications between vehicles and

infrastructures (V2X, V2I and V2V) stands out. In this way, there is a much richer mobility ecosystem with much more information that allows to increase efficiency and implement unprecedented new technologies.

- **Reliability**: As public transport is much more reliable than private vehicles due to the presence of periodic inspections and maintenance. Moreover, the expansion of the means of transport would allow obtaining a greater reliability in terms of timing.

Following the tendence of Smart Mobility, it is worth mentioning the term of the Smart City, which is closely related to Smart Mobility since they respond together to the purpose of changing the paradigm of mobility in cities.

The Smart City maintains the same premise of making a more efficient management of resources, in this case of the city. In this way, it focuses on adapting its infrastructure by prioritizing the pedestrian over the rest of the city's partners in various areas: social, administrative, financial, commercial, and intellectual.

Thus, the Smart City comprises a process of digitalization of cities that allows the integration of services and infrastructure under a common framework where the main focus is on citizens, social and environmental capital. This process implies a growing importance of information and communication technologies (ICT) that are the perfect tool to build Smart Cities. In this sense, developments in this area require intelligent communications that allow a more efficient use of the environment, in such a way that it has a direct impact in the quality of life of citizens. From the technological point of view, a smart city is an eco-sustainable system of great complexity, that is, a global ecosystem in which multiple intimately linked processes coexist and that it is difficult to approach or value individually.

Smart city could be perceived as the one that uses Information and Communication Technologies to make the city services and monitoring more aware, interactive, and efficient. At this juncture, the successful employment of multitude of recent technologies relevant to the various disciplines can be considered as a sustainable solution to overcome this situation. Application of various technological tools for the mapping of future could give rise to a socio-technologically competent cities, so called the “smart-cities”. [4]

According to Figure 1, the key areas of Smart City paradigm can be seen. These key areas are aligned with the principles described, and have aspects closely related to Smart Mobility, such as Smart Parking, Street Repair, Traffic Control or Energy Management. In this sense, it should be borne in mind that cities have been an important settlement that affect the environmental changes radically.

Figure 1. Key areas of Smart City paradigm [4]

In this way, Smart Mobility is contextualized within the increasingly relevant Smart City, thus reflecting its importance, as well as the importance of the communication technologies on which it is based.

1.2 Historical context

In order to understand the importance of Smart Mobility in actual scenario, it is important to perform a review on the history of transportation since the very beginning of it. That way, it will be easier to notice how this trend is stablishing the bases for the evolution that this sector is performing nowadays.

1.2.1 Mobility in the past

Mobility is a human need that has been solved by incorporating means of transport whose origins date back to the first steps of the human being. In this sense, the first of the advances incorporated by the human being in terms of mobility appeared with the invention of the wheel, which dates to the period between the year 3700 B.C. and 3200 B.C. This advance was revolutionary since it allowed to facilitate the transport of loads and people by means of 4-wheeled carts with animal propulsion.

This invention was a very important advance for civilization, as it facilitated the displacement of villages to different geographies in search of resources that would allow them to evolve and develop. Thanks to the invention of the wheel, societies began to explore new territories and settled in areas near rivers, seas and oceans, giving rise to the first boats.

At the same time as the wheel, around 3500 B.C., the first forms of maritime transport that could carry small loads and a few crew members on short journeys are recorded. At first, these boats used the arms and legs of their crew as propeller but, gradually, they evolved through the introduction of oars and, later, using masts and sails that allowed to make use of the force of the wind to move the boats, giving rise to more sophisticated boats such as galleys, caravels and frigates that significantly expanded the capabilities of this means of transport.

Thus, the invention became revolutionary and allowed civilization to expand its horizons. In this sense, this invention significantly improved the ability to obtain resources, since it allowed civilizations to exploit remote areas and transport large amounts of goods over long distances. Likewise, this type of vessels was the main driver of trade, allowing throughout the 18th century an important boost in commercial relations between civilizations.

Next, the great invention that allowed the evolution of transport systems was the steam engine in the 17th century. This engine was able to not only substantially improve the capacities (in terms of size and load capacity) of ships, but also to introduce new means of transport that would revolutionize mobility in a wide variety of aspects.

The steam engine follows Rankine's thermodynamic cycle and aims at transforming thermal energy into kinetic energy. This way, it should be noted that this steam engine acted as a precursor to the reciprocating internal combustion engines that are used today in all types of applications, including means of transport. Thus, this invention progressively gave rise to new means of transport, the pioneer being the steam train.

In this way, at the beginning of the 19th century there can be found the first vehicles powered by steam engines with a commercial character, since previously some experimental prototypes had been developed that used these engines.

In this area, there was a rapid evolution in rail transport based on the Trevithick prototype, since by the middle of the century there was adequate infrastructure and commercial locomotives that revolutionized again the transport of people and goods. This evolution in the means of transport allowed the human being to travel long distances comfortably and generate an infrastructure that interconnected remote places, thus being able to facilitate the transport of goods and, therefore, boost industrial production.

Progressively, this type of engine evolved to obtain the alternative internal combustion engines that we have today, and that have been the precursor of new revolutionary means of transport, among which the airplane and the automobile stand out.

Thus, in 1903 the Wright brothers made what according to the International Aeronautical Federation is considered "the first sustained and controlled flight of an aerodyne powered by an engine", settling one of the means of transport most desired by the human being since the beginning of the historical era, with records such as the Greek case of the flight of Icarus. In this way, by the middle of the 20th century there were passenger aircraft that represented a revolution in transport, allowing to travel long distances in a much shorter period of time than the existing trains so far.

Also, in 1886 appears the first commercial car in history with an internal combustion engine, the Benz Patent-Motorwagen. The interest and good reception of this means of transport allowed it to evolve very quickly, giving rise in a few years to an important car market with very sophisticated characteristics.

It stands out from all these advances that, its implementation, meant a notable improvement in the quality of life of society, expanding its possibilities and allowing its growth and evolution. In addition, all of them have in common the fact of being inventions whose use has been maintained until today, where we can continue to find the wheel, ships, trains, and planes.

1.2.2 Mobility in present time

In this way, today's scenario is reached, where mobility is part of the day to day of people, being a fundamental pillar of society both socially and economically. Thus, it has evolved in this area to have a great diversity of means of transport for short, medium, and long distance.

Thus, at present it can be found a high demand in terms of mobility by society, which makes it necessary to implement complex transport systems adapted to their needs. In this sense, it must be ensured that people can meet their transport needs and that productive resources can be transported safely and economically efficiently.

The current social situation makes it necessary to redefine the concepts of mobility in environmental terms and the new logic regarding sustainability paradigms. From this point of view, an efficient and intelligent transport system that makes a sustainable management of the means of mobility becomes essential for the health of the economy and for living standards.

In this sense, it is evident that at present the mobility scheme depends to a large extent on private vehicles that have determined the lifestyles of citizens and the infrastructure of the city, with their consequent impacts for the sustainability of the environment both in urban areas and outside them. However, the trend is now evolving towards mobility models focused on pedestrians and public transport, as a solution to the environmental impacts produced by the current model, both in terms of pollution, safety, and visual impact.

It should be noted that there are currently complex transport networks both urban and extra-urban. However, these networks are not extensive enough to cover the transport of the entire population and they do not do so sufficiently efficiently. That is why the concept of Smart Mobility appears, where on the one hand it is intended

to emphasize the character of mobility as a public service and not as a private action, and on the other, special emphasis is placed on the incorporation of new technologies that allow to provide a more attractive, sophisticated, and efficient service.

In this sense, Smart Mobility can be considered the new great evolution in terms of transport and mobility, as it aims to completely redefine the concept of mobility and its infrastructure, enhancing the presence of pedestrians and public transport, in such a way that a transport network sophisticated enough to meet the mobility needs of the entire population effectively and efficiently can be counted.

In this way, improvements would be obtained in terms of travel times and extension of the transport network. In this sense, Smart Mobility foresees a beneficial effect against the massification of cities, as it would allow a decentralization of the workplace, giving rise to the possibility of inhabiting peripheral areas separated from urban centers without this being an impediment to combine working life.

There are numerous advantages that would be had after evolving to Smart Mobility models, since a technologically sophisticated transport network would lead to improvements not only at the social level, but also at an economic and industrial level. Thus, it would be possible to significantly increase the productive capacities of industries thanks to the optimization of transport times. On the other hand, this new evolution of transport would lead to a much faster and simpler network of imports and exports, thus boosting the competitiveness and technological development of companies.

1.3 Application Industries

In order to quantify the scope of Smart Mobility, it is necessary to make an analysis of the environments in which the application of Smart Mobility technologies would lead into substantial advantages.

In this way, this section introduces the environments that make up the Smart Mobility ecosystem. Thus, various application environments can be distinguished where potential beneficial effects would be presented after the shift to the future mobility ecosystem.

The value shifts for these and other industries could have a tremendous impact on revenues across the ecosystem. Figure 2 summarizes some of the potential effects of the shift to the future mobility ecosystem. The graphic also includes potential societal benefits expected because of autonomous drive and shared mobility technological advances. The analysis does not yet account for new business models that could evolve within the future ecosystem; it is meant to illustrate the potential effects/directional impact that autonomous cars and shared mobility may have on today's ecosystem. [5]

Figure 2. Main application environments for Smart Mobility [5]

In accordance with this, the main consequences that the shift to Smart Mobility would have in the respective application industries are defined below: [5]

- **Automotive**
  - Decrease in personally owned vehicles sales and increase in fleet vehicles sales due to shift toward shared mobility.
  - Wider range of vehicle designs could emerge.
  - Value shifts from asset ownership and driving performance to software passenger experience.
  - Lighter vehicles could enable OEMs to meet CAFE and ZEV requirements more easily.

- **Finance**
  - Growth in fleet financing.
  - Shifts away from personal vehicles could lead to a decrease in auto loans and leasing.

- **Insurance**
  - Potential opportunities for experience-based insurance products.
  - Shifts from personal liability to catastrophic systems-failure insurance could lead to a decrease in insurance sales.

- **Energy**
  - Potential for increase in miles driven
  - Improved vehicle efficiency could lead to lower energy consumption.
  - Autonomous technology could further enable a transition to alternative fuels.

- **Public sector**
  - Reduced number of automobiles could decrease current revenues (e.g., licensing fees, fuel taxes, etc.)
  - New consumption-based, dynamic taxation models could offset tax revenue tax revenue decline.
  - Potential change in mix and usage of public transportation.

- **Medical & legal**
  - Fewer auto-related accidents and fatalities could reduce costs for emergency medical services and related legal fees.

- **Media**
  - Greater time available through autonomous drive and shared mobility increases consumption of multimedia and information.
  - Increases in advertising and subscription revenues and data monetization opportunities.

- **Telecom**
  - Increased demand for connectivity and reliability could result in additional bandwidth requirements.

- **Technology**
  - Emergence of autonomous drive operating system players.
  - Autonomous cars and shared mobility would likely lead to the rise of mobility management providers.

- **Retail**
  - Increased mobility of underserved segments (e.g., seniors) could increase retail sales.
  - Expands home delivery options.
  - Changes retail landscape in response to city demographics shift.

- **Transportation**
  - Shared fleet vehicles could substitute demand for traditional taxis, limos, and rental vehicles.
  - Increased automation creates new business models for long-haul trucking, movement of goods.

In this way, it is easy to estimate the magnitude of the scope that the evolution of mobility towards Smart Mobility models would present. In this sense, the scope of this new mobility paradigm, which is the object of study in this project, is not limited only to the mobility sector, since there are numerous sectors that would be affected (both positive and negatively) by the implementation of this mobility model.

1.4 Involved roles

This section aims to describe the different roles involved in the process of evolution towards models the Smart Mobility models described. The roles described will be part of Smart Mobility and will be key figures for its implementation correctly and effectively.

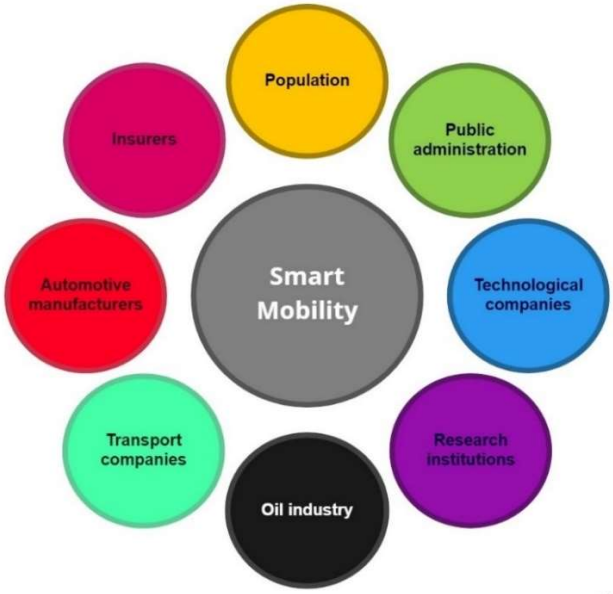

Figure 3. Different involved roles in the Smart Mobility paradigm

In this sense, there are different roles that have active or passive positions in the transition to this type of technology, in the sense that they can or cannot promote these technologies and favor their use and extension. In Figure 3 the roles involved with the Smart Mobility paradigm can be distinguished.

The following sections briefly describes the function and relevance of each of the differentiated roles, according to Figure 3.

Population

First, the most important role within the Smart Mobility paradigm, which is that of the population, is played. This role is key within this new definition of mobility, both in the sense that it is the core on which the various technologies and proposals of Smart Mobility are centred, and in the sense that they are the role with the greatest decision-making power when accepting or rejecting proposals.

As mentioned, Smart Mobility is focused on the pedestrian and offering an efficient and sustainable mobility service. Thus, the infrastructure developed focuses on the needs and requirements of pedestrians, so the position of the population in this area is crucial to allow mobility to evolve towards intelligent models.

Considering the growing environmental awareness of citizens, it is trivial to understand why mobility is evolving towards Smart Mobility. In this way, one can distinguish a large acceptance of the population, which welcomes very positively the developments in terms of mobility that give rise to transport not only better able to meet their needs, fast and economical, but also sustainable and eco-friendly.

In this sense, it is worth mentioning the conference paper of 2016 in which an analysis of the satisfaction of a sample of the population of 247 people with public transport services in the city of Sarajevo was carried out. Although the city of Sarajevo does not have very sophisticated public transport services, this allows us to detect what reasons push the population not to use public transport. The result of this analysis can be seen in Figure 4. [6]

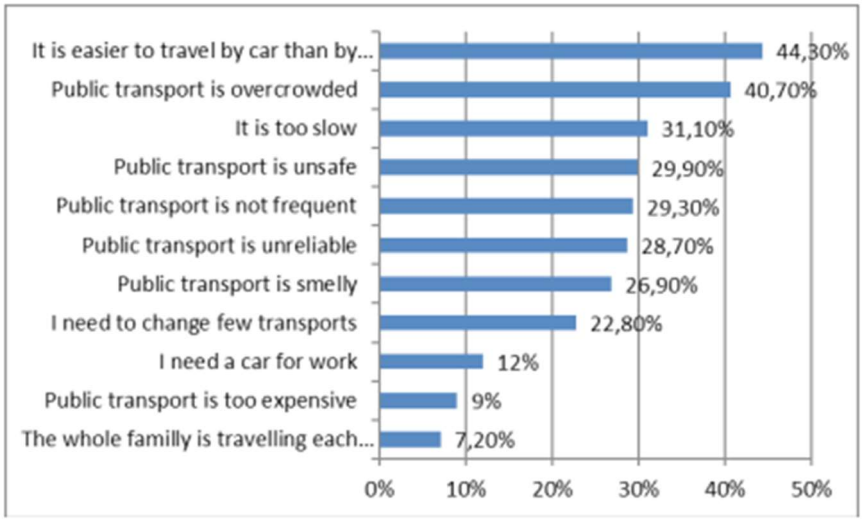

Figure 4. Reasons not to use Sarajevo's public transport [6]

According to the study carried out, it can be concluded that Smart Mobility aims to act in a large part of the problems detected by the population because, attending to the three most claimed reasons, Smart Mobility proposes models where the use of public transport is simple, its infrastructure is wider and therefore it is less overcrowded and works faster.

Public administration

Moving on to the next big partner on the Smart Mobility paradigm, public administration can be found. The position of the public administration in this field has a more than relevant role, as mobility is located in the cities that are their responsibility.

In this sense, public administration is responsible for legislating and therefore facilitating or hindering the implementation of measures that favor the evolution of mobility towards Smart Mobility models. Likewise, the public administration also acts as the main driver considering that they are responsible for establishing an adequate infrastructure for the implementation of new technologies. In this way, it should be noted that Smart Mobility in most of its applications depends on a public infrastructure that must be promoted by the public administration.

According to this, it can be distinguished that, indeed, the reception of Smart Mobility by public administrations is very favorable, since in recent years new forms of mobility have made their way at an accelerated pace. Thus, there is an established European goal of zero polluting emissions in the year 2050, for which the "Sustainable and Smart Mobility Strategy" was approved in 2020 and will require regulatory changes and an economic effort of 300,000 million euros in the next decade.

It can already be seen how the different governments are carrying out impulse programs through the Next Generation EU funds granted by the European Union. Thus, Diego Jiménez-Albarracin, Investment Officer Europe at Deutsche Bank, assures that Smart Mobility is one of the areas with the greatest growth potential within sustainability. In this same line, according to a report by the consultancy KBV Research, the Smart Mobility sector will reach a global turnover of 91,000 million dollars in 2026 (about 79,000 million euros), more than double the market value of 2019, presenting a growth rate of 18.4%. [7]

Technological companies

At this point, technological companies take place as the next big driver of Smart Mobility. In this way, another important role is presented in the goal of establishing Smart Mobility models in current mobility.

In this sense, it should be borne in mind that this role represents private sector contributors in the development of new technologies, especially in the field of communication. These companies are responsible for the realization and promotion of Smart Mobility projects where the technologies developed are tested and taken to the practical field that allows their commercial introduction.

According to the analysis that will be carried out in this project, it is intended to demonstrate the growing interest presented by the private sector in Smart Mobility, since recently it is possible to distinguish a greater presence of technological companies that invest resources in this sector, as well as recently created startups that seek to join the sector with innovative projects.

In this sense, the role of these companies is crucial, as they develop all the technology behind this mobility paradigm, allowing the sector to grow and adapt to the infrastructure available in each place. It should be borne in mind that progress towards Smart Mobility models is slow and progressive, which is why the incorporation of technologies must evolve according to the rest of the parts.

Research institutions

Research institutions are entities specifically aimed at development and, in this group, there can be distinguished all kinds of companies that directly or indirectly contribute to the development of Smart Mobility models.

In this sense, it should be borne in mind that all the technical developments produced come from the last three roles described, which are: public administration, technology companies and research institutions. Together, they play an active role in the development and implementation of Smart Mobility technologies, so they play a fundamental role in the transition to the new mobility paradigm.

Referring to Figure 5, it can be seen a graph extracted from a Web of Science study, which determines the number of papers published on sustainable development from 2000 to 2019.

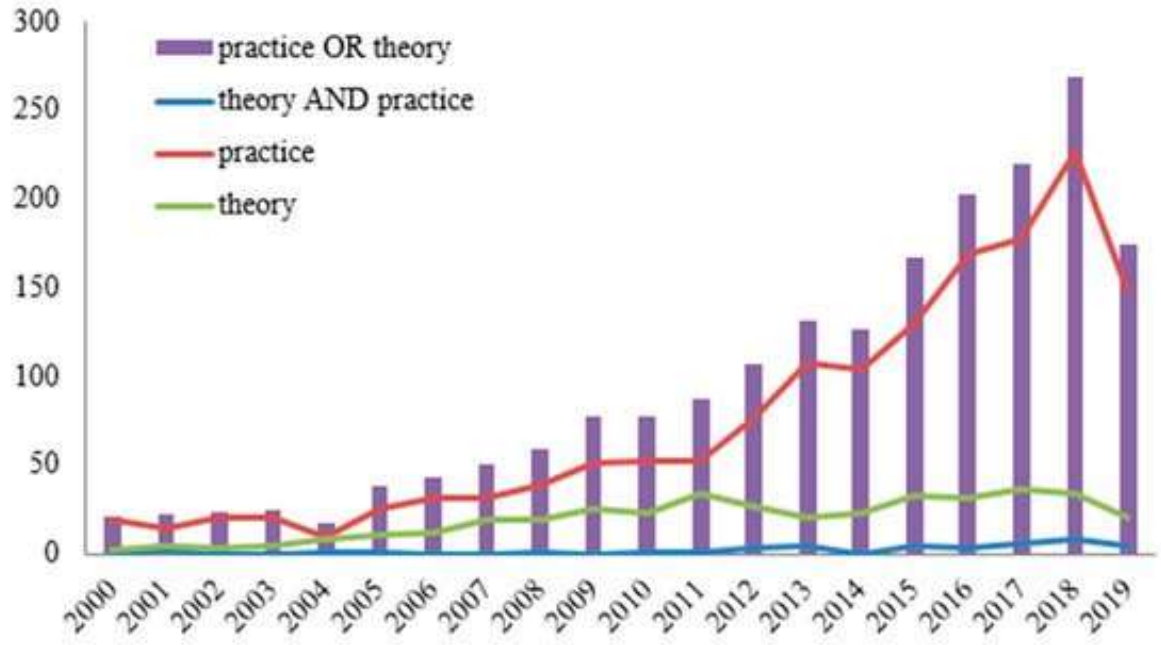

Figure 5. Number of papers on "sustainable development" published from 2000 to 2019 in Web of Science (WOS) core database [8]

Thus, there is a growing interest in sustainable development that has a direct impact on mobility. Specifically, there is an exponential growth related to the development of solutions at a practical level. In the values of 2019, it can be distinguished a certain setback that is associated with the COVID-19 crisis.

Oil industry

Next, there is one of the roles that present a reluctant position with respect to the evolution of current mobility patterns, and that is the oil sector. In this sense, the oil sector is not in line with the principles of sustainability considering that they are the producers of one of the main fossil fuels, of which the harmful effects of the pollutants that occur after their combustion are perfectly known.

Specifically, Smart Mobility seeks to leave the private vehicle in the background as this is an individual and inefficient method of transport. However, within the paradigm of sustainable mobility there is the presence of private vehicles in the form of PMV (vehicles for personal mobility) such as e-scooters, or even cars that make use of electric means of propulsion that decentralize the emission of pollutants. Both situations pose an unfavorable scenario for the oil sector.

In relation to this issue, it is worth mentioning the instability of the price of brent crude, which progressively increases over the years, according to the evolution that can be seen in Figure 6. Here, the sudden increase in cost after the start of the War in Ukraine can be highlighted.

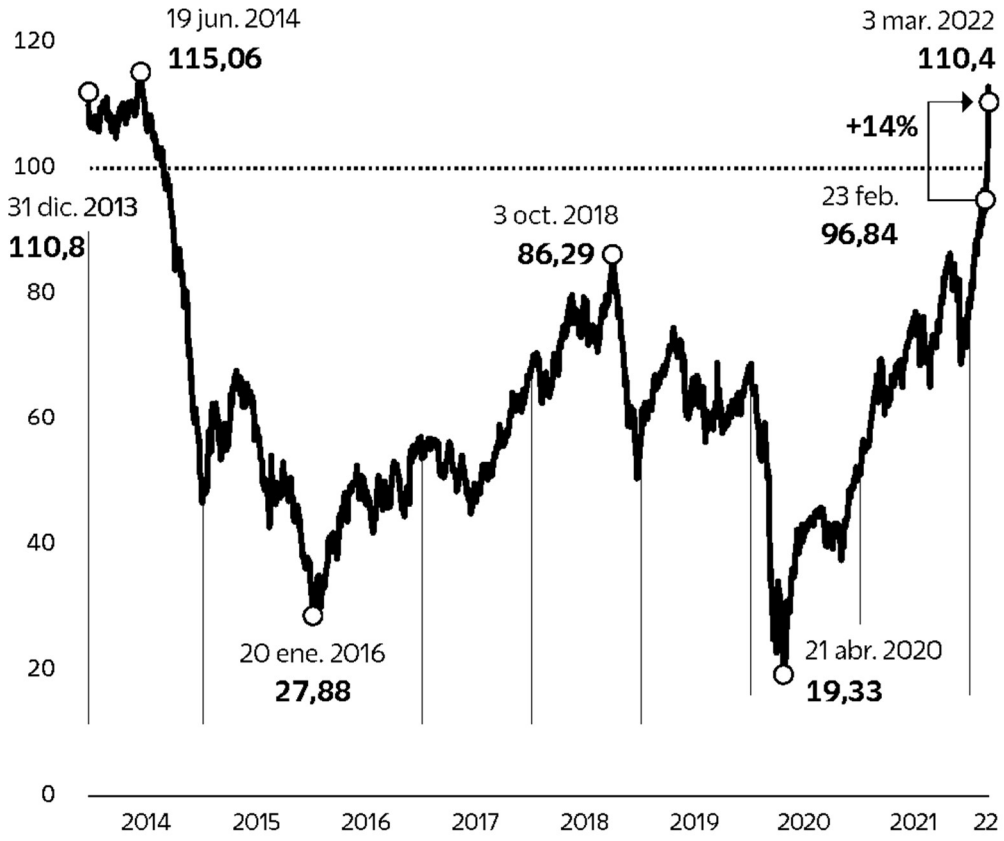

Figure 6. Evolution of the price of brent

Therefore, in this context, one of the main roles is held with a position opposed to the interests of sustainable mobility models.

Automotive manufacturers

The automotive industry can also be considered reluctant to switch to sustainable mobility models, and this is mainly due to the incompatibility of combustion engines with Smart Mobility paradigms.

However, although Smart Mobility focuses on sustainable mobility models based mainly on collective means of transport because they are cleaner and more efficient, in this there is room for the personal car. Despite this, the position of automobiles in

this scenario requires their reinvention from the technical point of view and from the point of view of their utility.

In particular, the automotive industry must focus on greener powertrains, such as hybrids and electrics, which are gradually gaining share in the car sales market, as can be seen in Figure 7.

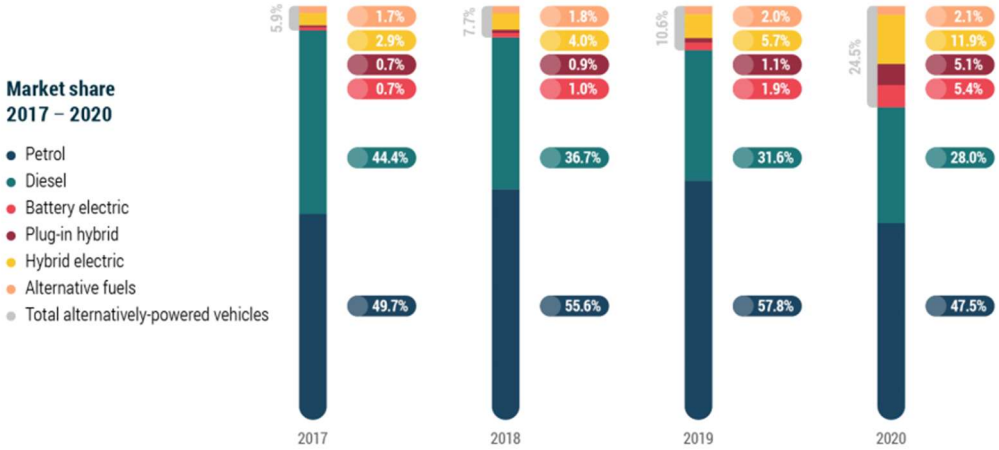

Figure 7. Fuel types of new passenger cars in the EU [9]

In this sense, it can be distinguished a notable reduction in the sales of cars with diesel engines year by year since they are the most polluting and their access to urban centers is progressively being limited. Likewise, it differs that the sales of alternatively powered vehicles (which include battery electric, plug-in hybrid, hybrid electric and alternative fuels vehicles) grows exponentially, assuming in 2020 24.5% of new purchases.

At the same time, in terms of utility, the way of using the personal vehicle is redefined, since in this sense the concept of sharing that links the personal car with a collective vehicle comes into play for a more efficient and sustainable use. In accordance with the principles of sustainable mobility, it is a question of dispensing with the car as a means of single-person transport.

In short, the role of the automotive industry does not have a favorable position in the transition to Smart Mobility, however, the car has space within this new paradigm, adapting its characteristics in the face of efficiency and sustainability.

Transport companies

Likewise, other roles are defined that, despite not having an active position in the transition to Smart Mobility, present a very favorable position considering that they represent a notable improvement in their operations.

In this sense, there are transport companies, whose operations would benefit significantly from the inclusion of technologies in Smart Mobility both at the urban level and at the extra-urban level.

Specifically, the new mobility paradigm emphasizes one of the main problems of logistics today, which is the last-mile delivery. In this sense, transport companies have significantly higher costs per kilometre when entering urban centers, a fact that significantly hinders their operation. Smart Mobility includes technologies that work to find sustainable delivery alternatives that solve this problem.

Likewise, in an extra-urban area, Smart Road technologies are proposed that aim to expand the possibilities of roads, offering innovative services and solutions over long distances by road, in such a way that it leads to more efficient and safe journeys.

Insurance companies

In line with the previous role, the role of insurance companies is presented. Despite not having an active role in the transition to Smart Mobility, there are numerous benefits that surround this sector.

Thus, it is highlighted that Smart Mobility is mainly based on communication technologies and this is precisely where the main interest of insurance companies lies. Considering the value that information technologies currently have in the industry at a general level, the use of techniques that allow insurance companies to obtain more information about vehicle users is especially interesting.

Specifically, the communication systems of vehicles with other vehicles and with the environment (V2X communications) allow to reduce traffic accidents, as well as share data about the driving styles of users, being able to accurately estimate their accident risks.

After the analysis of the main roles, it should be noted that all of them play a relevant role in the Smart Mobility paradigm and, to a greater or lesser extent, are important

in its transition. These roles, together, will allow adapting technology, infrastructure, and the habits of the population to the new mobility models that are proposed as the next great evolution of the sector.

Likewise, it is highlighted that, through the development and analysis to be carried out in this work, it is intended to observe the evolution of these roles, estimating if they have a favorable one to the implementation of new technologies in this matter. In addition.

Through the development and analysis carried out in this work, it is intended to observe the evolution of the different roles, to estimate if their position is favorable to the implementation of Smart Mobility technologies. In this way, once the project is over, it will be possible to have a more precise global vision of the transition process from mobility to the models that underpin Smart Mobility.

2. Chapter 2: Smart Mobility: State-of-the-art

In this section the research process of the Smart Mobility object of this project will begin. Specifically, this chapter aims to answer the first research question raised in section 0:

"What is the current state-of-the art of Smart Mobility?"

Therefore, this section will begin with an analysis of the database where each of the parameters to be analyzed will be specified separately, so that the scope of the analysis can be determined. Subsequently, an analysis of the most relevant practical use cases for each of the different application areas will be carried out.

2.1 Database analysis

To develop an analysis of the state-of-the-art of Smart Mobility, first of all, the content presented in the database must be categorized and studied, taking into account that it is the tool on which the research of this project is based.

In this way, this analysis is of special relevance to be able to know in detail the content of the database, so, first, the characteristics of the data analyzed for each of the projects within the tool will be detailed.

Next, an analysis will be made of the most relevant projects in each area extracted because of the development of the database. In this context, it can be noted that for its development information has been collected from a total amount of 135 projects of Smart Mobility.

2.1.1 Data distribution

In the following points, the information collected in the different columns of the database will be specifically detailed, as well as the criteria for ordering and characterizing the information used in each of the cases.

2.1.1.1 Project definition

The first group of data collects information about the initiative developed and the developer of the initiative in question. This information is essential to make a basic identification of the projects and their main characteristics.

Therefore, in relation to this information are the columns described below:

- Initiative name: The name of the proposed initiative is described. In case of not having a specific name, a title is specified where the proposed initiative and its respective partner appear (i.e., *Sacramento Mobility Hub*).

- Description: At this point, it is figured a brief description that summarizes the proposal raised in the project. This description of a few lines serves to quickly identify the content of the project.

- Launch year: This point includes the year in which the initiative was started. In this sense, the moment in which the initiative has been raised is counted and not the moment in which it has been executed.

- Progress: This column acts as an indicator of the development phase in which the project is. Specifically, the projects have been categorized into three groups, from lowest to highest degree of maturity: preliminary analysis, pilot or executive.

- Partner name: This column describes the name of the private company or public entity associated to the development of the project. In the case of collaborative projects, the different participating entities are specified.

- Company type: Here the typology of the company associated with the project is written within the categories of: Startup, Established company, Public

administration or Partnership between private sector and public administration.

In this way, the information contained in this group of data allows contextualizing the described project, being able to determine its general characteristics and facilitating its identification, while providing basic characteristics on the time and evolutionary framework of the project.

2.1.1.2 Geographical data

This section makes up all the information provided for each project in relation to its geographical origin. Thus, it is intended to include the necessary information to determine the origin of the various initiatives, being able to identify the areas where Smart Mobility has a greater impact.

In this way, it must be considered that, in most cases, the geographical origin of the initiatives does not coincide with the place where they have been executed. In this sense, it has been considered of interest to analyze both geographical locations, so the columns specified below have been defined:

- Geographic area: This column includes information regarding the geographical area where the initiative has been developed, specifically the continent of the initiative is specified, differentiating at this point between North America and South America.
- Initiative nation: At this point, the origin of the proposed initiative is more precisely located, specifically, the country of origin of the initiative is indicated. It should be noted that, for large multinational companies where the headquarters behind the development is not specified, the geographical data of the company's headquarters have been indicated.
- Region/city: This column is where the place of execution of the initiative is specified. In places where both places coincide, there will be coherence between the initiative nation and the region/city. However, in places where the initiative and execution are not carried out in the same place, the region/city will not be part of the initiative nation. Considering that the execution is much more specific, to determine its geographical information it

has been decided to detail more precisely, thus introducing the city or region, according to the extent of the execution.

By defining these parameters, the projects are correctly located geographically, so that, in the process of statistical analysis of the data, information of interest can be obtained to be able to determine the places where there is more development of new technologies or greater investment in their implementation.

2.1.1.3 Application area

Next, there were developed the columns that, probably, suppose of greater relevance for performing an analysis on the state-of-art of Smart Mobility. Thus, this section details information on the application area of the various projects introduced in the database.

According to this, in the definition of this information it has been necessary to carry out an iterative process in which, as projects were added, the various groups were adjusted to be able to encompass as many projects with similar applications as possible. Therefore, in this way it has been possible to characterize all the projects added in the database using a small number of groups.

However, this characterization generated the problem where, in some cases, larger groups were too generic that housed in turn subgroups with common characteristics. In this way, the need arose to differentiate between main and secondary application area, thus being able to also decompose the groups into subgroups according to the characteristics of the projects contained.

In addition, there was a conflict arising from the projects that provided technologies that could be framed in two different application areas. In this case, the criterion used focused on considering as the main application area the one that was most relevant in the project and specifying the other application area as a secondary.

According to the description made, the following sections detail the content of the two columns present in this group of data.

Application area (main)

After completing the project selection process, the final iteration of application area definition resulted in the groups detailed below:

- Green technologies: This application area encompasses all those projects that were focused on technologies directly focused on reducing the environmental impact of mobility. It should be borne in mind that, in most cases, the projects added in the database could be considered as eco-friendly given the nature of Smart Mobility, however, projects that are not specifically focused on this purpose have not been included.

- Logistics: This group focuses on projects with a fundamentally logistical component. In this sense, projects focused on logistics at the urban level can be distinguished, so that last mile delivery projects are mainly distinguished. It should be noted that at the level of extra-urban logistics there are also many developments, but given the nature of their proposals, it has been decided to frame them within the application area of Smart Road.

- Safety: The projects included within this application area are focused on increasing the safety of mobility, especially in the field of mobility with private vehicles, which is where there is more presence of accidents. Within this group there is a large presence of projects that focus on increasing safety in communication technologies between vehicles, to prevent accidents.

- Sharing mobility: One of the main pillars of Smart Mobility are the technologies of Sharing Mobility, in this sense a multitude of projects have been found in which this phenomenon extends to unprecedented places. It should be noted that the keys to the success of the sharing concept are focused on the ease of its implementation, which does not require a special infrastructure and therefore its initial investment is small, and also in its wide scope, since it is applicable in all types of private vehicles and vehicles for personal mobility such as e-scooters or bicycles.

- Smart Road: This application area has projects which, given its technology, could be grouped within the logistics field. However, in this group there are projects focused on technologies to improve the infrastructure of the roads,

allowing to improve their characteristics in terms such as connectivity, services, data analysis, management and maintenance or safety.

- Software and platforms: This group of application area is essential considering the position of Smart Mobility as a concept within Information and Communication Technologies (ICT), of digital nature. In this sense, a multitude of projects related to the field of software and digital platforms have been grouped. In this sense, a multitude of software can be distinguished for various services such as Mobility as a Service (MaaS), the management of city infrastructures or the connection between vehicles. However, again it should be borne in mind that most Smart Mobility projects have software components and platforms, however here only those completely focused on this area have been included.

- Traffic management: The last of the groups of application areas categorized is traffic management and, again, is one of the fundamental pillars of Smart Mobility. Considering the relevance of public transport within the proposed paradigm, traffic management technologies are essential to improve its operation. Also, through efficient and intelligent traffic management, the number of accidents between both vehicles and pedestrians can be drastically reduced. In this sense, there are projects focused on the exchange of data between vehicles, the extraction and analysis of data, the management of intersections or parking spaces, among others. Finally, it is worth noting the intrinsic advantage to the application of these technologies related to the operation of emergency vehicles, which could operate much faster and meet emergencies with a greater degree of success.

Application area (secondary)

Once the main application areas of the projects have been defined, they are duly bounded for statistical treatment. However, to obtain a more precise characterization and to be able to correctly determine those projects that can be framed within two application areas, a second column of secondary application areas is developed.

In this way, the following lines detail the subcategorizations made for each of the main application areas described:

- Green technologies
  - Charging technologies: It includes innovative electric vehicle charging technologies through efficient strategies, mobile technologies, or high-speed systems.
  - Environmental parameters monitoring: Monitoring of environmental parameters such as the level of pollution or the noise load through various systems, so that specific strategies can be applied to reduce their presence.

- Logistics
  - Autonomous vehicle deliveries: Projects are included with logistics proposals for last mile delivery through alternative means of transport with autonomous driving.
  - Trunk deliveries: Proposals where parcel delivery technologies are introduced directly in the trunks of cars, making use of modules to connect the opening of the trunk to the system.
  - Deliveries optimization: In general, there are included projects that seek an optimization of logistics in any aspect that does not include the previous subcategories.

- Safety
  - Connected vehicles: Projects are included that improve safety in any aspect of mobility and not only in protection against accidents using communication technologies between vehicles.
  - Insurance services: These projects are focused on improving the services of insurers, carrying out an analysis of insurance use behavior.
  - ADAS: Advanced Driving Assistance Systems are technological systems that focus on improving driving safety by assisting the driver and avoiding some of the most frequent accident situations.

- Sharing mobility
  - Car sharing: Projects to incorporate systems, infrastructure or technologies related with automobile sharing.
  - Scooter sharing: Projects to incorporate systems, infrastructure or technologies related with scooter sharing.
  - Bike sharing: Projects to incorporate systems, infrastructure or technologies related with bicycle sharing.

- Smart Road
  - Road management: Projects related to road management are included where, mainly, information is extracted from the circulation to adjust its management and be able to make a more efficient use of resources and traffic management.
  - Data analytics: The projects gathered in this group are exclusively focused on obtaining data on traffic and circulation in order to contribute within the field of communications.
  - Connected roads: Within this subgroup there can be found proposals focused on the incorporation of technologies where roads facilitate communication processes between vehicles or with other infrastructures.
  - Services: Other services such as cleaning services or maintenance of infrastructures and vehicles are included in this category.
  - Charging technologies: Again, the technologies for charging electric vehicles are categorized, but this time in an integrated way with the road infrastructure itself.

- Software and platforms
  - MaaS: The concept of Mobility as a Service is fundamental in Smart Mobility, so it has been subcategorized within the generic group of software and platforms. In this sense, there are initiatives that seek to integrate various means of mobility in a single platform or service.
  - City management: Included in this group are proposals related to the management of the city's infrastructure, both in terms of maintenance and in terms of operation.
  - Connected vehicles: Again, a subgroup focused on the connection between vehicles is included, having in this case a more software-based approach.

- Traffic management
  - Public transport: Within traffic management, those initiatives focused on public transport and the improvement of its operations have been subcategorized.
  - Emergency vehicles: In the traffic department, emergency vehicles have the most priority position considering that they must attend emergencies, so

there are many proposals focused on making their journeys faster and smoother.

- Parking management: In traffic management with a private perspective, there is a high frequency of initiatives focused on parking optimization. In this sense, the search for parking implies fuel consumption and emission of pollutants that could be avoided through new Smart Mobility technologies.
- Intersections priority management: This is one of the most prevalent subcategories within this group and includes initiatives where different systems are proposed to perform intelligent priority management at intersections. In this sense, it tries to reduce traffic jams, improve the flow of traffic, and give priority to public transport or emergency vehicles.
- Data analytics: Again, this subcategory appears, in this case focused on the use of data for traffic management and optimization purposes.
- Connected vehicles: Again, the category of connected vehicles will appear, considering that it is one of the pillars of Smart Mobility. In this case, traffic management projects that are expressly focused on connectivity between vehicles have been included.

2.1.1.4 Communication technologies

As can be distinguished from the characterization of secondary application areas and, considering the importance it has within the paradigm of Smart Mobility, communication technologies are of great importance. In this sense, it is highlighted that it is necessary to carry out an analysis of these technologies to respond to the second research question raised in this project.

In this way, for each of the projects included in the database, an analysis of the communication technologies and protocols on which the initiatives are based has been made. It should be noted that for some projects it has not been possible to determine the exact communication technology used because it has not been published, not being able to distinguish in these cases the communication protocols used.

The columns analyzed for each project are detailed below, as well as the different technologies and protocols categorized within them:

- Communication technology
  - Cellular network
  - Cloud platform
  - DSRC
  - GPS
  - Smartphone app
  - Wired technologies
  - Wireless technologies
  - Vehicle communications (V2V, V2I, V2X)
- Communication protocol
  - 5G
  - C-ITS
  - ITS-G5
  - Optical fibre
  - 802.11p
  - 3GPP
  - WiFi
  - LTE
  - LoRaWAN
  - Bluetooth

Specifically, for the correct implementation of communication technologies and protocols, it has been necessary to define two columns for each one, so that all the information could be recorded, in projects that have several communication technologies.

2.1.1.5 Other technologies

Finally, the last of the data groups entered within the database is defined and corresponds to other technologies not directly related to communications.

It has been determined to analyze this group of data because certain technologies outside the field of communications that are also of interest are distinguished. In some cases, there are new or unprecedented technologies within the field of mobility, so their analysis is interesting to know those that are of greater relevance for the different areas of Smart Mobility.

In this sense, three columns have been defined in the database, to be able to register multiple technologies in the same project, and, specifically, the most relevant technologies that have been registered are described below.

- Artificial intelligence
- Autonomous driving
- Camera
- Data analytics
- Radar
- LiDAR
- IoT
- Big Data

- Blockchain
- Presence sensors
- ITS (Intelligent Transport Systems)
- 360º Scanner
- ALPR
- Microwave detection
- RFID
- Sound recording
- Stereoscopic vision

Again, it should be borne in mind that not all the projects entered in the database describe their proposal in sufficient technical detail, so not in all of them it has been possible to detect technologies of interest.

2.1.2 Use cases

Once the content characterized within the database used as a research tool in this project has been defined, a series of practical cases that help contextualize the concept of Smart Mobility continues to be analyzed.

In this sense, a selection of the most interesting projects from the point of view of innovation will be made in this section, highlighting some of the most interesting proposals within the built database.

The analysis of the projects carried out in this section of the will serve as the first introduction in the current state-of-the-art of Smart Mobility, and will be the precedent of the analysis of the results of the statistical analysis of the database that will allow quantifying and measuring the state-of-the-art.

2.1.2.1 Vivacity AI analytics

Partner name: Vivacity Labs.

Application area: Green technologies.

Location: London (United Kingdom).

Partnership with public administration.

Description [10]: Vivacity has developed in a partnership with London public administration a project of data analytics of traffic in the cities. In its proposal, Artificial Intelligence technologies are used by various sensors that allow analysis to be carried out that deciphers the interactions between road users and pedestrians.

Making use of their own software with integrated Artificial Intelligence algorithms, they are able to analyze the mobility of the city and look for certain patterns susceptible to substantial improvements. In this regard, they are currently developing means for improving traffic regulation and air quality around London schools.

Key technologies: Artificial Intelligence.

According to the developments that are currently being carried out, it is distinguished that this project is of great interest for an eco-friendlier management not only of the means of mobility, but of the city's own infrastructure. Although they are currently focused on the project to improve the environments around London schools, this project stands out for representing the pillars of Smart Mobility and for the great capacity and scope that would be available by implementing its technologies on a larger scale.

Other remarkable projects:

- **E-Gap**: This company offers a mobile recharging service for electric vehicles. Its service comprises a van with load capacity thatmoves to the places required by users to provide a temporary portable charging point. [11]
- **Move-in**: Project promoted by Lombardia public administration that provides limitations to the circulation of Euro 0 to 3 vehicles based on a predetermined amount of km which can however be increased by adopting a moderated and ecological driving style or along extra-urban roads. Everything is regulated by installing a black box inside the vehicle. [12]
- **Qualcomm Halo wireless electric vehicle charging**: Project for the development of a wireless charging system for electric vehicles. Installation can be planned in private garages, but also in public and private parking lots. [13]
- **ShargeMe**: Online platform that allows owners of electric vehicles to make part of the charge of their vehicle available for other users who need to buy it, perhaps if there are no filling stations close enough. [14]
- **Autofleet EV Fleet Optimization**: This company is giving ride-as-a-service solutions in which they focus on optimization. They perform different analysis in order to provide a very optimized service in which the EV operations are

previously simulated and analized, the charging infrastructure is properly distributed and the charging planning for the vehicles is optimized too. They have signed an agreement with a very important taxi company in Asia. [15]

It should be noted that projects within the field of green roofs are essential considering that they provide new solutions and technologies in the field of sustainability and environmental improvement, so they are one of the main pillars of the new paradigm of mobility.

2.1.2.2 Yape

Partner name: e-Novia.

Application area: Logistics.

Location: Milan (Italy).

Private company.

Description [16]: Yape is an initiative of the Italian technology and research company e-Novia to improve the logistics system of cities using a small autonomous electric vehicle.

This small electric vehicle is intended to meet the deliveries of the last mile logistics in an automated way and with zero emissions. This proposal is in a phase of pilot maturity, but quite developed, where tests are already beginning to be done in real environment. Figure 8 the proposed prototype operating in a real environment during the testing period.

Figure 8. Yape autonomous last mile logistic vehicle operating in the streets

Key technologies: Cellular network, 5G, GPS, Autonomous driving.

Yape's proposal aims to act on the problem of last mile logistics, which is the biggest drawback of logistics today. In this sense, transport costs in terms of cost per kilometer skyrocket within urban centers and it is in this same aspect where Smart Mobility intends to act.

Other remarkable projects:

- **Amazon Prime Air**: Delivery service by electric and completely autonomous drones. It will therefore be possible to receive a package from Amazon in about 30 minutes, provided that you are less than 15 miles from the depot and that the package has a weight of less than 2.2 Kg [17]
- **Digit**: Robot capable of interacting with the sensors of the car and the surrounding environment to deliver products in front of the front door. Once the self-driving car has reached its destination, the robot uses the vehicle's sensors, as well as its own, to analyze the surrounding environment and deliver the package in front of the door. [18]
- **EHang AAV**: This company has built an autonomous passenger grade drone that is starting to make its first trial flights in the city of Lange, Estonia. Their first flights are parcel deliveries without passengers from the city airport to a cargo terminal. [19]
- **Zero-emission delivery solutions:** These companies are working on a zero-emission program for sustainable last-mile deliveries. They have developed an algorithm that dynamically optimizes delivery routes in order to use the minimum quantity of vehicles. Moreover, they have released a micro-container delivery system propelled by a bike. [20]
- **Zoox Autonomous Vehicle**: Zoox is an Amazon startup that has developed an autonomous vehicle in order to have different functions. It will try to be the direct competence of Uber and Lyft in terms of passenger transportation, and it will also serve as logistics vehicle in order to cover the 'last-mile' delivers. [21]

It should be noted that most of the projects added to the database in this area propose various solutions for the last mile logistics, mainly focused on the use of

alternative or autonomous means of transport, to optimize the operation of the order distribution phase.

2.1.2.3 Damon Motorcycles CoPilot™

Partner name: Damon Motorcycles.

Application area: Safety.

Location: Vancouver (Canada).

Private company.

Description [22]: CoPilot™ is an Advanced Warning System for Motorcycles (AWSM) developed by the electric motorcycle company Damon Motorcycles that aims to improve the safety of motorcycle users.

In this sense, the AWSM is the equivalent of an ADAS in a car, with technologies focused on motorcycles. The award-winning proposal of CoPilot™ incorporates a series of LED warnings and haptic response on the handlebars of motorcycles, so that it can warn the rider about the dangers detected.

For this purpose, there are several cameras and sensors, as well as radars, so that they can be processed by their onboard neural net and Artificial Intelligence engine for anticipating threats and relays the information to the rider. Figure 9 represents the working of this system in a highway situation.

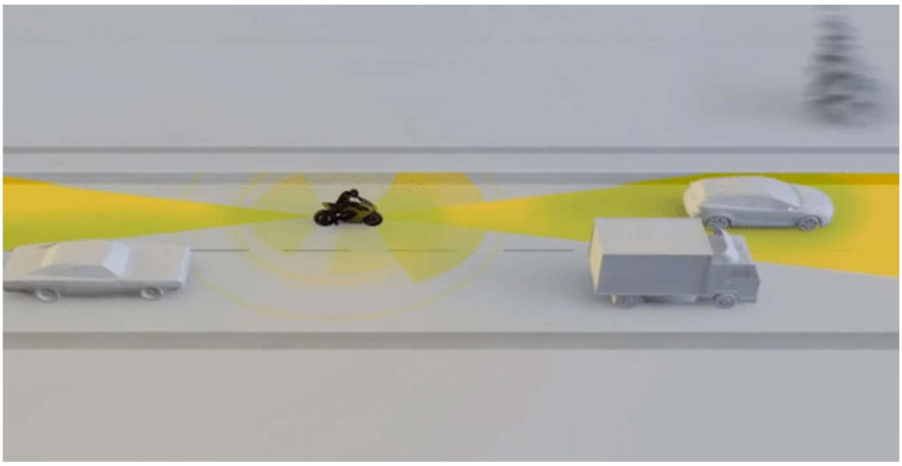

Figure 9. CoPilot™ AWSM system working on a highway scenario

In addition, this system collects information about the user's driving style, so that they can learn it and adapt their alerts in a personalized way for each user, obtaining a more accurate and reliable system.

Key technologies: Cellular network, C-V2V.

Other remarkable projects:

- **ConVex**: System based on C-V2X technology capable of connecting cars, motorcycles and road infrastructure to detect dangerous situations and ensure the safety of vehicles on the road, especially motorcycles. [23]
- **FindMyBicycle**: Tool that allows geolocating bicycles thanks to an interconnection between the various devices. In this way, a network is built that allows the bicycle to be tracked even in garages or underground places. It is also possible to be warned via mobile in case of vehicle movement. [24]
- **THEA Connected Vehicle**: The project aims to connect cars, buses for public transport, pedestrians (via app) and infrastructures for, mainly, safety and in general, traffic management purposes. [25]
- **Marshmallow**: Project that specifically targets underserved segments of the insurance market, using tools and analytics that focus on customers with high risk for insurers. The company began in 2018 by insuring ex-pat drivers, who often struggle to find affordable insurance because they lack a UK driving record. In response, Marshmallow built an assessment algorithm that included global data, to take into account the drivers' record in their home country. [26]

Safety projects are of special relevance within the paradigm of Smart Mobility and, specifically, the project selected within this category perfectly represents how the processing of data about mobility and its management in an intelligent way can help reduce the dangers of driving.

2.1.2.4 AI e-scooter

Partner name: TIER & Luna Micromobility.

Application area: Sharing mobility.

Location: Dublin (Ireland).

Private companies.

Description [27]: TIER and Luna Micromobility are two car sharing companies for personal mobility that are working together on a pilot project that aims to take the world of sharing a step further, integrating it with the latest Artificial Intelligence technologies.

In this sense, the initiative has developed an e-scooter to incorporate into the sharing fleet of the city of Dublin that has multiple sensors and Artificial Intelligence vision. This technology allows to analyze very important information on mobility such as congestion reports, incident registration, analysis of road conditions, among others.

Thus, this project combines the already widespread concept of sharing mobility with data analysis technologies, so that the proposal has a great scope and possibilities of exploitation. In this sense, the proposal can detect different patterns in the information to determine the areas that require action due to frequent congestion, accidents, or other incidents.

Figure 10 shows the AI e-scooter model that, equipped with technologies for software processing by Artificial Intelligence, has been deployed around the DCU campuses to test the initiative in a pilot test phase.

Figure 10. TIER and LUNA Micromobility AI e-scooter

Key technologies: Smartphone app, Cloud platform, Artificial Intelligence, Camera.

The proposal of these companies is of special importance since it is contributing new technologies of great interest and with many capabilities to a branch of Smart Mobility that is already being exploited and is established extensively in many cities around the world.

Other remarkable projects:

- **BePooler:** BePooler is an application for workers arriving from outside Milan that favours parking in certain peripheral areas, to then reach the central area together with other drivers who have parked in the same area. In this way they aim to reduce pollution in the city. [28]
- **MVMant**: MVMant is the smart urban mobility solution able to solve the traffic problem. It provides a service on a fixed line with availability on request via the app. Intelligent algorithms predict demand, placing vehicles where and when they are needed, ensuring minimum waiting times and optimal vehicle occupancy. [29]
- **Surve Mobility**: This company provides a maintenance service for shared mobility and micromobility. They optimize the resources availability by

analysing their level of usage and relocating it in order to optimize it. It also considers the maintenance operations and recharging strategies in order to match their objectives. They operate for a lot of companies and have been widely awarded. [30]

These types of proposals aim to make use of a Smart Mobility system such as vehicle sharing for personal mobility to extend its capabilities and contribute to the Smart Mobility ecosystem, making use of zero-emission and sustainable transport systems.

2.1.2.5 Toyota Woven City

Partner name: Toyota & NTT.

Application area: Smart Road.

Location: Woven City (Japan).

Private companies.

Description [31]: Toyota with the help of NTT (Nippon Telegraph and Telephone Corporation) have proposed an initiative for the construction of a Smart City from scratch, where different initiatives related to this area can be tested. This city will be built considering the concept of city from the future, and all the infrastructure will be built considering this premise.

This ambitious proposal aims to act as a testbed of various technologies, as well as to test and perfect their operation, significantly boosting their propagation and validating their use. Figure 11 a representation of a preliminary design of Woven City.

Figure 11. Toyota Woven City concept design

Specifically, in the field of mobility they intend to completely redefine the streets and roads, making a new proposal where a division is made into three interconnected groups: fast traffic prepared for autonomous vehicles with multiple sensors, another for low-speed personal mobility vehicles and a last exclusive type for pedestrians.

In this sense, the proposal is very focused on the incorporation of communication technologies based on 5G technologies, in vehicles and infrastructures, so all the proposed developments have this premise in their design, to form an infrastructure totally focused on the mobility of the future.

Key technologies: Cellular network, 5G, V2X, Artificial Intelligence, Data analytics.

Other remarkable projects:

- **5G-Carmen**: Implementation of 5G technology on a 600km stretch of motorway from Munich to Bologna. All this will serve to improve the performance of connected cars and the management of traffic and certain situations. [32]
- **Integrated Roadways Smart Road**: Project of the replacement of 500 meters of Highway 285 pavement with smart pavements capable of detecting the speed, direction and weight of vehicles to communicate any incidents in a timely manner. [33]

- **City Brain**: City Brain is a huge Chinese project in which the big company Alibaba is trying to use the information extracted from the city environment to provide different services, such a smart control of traffic lights. It is already implemented in 23 Chinese cities, from which the city of Hangzhou should be highlighted as it has been able to decrease the traffic congestion significatively in 2020. [34]
- **SONAL™**: Securaxis SONAL™ is a system that measures and analyses noise levels in the city in order to obtain data such as traffic congestion. This information can be used for traffic management, reduction of sound pollution or smart lighting. It is integrated in a Switzerland traffic virtualization project and its already working in a street in the city of Genova. [35]
- **RealityAI**: RealityAI is a company that uses AI for different mobility, industrial and comercial applications. They have developed a technology that detects emergency vehicles and information about their speed, direction, and location, even considering the reflections and refractions in the surroundings. Now they are implementing this technology with the company Infineon in order to work in an ADAS system for cars. [36]

This Project, although not exclusively focused on Smart Road technologies, is a remarkable development considering that, in addition to all the proposed development, it aims to implement a street and road infrastructure from scratch with all kinds of technologies focused on communications.

2.1.2.6 CDS-M (City Data Standard – Mobility)

Partner name: TOMP-WG.

Application area: Software and platforms.

Location: Amsterdam (Holland).

Partnership with public administration.

Description [37]: This initiative has been carried out by TOMP-WG, which is an organization promoted by the Ministry of Infrastructure and Water Management in the Netherlands, where it has the collaboration of the G5, which is made up of representatives of the five largest cities in the Netherlands.

In this sense, this initiative aims to define a standard for the delivery of data between transport operators and the cities that they operate within. This is of great relevance considering that a large part of the new proposals detected in relation to Smart Mobility present communication technologies.

Therefore, with a data standard for mobility it can be provided a better understanding of the use of shared mobility and the possible effects on public spaces, and in this way contributing to an optimal use of public spaces through a dynamic control of traffic and permit areas. Through the defined platform it will be possible to get information about mobility patterns, including the use of shared vehicles, traffic flows and parking, according to Europe's GDPR.

Key technologies: V2X.

This project is of special importance and has been highlighted within the application area of software and technologies considering the implication that it will present on a large scale.

Other remarkable projects:

- **iomob**: A B2B platform to allow any mobility service to be connected to a backend protocol and a white label frontend user app. It is a turnkey solution to enable large transport companies and startups to launch their own white labeled Mobility as a Service (MaaS) solution. They already have agreements with Renfe in Spain and Ford in Pittsburg. [38]
- **ICT4CART**: They work for the development of Infrastructure for Connected Transport (ICT) platform which benefits the transition to automated transport. Moreover, their objective is to use the information that automated and connected vehicles take from the road in order to have an extra information source. Their solutions are being tested in four different countries. [39]
- **Volkswagen Automotive Cloud**: Collaboration for the development of a Cloud to be implemented in connected vehicles. The basis of this system will be Microsoft Azure, with its cloud, artificial intelligence and IoT capabilities. The first vehicles to be equipped will be those belonging to the Volkswagen ID range, due out in 2020. [40]

- **COORD**: Coord is an online platform that helps cities manage their curbs so that they can reduce congestion, improve safety, and drive new revenue. Get a detailed digital curb inventory so you can see, for each curb space, who may use it, for how long, and at what price. Automatically combine asset data, municipal code, parking prices and more to unlock insights. It is being tested in a pilot stage in Nashville, Aspen, Omaha, and Palm Beach. [41]
- **Whim**: In Finland, Transdev is the integrator and supplier of Whim, the application that provides access to all available transport offers, including taxis, under one subscription. With Whim, travellers can also plan and pay for their transport, and record their travel preferences, resulting in an 80% of users satisfied. By offering a user friendly, multimodal service that takes into account all aspects of the journey (not just some), they help travellers meet their daily transport needs. [42]

As highlighted, communication technologies are present in almost any Smart Mobility project, since information is one of the most valuable and exploitable resources in this sector and, having a standard for its correct implementation, is essential to ensure a standardization that facilitates the transition to models with this type of technologies.

2.1.2.7 ImFlow

Partner name: Peek Traffic (by Dynniq).

Application area: Traffic management.

Location: Copenhagen (Denmark).

Partnership with public administration.

Description [43]: The present project by the startup Peek Traffic (by Dynniq) in collaboration with the Copenhagen public administration has implemented a technology to intelligently optimize traffic flows at intersections.

This proposal is in an executive phase and its use has spread in more than 30 countries around the world thanks to the project's collaborators. This is due to the substantial improvement associated with the implementation of traffic management

technologies that the implementation of this type of technology entails, at a relatively low implementation cost.

In this sense, this project focuses on traffic lights, optimizing their use and applying dynamic flow control algorithms making use of diversity of traffic data and prediction models that, given their decentralized capacity, does not require a traffic control center for its optimization.

Specifically, the proposal has different optimization methods: adaptive, local and "green wave", which depend on the amount of general traffic, the amount of traffic at that intersection, or certain routes classified as efficient. Likewise, the system proposes an intelligent management of the priority, favoring public transport vehicles, emergency vehicles and bicycles.

Key technologies: Cellular network, C-ITS, GPS.

Other remarkable projects:

- **Qrowd**: This is a Horizon 2020 funded project that focus on optimizing general mobility by making use of Big Data. Their proposal is based on obtaining information of as many sources as possible (such as meteorology, transport, geographics, real-time information of crowds, infrastructure, and public transportation) and so improving transport management and making better traffic prediction. This project was already tested in Trento, Italy. [44]
- **Velodyne LiDAR**: Bluecity has developed an AI system based in Lidar technology. This system allows doing multiple solutions such as traffic management, priority management and smart lighting. They defend that this system is easier to integrate and is more cost-effective than actual camera+radar alternatives. [45]
- **Transforming Transport Project**: This is a widely financed European project with a total budget of EUR 18.7 million that is focused on Big Data and Artificial Intelligence, in which 48 organisations from 9 countries are working. They are working to find a more efficient and more sustainable transport paradigm. Their aim is to show concrete, measurable and verifiable evidence of data value that can be achieved in mobility and logistics by leveraging big

data, i.e., the massive amounts of information that can be analysed using powerful software to reveal trends, patterns, and associations. [46]

- **Sacramento Mobility Hub**: Sacramento is following the trend of the mobility hub with its historic train station. They are willing to transform this place into a people-first space in which priority is people rather than cars. This mobility hub will follow zero-energy and zero-carbon sustainability standard, and also will be the centre of mobility, connecting heavy and light rail, inner-city and regional buses, shared mobility services and so on. [47]
- **Autotalks V2X technologies**: The company has successfully implemented his V2X communication platform with the support of Applied Information Inc. with the objective of having a functional system for emergency vehicles and public transport in the city of Alpharetta. It allows the traffic lights in intersections having information about priority vehicles approximation and it gives absolute priority, reducing significatively the arriving time. [48]

This application area has been the most frequent within the initiatives added in the database. A high presence of projects in this area is distinguished due to the large number of advantages they present, considering that they allow a better management of private vehicles, reducing the presence of congestion on the streets, and therefore of polluting emissions, as well as improving the operation of public transport and emergency vehicles.

2.2 State-of-the-art analysis

Once the analysis on the database and its most remarkable projects has been done, the analysis proceeds by detailing the situation the state-of-the-art, according to the information extracted from the projects through the database.

In this sense, this section will include the beginning of the statistical analysis of the data and will be useful to answer the first of the research questions raised, so the results obtained are detailed.

2.2.1 Typology of the developer entity

First, an analysis is made of the various types of companies that have developed Smart Mobility projects recently. In this sense, Figure 12, where it can be seen a pie chart with the different types of company associated with the projects introduced in the database.

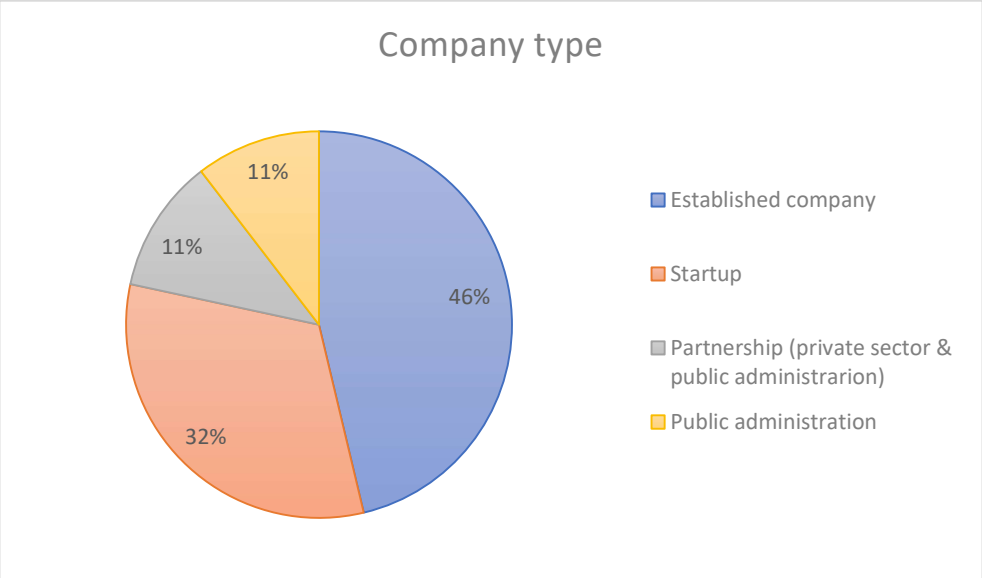

Figure 12. Company types of the initiatives analyzed

In this way, it can be distinguished that it is mainly established companies that investigate in the field of Smart Mobility, with a presence of 46%. Likewise, a high percentage of startups representing 32% of the sample stands out, a relatively high value compared to the established companies mainly due to the innovative nature of the initiatives proposed in this sector.

On the other hand, the analysis allows to determine that in 22% of the initiatives there was participation of the public administration, distributed in equal parts in exclusive participation or collaborative participation with the private sector.

It can be concluded from the analysis carried out that research and development in Smart Mobility technologies is not exclusively dedicated to the private sector or large companies, so it is remarkable the great interest that this paradigm arouses in society in general. In another scenario it would be normal not to have the presence of the public administration and to have a much less significant presence of startups.

2.2.2 Timelines and development stage

Next, the analysis of the data continues by distinguishing the number of initiatives detected for recent years. In this sense, initiatives prior to 2016 have been discarded because they are too old for a sector with growth as fast as mobility.

According to the analysis carried out, the bar graph that can be distinguished in Figure 13.

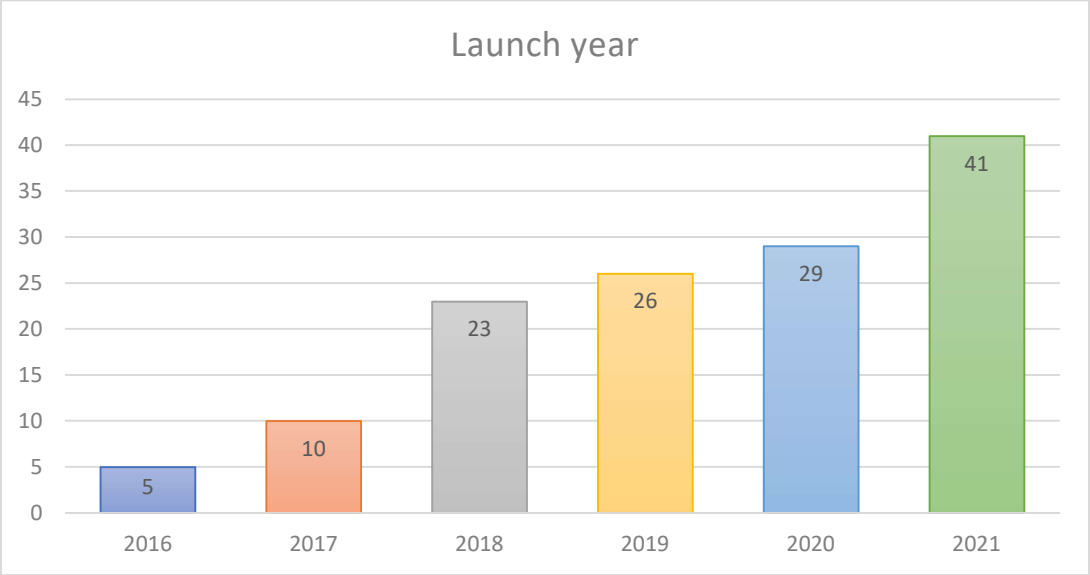

Figure 13. Number of projects analyzed per year

After performing this analysis, it can be distinguished a very low presence of projects from 2016 and 2017 that is not realistic and is mainly associated with two factors. First, by the very nature of information searching, the articles, news and projects detected tend to be the most recent, so the older an initiative is, the more difficult it will be to find information about it. Secondly, by the own criterion of selection of initiatives, in which projects of these years have been discarded for not presenting continuity at present or for not presenting a proposal interesting enough for their inclusion.

In this sense, it is worth mentioning that most of the Smart Mobility initiatives that can be found in the state-of-the-art are in phases prior to their execution and it is precisely for this reason that a large part of the initiatives have been discarded in the years 2016 and 2017.

In this context, Figure 14 introduced, where it can be seen the development stage of the initiatives that have been analyzed.

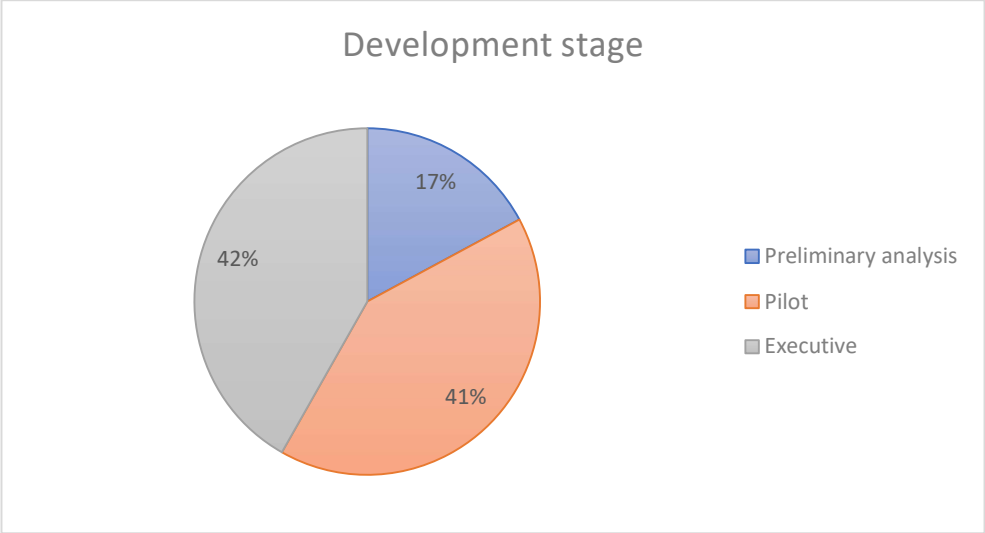

Figure 14. Development stage of the initiatives analyzed

As mentioned, most of the proposals are in a pre-implementation phase. Specifically, 17% of the proposals are in a preliminary analysis phase and 41% in the pilot phase. Thus, 42% of the projects analyzed in a final execution phase are counted.

It should be borne in mind that there is a low presence of initiatives in the preliminary phase since, according to the research criteria, only initiatives with a projection in real environment have been included, a situation that is not frequent in projects in preliminary status.

2.2.3 Geography

The study continues through an analysis of the geographical parameters of the initiatives introduced in the database. This analysis makes it possible to distinguish the places where Smart Mobility has a greater presence, and its research is of greater relevance.

In this sense, in the first place, a distinction must be made at a low level of the geographical areas where the initiatives that have been analyzed are developed and, thus, Figure 15 where a chart foot is appreciated with the different continents where the initiatives have been developed.

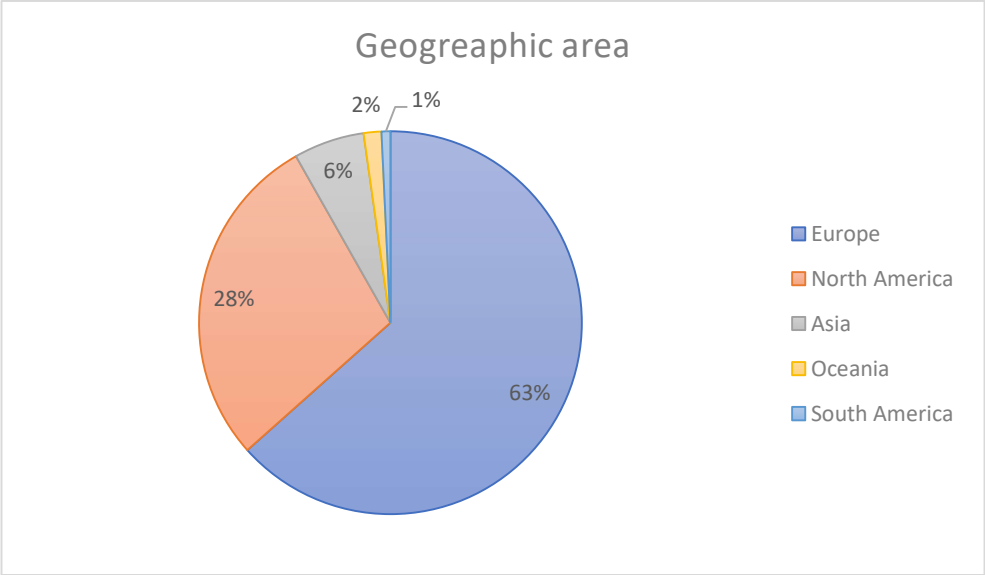

Figure 15. Geographic area of the initiatives analyzed

With the results obtained, it can be distinguished a very wide presence of initiatives in Europe, which has 63% of the projects analyzed, followed by North America with 20% of the projects.

Consequently, a low presence of projects corresponding to the area of Asia, Oceania and South America can be distinguished, which, together, account for 9% of the projects. While it is true that the role of South America and Oceania is not as relevant as that of the rest of the parties, Asia is a great power within the development of Smart Mobility, however, this is not reflected in the analysis carried out.

This deviation in the projects detected in the Asian continent is mainly due to the process of searching for resources used that, due to cultural proximity, allows to distinguish a greater number of projects in the European and North American framework. The difference in language and in general the cultural leap with Asia makes it significantly difficult to distinguish initiatives, so it has only been possible to distinguish those with greater renown or in a more advanced development phase, associated mainly with stable companies and public administration, but not startups.

In this sense, a breakdown of the nations behind the initiatives for each of the continents has been made. First, Figure 16 shows the distribution of nations associated with the development of initiatives within the Asian continent.

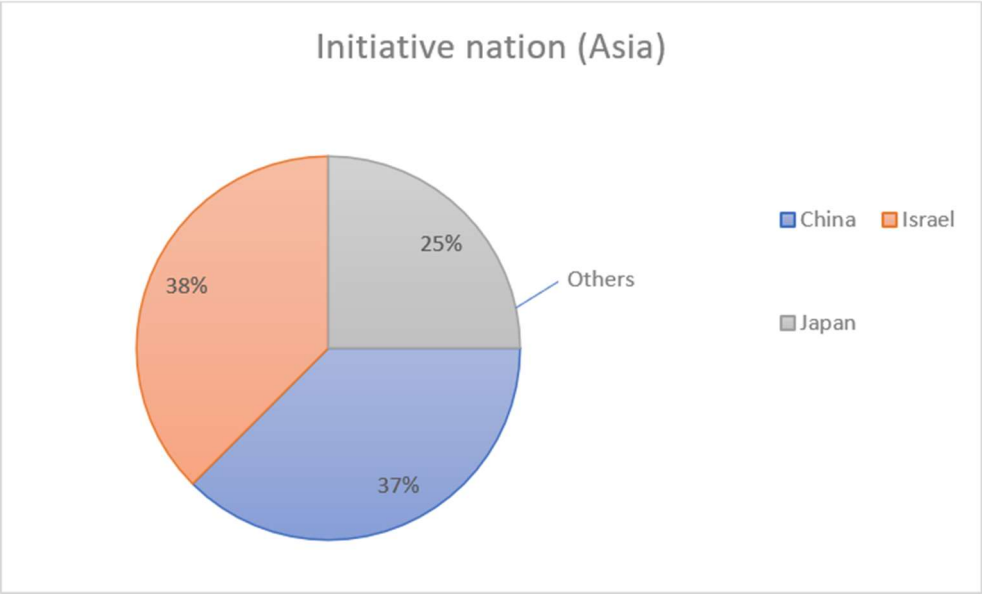

Figure 16. Initiative developing nations within the Asian continent

It is distinguished from this graph that the initiatives arise mainly from China and Israel, followed by Japan. This result is consistent considering that they are together with South Korea (of which no records have been obtained) the main technological powers of the continent.

Similarly, Figure 17 shows the different nations behind the initiatives included in the database concerning the European continent.

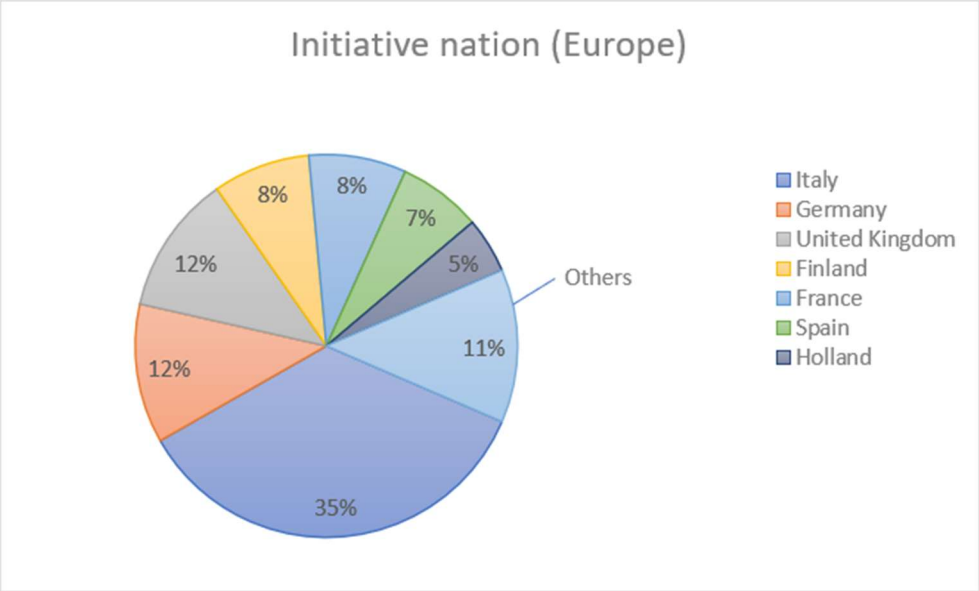

Figure 17. Initiative developing nations within the European continent

According to the results of the graph, there is a uniform distribution between the different European countries, unlike Italy. In this sense, according to the Italian origin of the project, it is normal to distinguish a greater presence of projects from this nation within the analysis carried out, where 35% of European projects belong to this country.

On the other hand, Oceania and South America have too low a presence to make a distinction by nation. Also, as for North America, most of the projects come from the United States, with a slight presence of Canadian projects, so their graphics are not relevant.

2.2.4 Application area

Finally, in the analysis carried out in this section, the different areas of application distinguished in the database will be analyzed, as well as the incidence of each of them, as well as their secondary applications.

In this sense, as described in section 2.1.1.3, there is a division of the initiatives into seven different groups according to their main area of application. In Figure 18, it can be distinguished the incidence of each of the application areas in analysis carried out through the database.

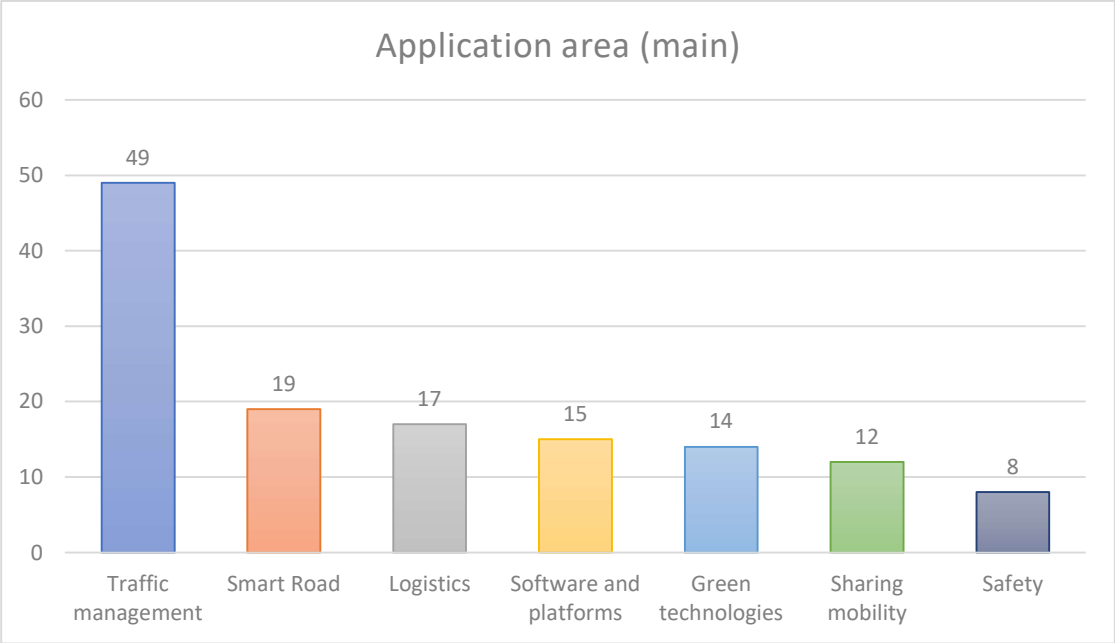

Figure 18. Main application areas of the initiatives analyzed

From this analysis, it is possible to conclude a significant greater presence of projects related to the field of traffic management, with 49 projects representing 37% of the total. Next, there are the initiatives of Smart Road, with 19 projects (14% of the total), logistics with 17 projects (13% of the total), software and platforms with 15 projects (11% of the total), green technologies with 14 projects (10% of the total), sharing mobility with 12 projects (9% of the total) and finally, safety initiatives with 8 projects (6% of the total).

This analysis makes it possible to distinguish between the latest technologies relating to intelligent traffic management while distinguishing a relatively balanced distribution between the rest of the application areas.

In this way, the analysis proceeds by making a breakdown of the incidence of the secondary application areas for each of the main application areas detected. First, and in accordance with Figure 19, the distribution of secondary application areas for traffic management initiatives is presented.

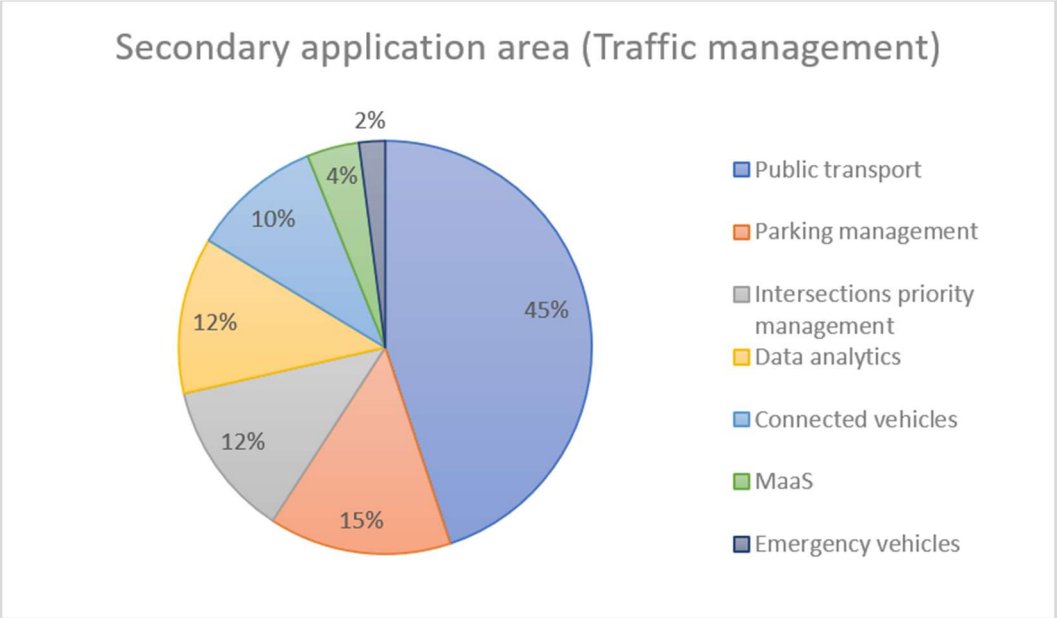

Figure 19. Secondary application area distribution for traffic management initiatives

This graph shows an upswing in initiatives focused on public transport, which account for 45% of all initiatives within traffic management. Next, proposals corresponding to parking management, intersection priority management and data analytics are distinguished with an incidence of 12%. Finally, there are initiatives related to connected vehicles (10% of the total), Mobility-as-a-Service (4% of the total) and emergency vehicles (2% of the total).

In this sense, it should be borne in mind that some of the subcategories that make up these secondary application areas are found simultaneously in several projects, in which case it has been framed within that secondary application area in which it is more focused. For example, a large part of public transport initiatives includes improvements for emergency vehicles, just as intersections priority management and data analytics initiatives often require technologies that could be framed within the framework of connected vehicles.

Next, it can be distinguished in Figure 20 the distribution of application areas for the Smart Road initiatives analyzed in the database.

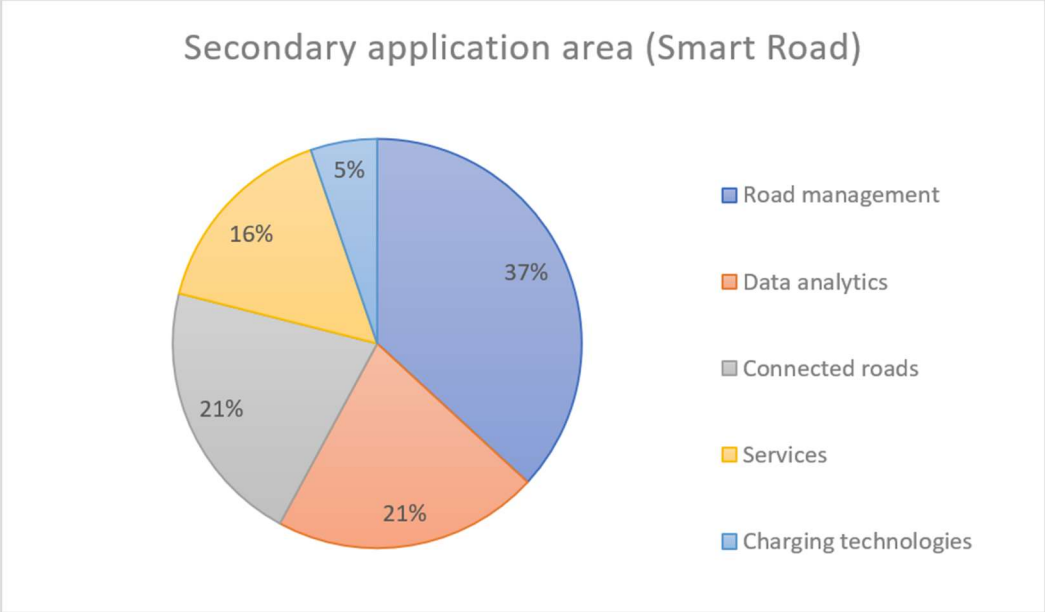

Figure 20. Secondary application area distribution for Smart Road initiatives

In this case, projects related to road management have a higher incidence, covering 37% of the initiatives, while the least frequent initiative is that of charging technologies, with a presence of 5% of the same.

Likewise, there is an incidence of 21% in projects related again to data analytics and connected roads, followed by initiatives related to services, which cover 16% of the projects.

In this sense, the different types of areas covered by Smart Road projects can be distinguished, where the presence of projects for road management clearly stands out, due to the nature of Smart Road initiatives.

Then, the analysis proceeds with the secondary application areas corresponding to logistics initiatives, according to the graph in Figure 21.

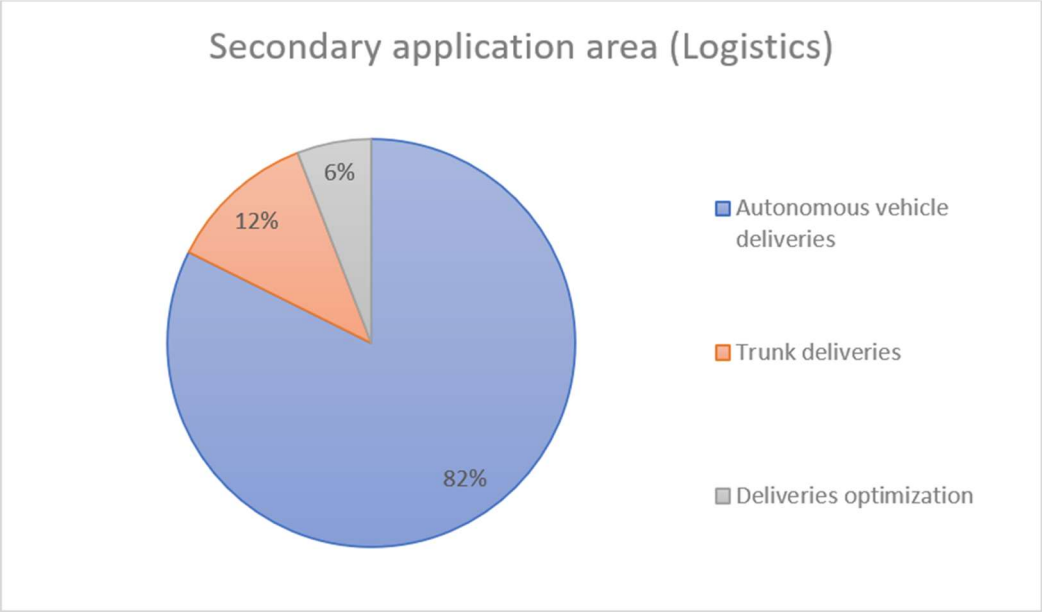

Figure 21. Secondary application area distribution for logistics initiatives

From this graph it is possible to distinguish little variety within the logistics initiatives of Smart Mobility, since 82% of the initiatives focus on deliveries through alternative autonomous vehicles.

Likewise, a presence of 12% can be seen referring to trunk deliveries projects and 6% for the optimization of deliveries in general and without necessarily making use of autonomous vehicles.

In this area, it is highlighted that most of the initiatives within the application areas of autonomous vehicle deliveries and deliveries optimization are focused on solving the difficulties currently presented by the last mile deliveries. This part of the deliveries is especially problematic because, due to the difficulty of logistics and circulation in cities, the costs per kilometre in the last section of the transport of orders increase significantly, requiring the incorporation of new technologies that propose alternative delivery systems.

The analysis continues through the characterization of the different secondary application areas within the software and platform initiatives, as can be seen in Figure 22.

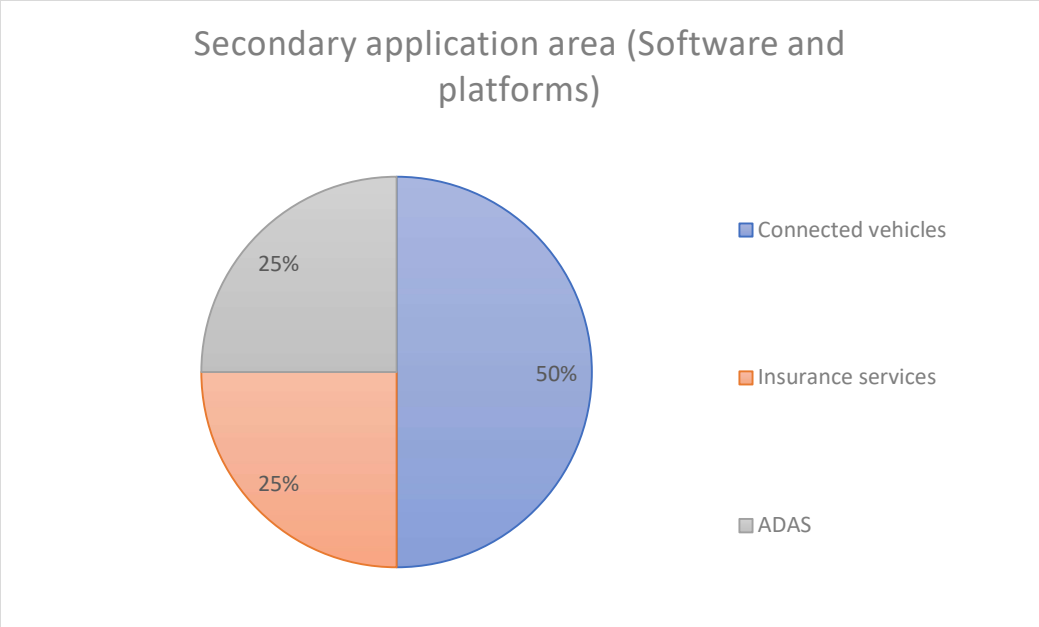

Figure 22. Secondary application area distribution for software and platforms initiatives

This application area has been characterized into only three subcategories. Mainly, the initiatives consist of Mobility-as-a-Service proposals that represent 46% of the sample and focus on offering mobility as a single service and not as multiple independent and decentralized services. In this sense, the initiatives seek to implement an integrated mobility service where it seeks to offer the best possible service by making joint use of the entire infrastructure available for the demanded routes.

On the other hand, with an incidence of 27%, there are city management and connected vehicle initiatives. These initiatives seek the implementation of platforms and software that allow a more efficient management of the city's resources and implement communication systems between standard vehicles, respectively.

This is done by analyzing the applications areas for the initiatives corresponding to green technologies, giving rise to the graph in Figure 23.

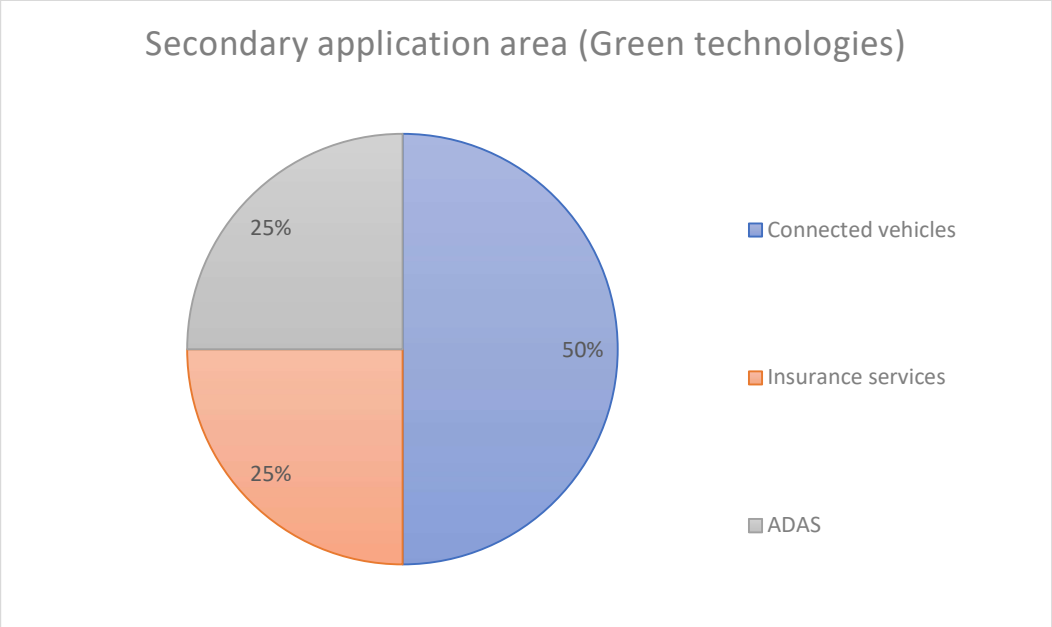

Figure 23. Secondary application area distribution for green technologies initiatives

This category corresponding to green technologies has been divided into charging technologies, with a majority incidence of 64% and environmental parameters monitoring, with 36%.

In the initiatives corresponding to charging technologies, projects are proposed to carry out a better management of the means of charging for all types of electric vehicles, as well as an adaptation of the infrastructure in such a way that it can be prepared to house the new mobility paradigm, where most of the vehicles in cities are zero emissions.

Likewise, the proposals corresponding to the monitoring of environmental parameters focus on controlling parameters of both noise pollution and polluting particles, in such a way that much cleaner and healthier cities can be counted. The measurement and analysis of these parameters is key to be able to make a traffic management in cities focused on maintaining a clean and healthy environment for citizens, with all the health advantages that this entails.

The project proceeds with the analysis of the initiatives corresponding to sharing mobility, which is one of the most solidly established and standardized application

areas in large cities today. Figure 24 the characterization obtained for this type of initiative.

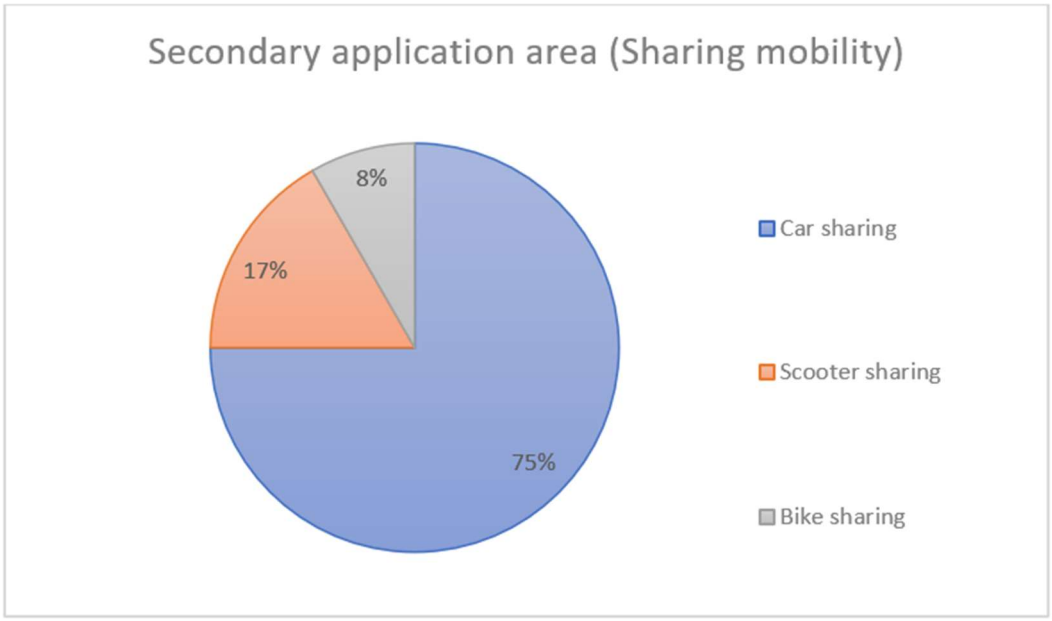

Figure 24. Secondary application area distribution for sharing mobility initiatives

Within this characterization se distinguishes a division according to the type of vehicle on which the sharing is based. This way, 75% of the initiatives are focused on cars, while 17% on scooters and 8% on bicycles.

These results make sense considering two factors. First, bicycle and e-scooter sharing systems are solidly implemented in the main and largest cities subject to the development of Smart Mobility technologies, so their implementation is already considered robust and successful, and only projects that provide new and innovative technologies have been included. Secondly, cars are currently the main source of pollutant emissions within urban centers, so it is natural that projects and research focus on implementing sharing technologies for this type of vehicle, that are not currently sufficiently widespread and consolidated.

Finally, the last of the application areas analyzed includes initiatives related to the field of security, which is the category that encompasses a smaller number of projects. Figure 25 shows the distribution of secondary application areas for this category.

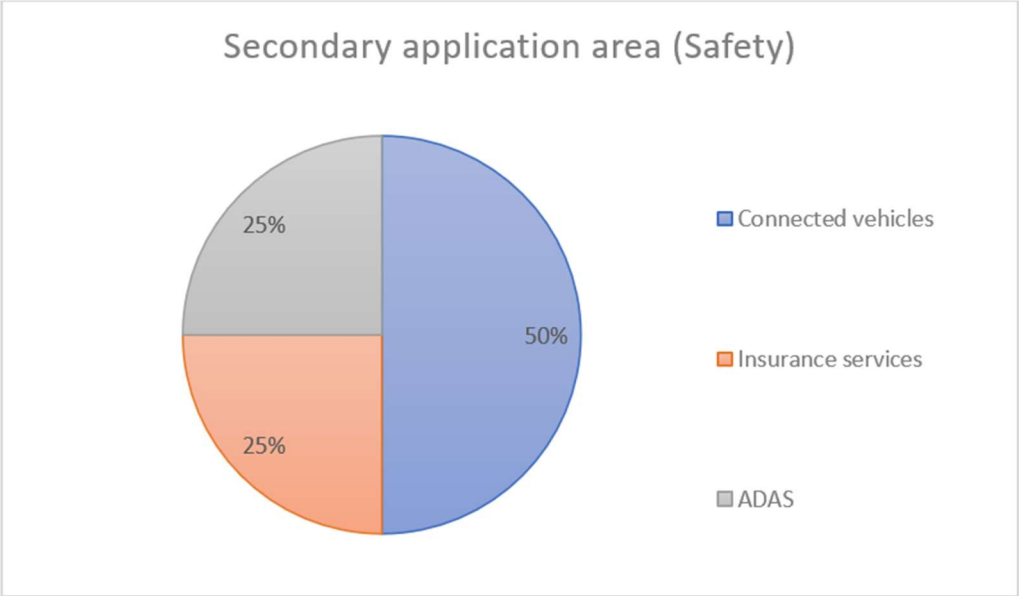

Figure 25. Secondary application area distribution for safety initiatives

In this category, it mainly can be distinguished connected vehicle initiatives that account for 50% of the projects. This result is coherent considering that one of the pillars on which Smart Mobility is based is the communication between all parts of mobility, both infrastructure and vehicles and pedestrians. These projects seek to reduce the presence of accidents through an intelligent management of vehicles that can avoid, in a totally autonomous way and with the help of communications, accidents both with other vehicles and pedestrians, and with the infrastructure itself.

With a presence of 25%, there are initiatives related to insurance services and ADAS. On the one hand, insurance services focus on making an analysis of user data to establish precise rates for their insurance, which allows both to establish fairer rates, and to avoid reckless behaviors at the wheel. On the other hand, ADAS technologies are responsible for assisting the driver in the face of safety, without including in this case communication with other vehicles or infrastructure.

In this way, the analysis carried out corresponding to the state-of-the-art of Smart Mobility is included, being able to have a precise global vision of the main initiatives carried out at present, as well as the categorization and the application areas of greatest interest for industry and public administration within this sector. Thus, the chapter concludes having made a precise analysis that allows to answer the first of the research questions raised for this research project.

3. Chapter 3: Emerging technologies in Smart Mobility

Once the first research question has been answered, Smart Mobility research focuses through this chapter on responding to the second research question raised in section 0, which states the following:

"What is the current "What are the trends in Smart Mobility developments in terms of adoption of technologies for the different application environments?"

In this way, this chapter will focus exclusively on analyzing the data extracted from the initiatives related to the technologies used in the projects. Specifically, the main technologies are those related to communications, and, in addition, they are the ones that are of greatest interest within this paradigm. Therefore, in the following sections, communication technologies and other emerging technologies that are of interest will be analyzed separately.

The analysis carried out in this section will allow us to conclude with the research object of this project, being able to have precisely determined the degree of development that the Smart Mobility paradigm currently presents and allowing us to establish which are the areas with the highest incidence and the technologies with the most interest within the sector.

3.1 Communication technologies analysis

This section aims to perform a statistical analysis of the information regarding the communication technologies of the various projects introduced in the database.

Specifically, an analysis of the communication technologies, the communication protocols used, and a cross-analysis of the parameters of communication technologies and application areas will be carried out.

3.1.1 Communication technologies

First, the communication technologies used in the various initiatives considered are analyzed, in such a way that the results that can be seen in the graph of Figure 26.

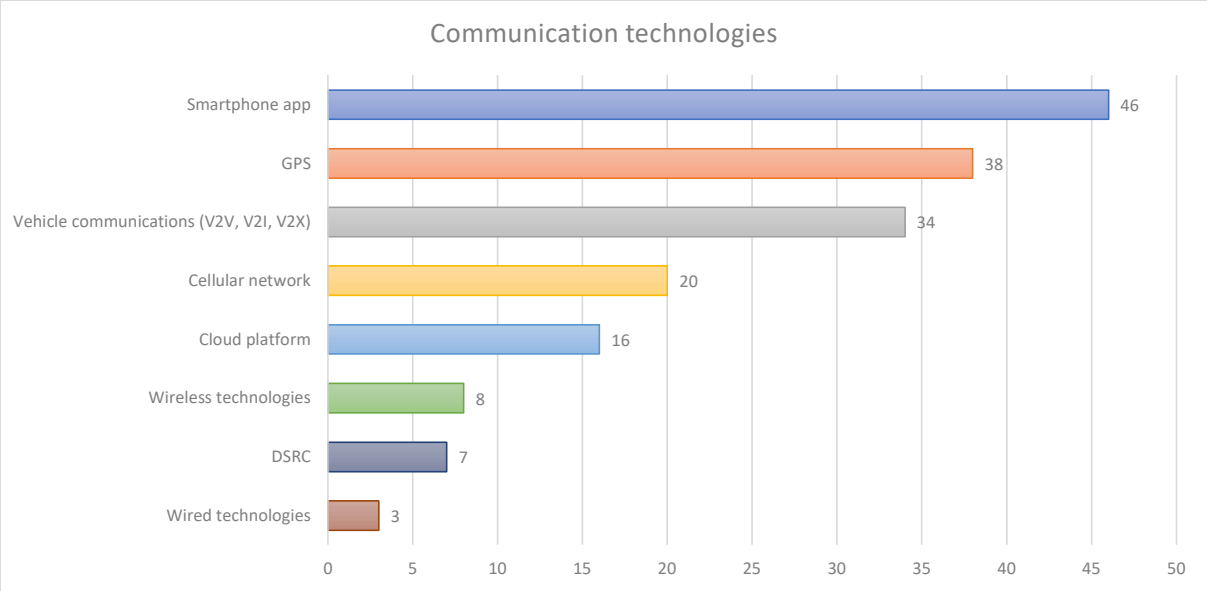

Figure 26. Communication technologies used in the various projects analyzed

In this way, it is possible to distinguish that the most frequent communication technology within the projects is the smartphone app, with an incidence in 46 projects. This result is consistent since smartphones are devices with a high level of technology and with great capacity for the exchange of information that, in turn, have penetrated deeply into society being accessible to everyone. Therefore, smartphones are the perfect tool for the exchange of data in a simple way between the different users of public roads. Specifically, a large part of the projects that include communication between the different parts that make up the mobility paradigm or those that involve interaction with the user make use of this type of communication technology.

On the other hand, the presence of GPS technologies for positioning is distinguished with an incidence of 38, that are essential to provide one of the most relevant data within mobility, which is location. In this sense, it can be given as an example the need to locate the different vehicles on the road to make an intelligent management of intersections or to give priority to those vehicles that require it, such as public

transport or emergency vehicles. Also, to offer a mobility service to a user, it is essential to know their position and the point they want to reach, so GPS technology is more than frequent in the paradigm of Smart Mobility.

Linking with what has been described, there is in third place, and with an impact on 34 projects, general vehicle communication technologies that encompass global communication technologies (V2X), with other vehicles (V2V), infrastructure (V2I) or with the cloud (V2Cloud). Considering the nature of Smart Mobility projects, the result obtained makes sense, since the lack of communication of the vehicles that circulate on the streets with their surroundings is one of the main limitations that are currently in the sector.

As mentioned above, incorporating technologies that allow the communication of vehicles is essential to be able to count on benefits such as a dynamic and efficient management of traffic flows, avoid accidents, report incidents, or favor the processing of mobility data. However, in this sense there are some projects that do not specify the type of technology used to proceed with this type of communications and, despite this, they have fallen into this category.

Next, there is the category of communications by cellular networks, which has an impact on 20 projects. This result is consistent with the fact of having the recent 5G communication protocol, which significantly increases transfer speeds, reaching a limit of transfer speeds 20 times higher (20Mbps) than in previous technologies. Companies working on Smart Mobility projects are introducing themselves to the use of these technologies because of the wide possibilities they offer and their ability to cope with the electromagnetic neck present, which has a more significant incidence in urban centres.

With an impact on 16 projects, there can be seen the cloud-based technologies that are essential to complement initiatives based on Big Data, moving a large amount of information regarding traffic data, mobility in general and its entire ecosystem.

Likewise, with an impact on 8 and 3 projects, there are general communication technologies by wireless and wired means, respectively. This category has encompassed those projects that have communication technologies but cannot be framed within other more specific categories.

Finally, communications by DSRC (Dedicated Short-Range Communications) are distinguished with presence in 7 projects. This type of communication is very interesting, because they are specific communications for vehicles in short distances that allow mono or bidirectional communications of little information at very high speed, so their use is emerging to encourage, mainly, the interaction between vehicles during their circulation.

3.1.2 Communication protocols

The effective analysis of the communication technologies is carried out through an analysis of the differentiated communication protocols in the different projects that have been introduced in the database. In relation to this analysis, it can be distinguished Figure 27, which graphically represents the number of projects in which each of these protocols is used.

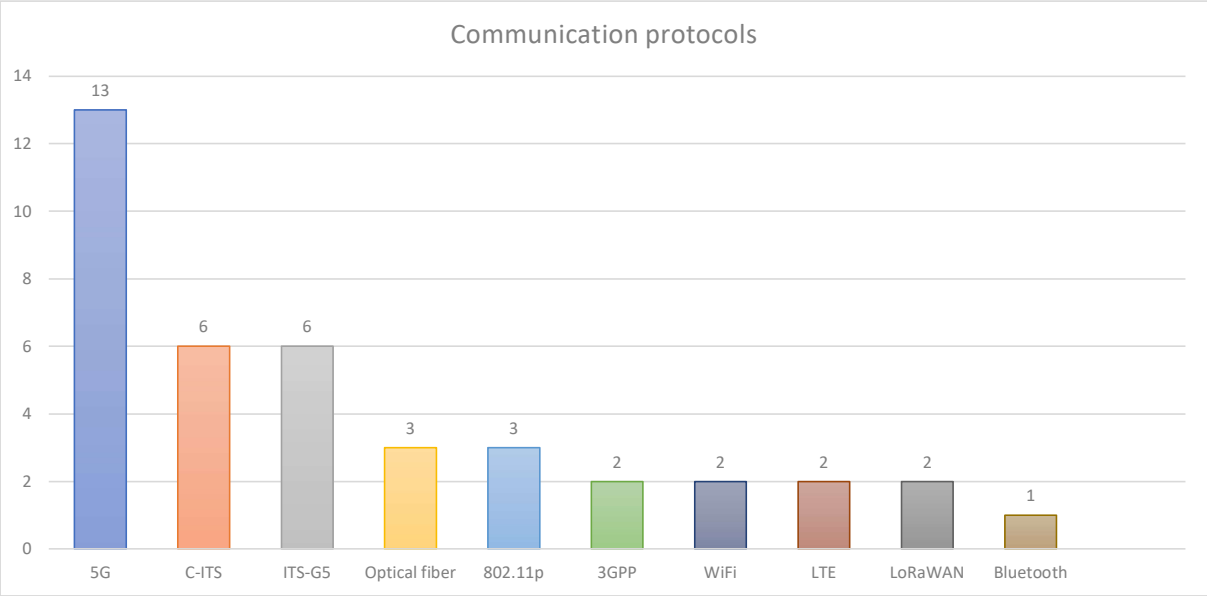

Figure 27. Communication protocols used in the various projects analysed

The analysis carried out here aims to list the different communication protocols that have been used in the various projects studied during the analysis, as well as to differentiate those that are of greatest interest within the Smart Mobility scene, as they have a higher incidence.

In this context, there is a significantly higher presence of 5G technologies with respect to the rest of the protocols. This is mainly because it is one of the most recent communication technologies and that it covers more field of application, so its capabilities are much broader than in other protocols.

Among the many advantages of this wireless communications protocol stands out, as mentioned above, the notable increase in file transfer speed, which has a bandwidth of 20Mbps. In this sense, the new 5G networks not only allow communications with much more speed, but also allow the creation of network infrastructures connected with a large multitude of users without overloading and collapsing bandwidth, so these solutions are essential within the Smart Mobility paradigm, which is based on communication between the different participants in the mobility paradigm.

In this sense, it is important to bear in mind that in the analysis carried out, the use of the 5G communication protocol has been added only in those projects in which it has been possible to find documentation that specifies that their proposals are carried out through this protocol. This criterion has been maintained with the rest of the protocols, and this is the reason why, in general, there is a low incidence of protocols in the projects analyzed, which is associated only with the lack of available documentation about the initiatives.

Secondly, the presence of ITS (Intelligent Transport Systems) communication protocols stand out. Again, this protocol is based on communications between vehicles and within it, it has been possible to differentiate between C-ITS (Cooperative Intelligent Transport Systems) and ITS-G5, with an incidence of 6 projects in both cases. In this sense, while C-ITS is only the V2X communication standard for different technologies, with different communication modes, the ITS-G5 deepens the protocol, limiting communications to the 5Ghz frequency band, which is reserved for this purpose, avoiding the collapse of frequencies, and facilitating the correct communication between vehicles. [49]

For this type of communication, there is already a specific protocol established in the European standard. [50]

Then, with a much lower incidence, between 1 and 3 projects, there are other communication protocols, which are: Optical fibre, 802.11p, 3GPP, WiFi, LTE, LoRaWAN and Bluetooth.

In this sense, it is first that the only wired communication protocol that has stood out among the different initiatives analyzed is optical fibre, which has a significantly higher data transmission speed than other types of wired communication protocols.

Then, it can be distinguished the presence of the 802.11p protocol, which is a specific WAVE (Wireless Access in Vehicular Environments) protocol framed within the IEEE working group. In this sense, the protocol is again dedicated exclusively to providing V2V and V2I communications in a rapidly changing environment where information exchanges are required to be completed in a very short period. In a more technical context, it stands out that the protocol works on a bandwidth of 10Mhz, so it is not prepared for the transfer of a large amount of data, and in turn has a reserved band spectrum divided into 7 specific channels. [51]

Likewise, the use of communications has been differentiated following the standard of the 3GPP protocol (3rd Generation Partnership Project), which is responsible for grouping a set of seven telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDI, TTA and TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports ad Specifications that define 3GPP technologies. In this way, the use of cellular telecommunications technologies is covered, including access by radio, core network and service capabilities, thus being able to facilitate mobile communications. [52]

Moreover, the presence of communications by means of the LoRaWAN protocol (Low Power Wide Area Network) is highlighted. As its name suggests, this technology is specifically designed for low-power devices and has the capacity to operate in networks of local, regional, national, and even global scope. From a technical point of view, the protocol operates on frequencies of 433 MHz, 868 MHz, and 915 MHz at different speeds. This type of technology has the advantage of being used to connect various LoRa devices (low-power communication devices) managing their channels and connection parameters, in such a way that it is very interesting in applications of small infrastructures of the mobility environment such as sensors, meters, traffic lights, among others. [53]

Finally, the use of more common and frequent communication protocols such as WiFi, LTE (cellular) or Bluetooth communication has also been highlighted in some projects.

3.1.3 Communication technologies per application area

In this section, it is intended to expand the analysis carried out in reference to communication technologies, relating it directly to the state-of-the-art in terms of application environments, so a cross-dimension analysis has been carried out with the value of application area.

In this sense, the incidence of the different communication technologies used for the initiatives corresponding to each of the application areas in which the projects have been categorized has been analyzed.

In this way, in the first place, there is the analysis carried out on the application field of traffic management, on which the results that can be distinguished in the graphs of Figure 28, where a pie chart with the distribution of the technologies can be distinguished as well as a bar chart with the number of times that each technology affects within this category.

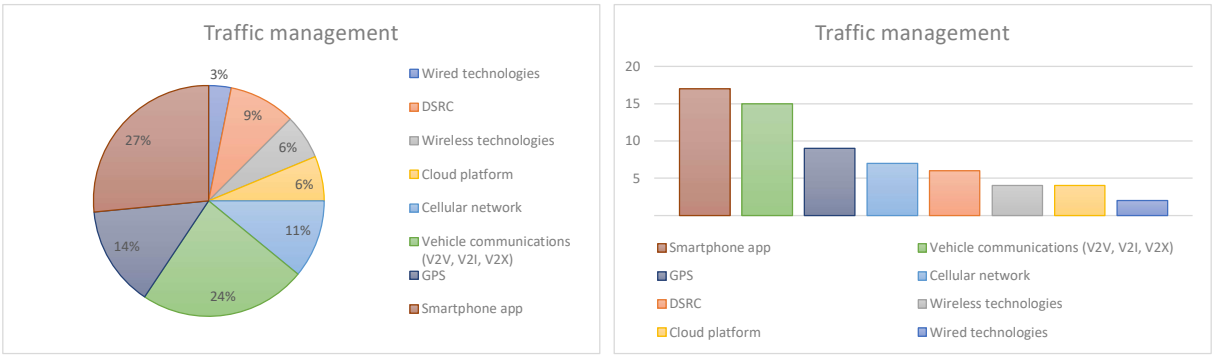

Figure 28. Communication technologies distribution and incidence for traffic management initiatives

From this information, it can be extracted the fact that there is a majority presence of smartphone applications, vehicle communications and GPS technologies, with a distribution of 27%, 24% and 14%, respectively.

In this sense, it should be borne in mind that solutions through smartphone applications are very generic and, therefore, applicable to a large number of initiatives. Specifically, in this area of application it has been possible to distinguish as a solution to provide communication between vehicles at a low level, as well as to be able to interact with users of public roads.

On the other hand, it is consistent to find a high presence of vehicle communication technologies (V2X) accompanied by GPS for their location, because within the scope of traffic management, it is essential to locate road users and share information, to be able to make an intelligent traffic management.

Next, the analysis proceeds with the communication technologies for Smart Road initiatives. In this sense, an analysis similar to the previous one has been developed, where the two graphs of Figure 29.

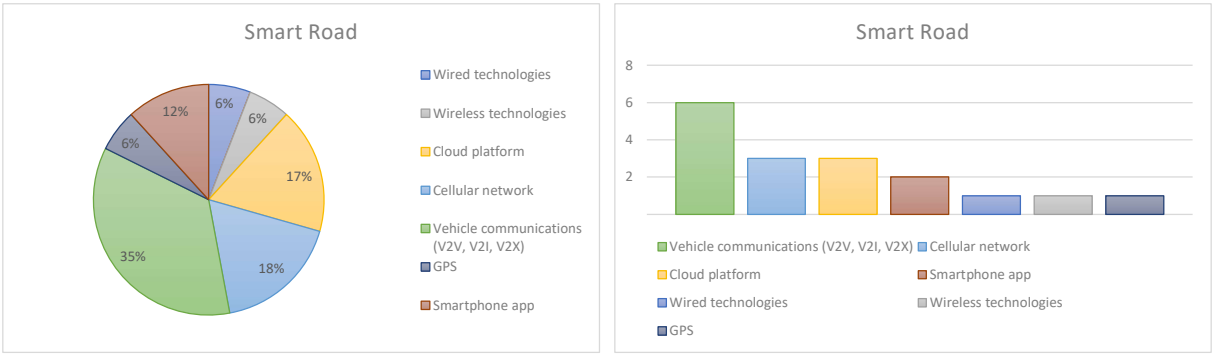

Figure 29. Communication technologies distribution and incidence for Smart Road initiatives

According to these results, a greater incidence can be distinguished in vehicle communications (V2X), cellular network and cloud platform technologies, with a distribution of 235. In this sense, the technologies within this application area are focused to a greater extent on the transmission of data, leaving the interaction with the user in the background.

Thus, vehicle communications are of great importance within the Smart Road in the sense that this application area is focused on the users of the road itself, which are the vehicles, and their connectivity with the environment to be able to provide

services and optimize their operation. In a complementary way, there is cellular communications to favour this type of communications.

Also, taking into account that this is one of the applications most focused on the extraction and analysis of data, the presence of cloud platforms has a greater relevance, as a solution for the easy storage, access and treatment of the data extracted from the roads themselves, which are very useful within the analysis of Smart Mobility.

The analysis comes from an analogous way with the logistics area after which, as in the previous cases, the distribution and incidence graphs that can be distinguished in Figure 30.

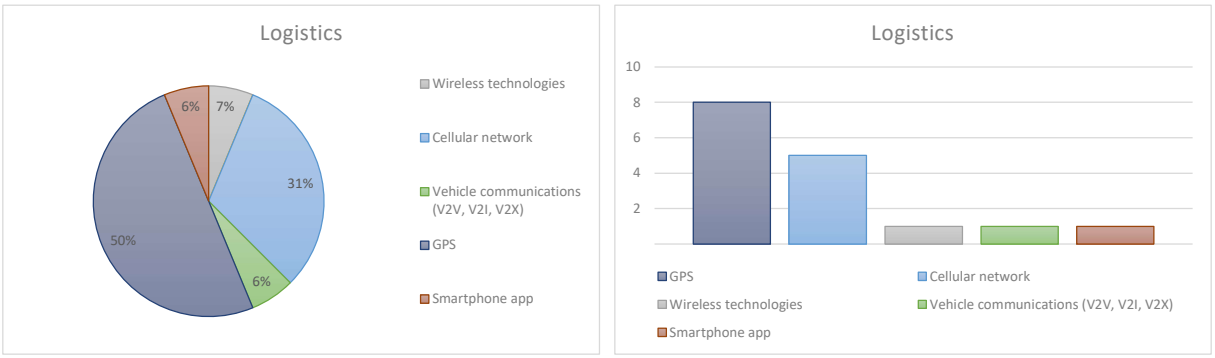

Figure 30. Communication technologies distribution and incidence for logistics initiatives

In the field of logistics, the needs are very different, and this is reflected in the most prevalent communication technologies among the new initiatives detected. In particular, it can be distinguished that these initiatives use, above all, GPS location technologies (in 50% of cases), in such a way that the different goods delivery vehicles can be correctly tracked. Thus, the proposed solutions mainly use this technology to draw up the most efficient delivery strategies, especially in the last mile deliveries that currently represent one of the main challenges of the sector.

Likewise, as a technology for data transmission, most of the proposed initiatives are established on cellular network technologies (with a distribution of 31%) that, in general, do not require special applications for their operation, which is currently based on this type of communication.

The analysis continues using the communication technologies detected in the software and platform initiatives introduced in the database. Thus, the present analysis results in the graphs that can be distinguished in Figure 31.

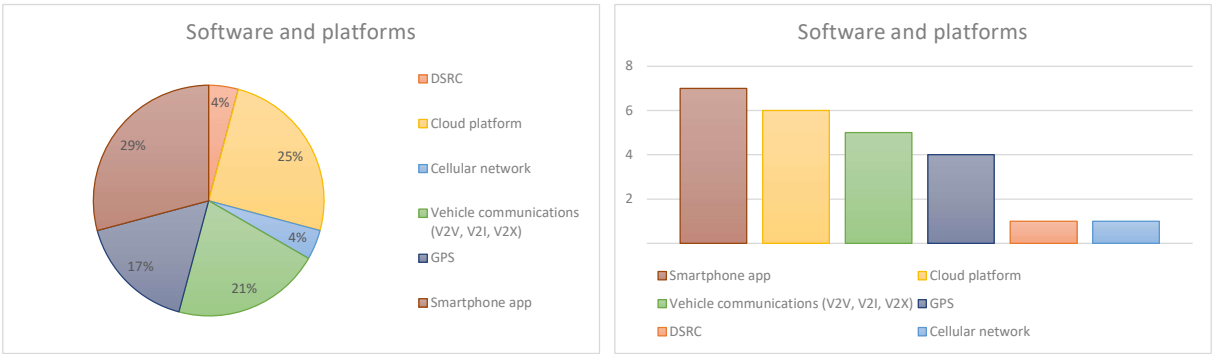

Figure 31. Communication technologies distribution and incidence for software and platforms initiatives

In this area of application, the use of four communication technologies can be highlighted: smartphone app, cloud platform, vehicle communications and GPS, which appear in 29%, 25%, 21% and 17% of the initiatives analyzed, respectively.

Specifically, it is consistent to distinguish the presence of smartphone applications considering the nature of the software, where a large part of the initiatives seeks the ability to interact with the user, this technology being one of the simplest and most accessible.

Likewise, in the projects more focused on the extraction and processing of data for statistical analysis and to make a more efficient management of mobility resources, the use of cloud platforms can be differentiated. In this sense, this type of communication technology allows a decentralized use of information and facilitates the obtaining of data, allowing to obtain clouds with a large amount of information useful for the mobility paradigm. In this sense, the present communication technology is complementary with Big Data technologies, which are spreading in recent times, reaching the field of mobility.

Finally, vehicle communications and GPS technologies are distinguished, which are basically associated with those software projects and platforms that are expressly focused on vehicles and expanding their communication and traceability capabilities.

In this way, the analysis continues through the communication technologies associated with the application area of green technologies, whose results can be distinguished in Figure 32.

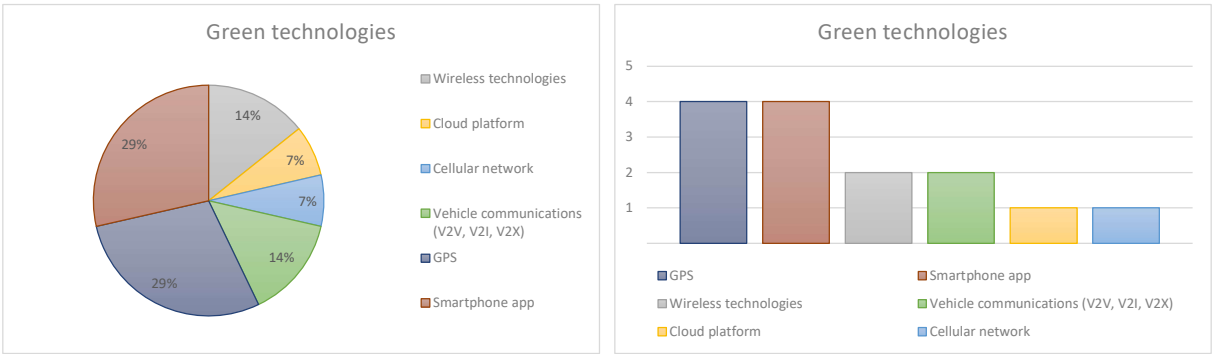

Figure 32. Communication technologies distribution and incidence for green technologies initiatives

In this category of application, it can be distinguished that again prevail, with a distribution of 29% of projects, GPS communication technologies and Smartphone app.

Again, the presence of smartphone applications translates into the need to interact with users and establish means to obtain their data in a simple and accessible way.

In addition, the presence is distinguished with an incidence of 14% of vehicle communications and wireless communications. Vehicle communications follow the general line of Smart Mobility initiatives, however, the presence of Wireless technologies stands out, which, on this occasion, have not been limited to communication between vehicles, but, for example, to communication between various pieces of infrastructure that seek to make efficient and ecological use of resources. In this line, there can be highlighted the developments carried out in the field of measurement of noise pollution and pollutant emissions that, fundamentally, use wireless communication technologies to transfer data.

In this way, the analysis line continues with the technologies detected for mobility sharing initiatives, the results of which are summarized in the graphs in Figure 33.

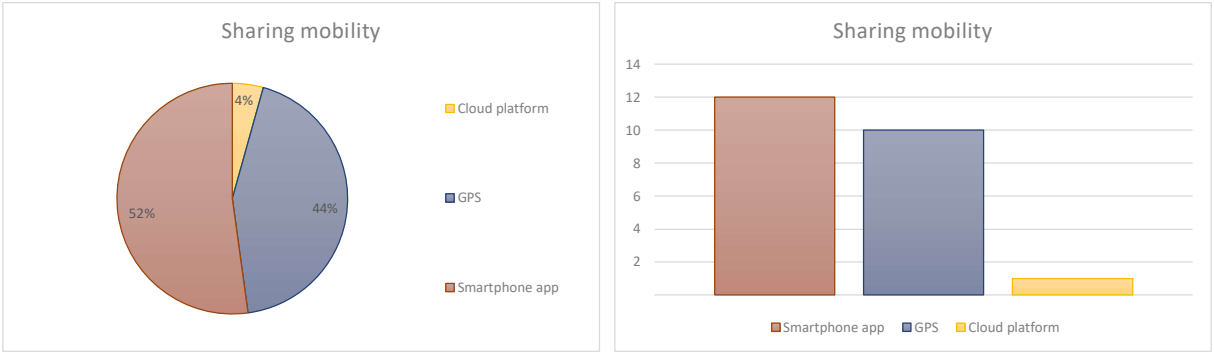

Figure 33. Communication technologies distribution and incidence for sharing mobility initiatives

In these results, as expected considering the nature of sharing, they are based on smartphone applications and GPS technologies. This is reasonable considering that sharing initiatives are usually carried out using a platform built on a smartphone application that detects the user's location by GPS and offers one or more mobility sharing services. Specifically, in this case there can be distinguished a distribution of 52% of initiatives with smartphone application technologies and 42% associated with GPS technologies.

Finally, the last of the application areas on which communication technologies will be characterized is security. In this area, the two graphs that are distinguished in Figure **34**extracted, analogous to the rest of the results.

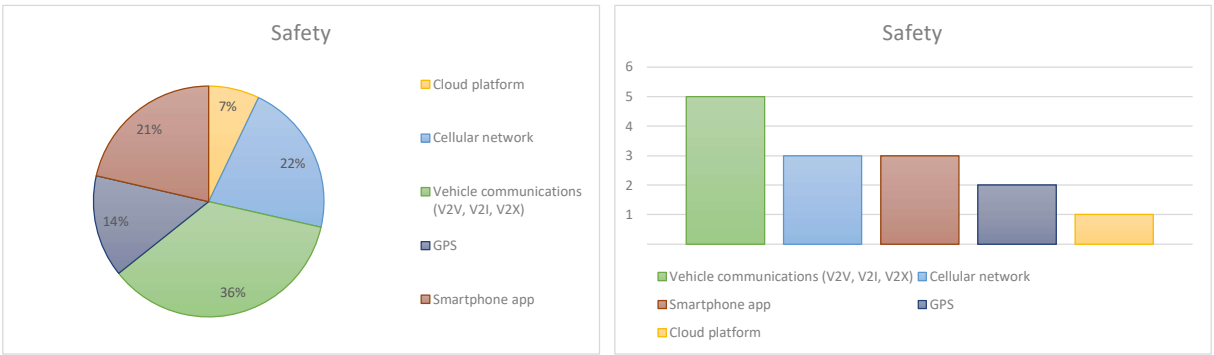

Figure 34. Communication technologies distribution and incidence for traffic management initiatives

According to the results, it can be noted that the main communication technology, with a 36% incidence, is vehicle communications technology. In this sense, these

technologies are complemented by the use of cellular network, which in many cases make up the vehicle's own means of communication. This type of communication is essential considering that the main problem in terms of safety currently present is in cars and personal vehicles in general, so the initiatives within this category are mostly focused on increasing the communication capabilities of vehicles to mitigate the accidents that are due, mainly, to the human factor of the user himself.

Once the analysis of each of the technologies for each of the application areas has been completed, Table 2 is developed. Here, the incidence of all the communication technologies described is summarized, for each of the application areas, in such a way that it can be analyzed together in a simple way.

Table 2. Summary of the distribution of communication technologies for each of the application areas

	Wired technologies	DSRC	Wireless technologies	Cloud platform	Cellular network	Vehicle communications (V2V, V2I, V2X)	GPS	Smartphone app
Traffic management	1.2%	3.5%	2.3%	2.3%	4.1%	8.7%	5.2%	9.9%
Smart Road	0.6%		0.6%	1.7%	1.7%	3.5%	0.6%	1.2%
Logistics			0.6%		2.9%	0.6%	4.7%	0.6%
Software and platforms		0.6%		3.5%	0.6%	2.9%	2.3%	4.1%
Green technologies			1.2%	0.6%	0.6%	1.2%	2.3%	2.3%
Sharing mobility				0.6%			5.8%	7.0%
Safety				0.6%	1.7%	2.9%	1.2%	1.7%

Thus, the various boxes whose cross-correlations are more frequent and therefore relevant are highlighted. According to this analysis, there is a particularly high incidence (more than 7% of the total cases) in smartphone application technologies for traffic management and sharing mobility initiatives, as well as vehicle communications technology in the field of traffic management.

At a lower level (with between 4% and 7% of incidence), it is also worth highlighting the relationship detected between smartphone applications and software and platforms projects, also between GPS positioning technologies and traffic management, logistics and sharing mobility initiatives and, finally, between cellular network technologies and traffic management projects.

3.2 Other technologies analysis

Following the analysis of the technologies related to the new initiatives of Smart Mobility, this section proceeds to carry out an express analysis of alternative technologies that are independent to communications.

In this way, this analysis is based on those technologies not related to telecommunications, but of a technologically innovative nature, which have been found in the initiatives analyzed.

3.2.1 Other technologies

The analysis begins by broadly defining the incidence detected for each of the alternative technologies that have been detected in the initiatives introduced in the database. In relation to this, the graph in Figure 35 can be seen where the incidence of each of the technologies analyzed is distinguished.

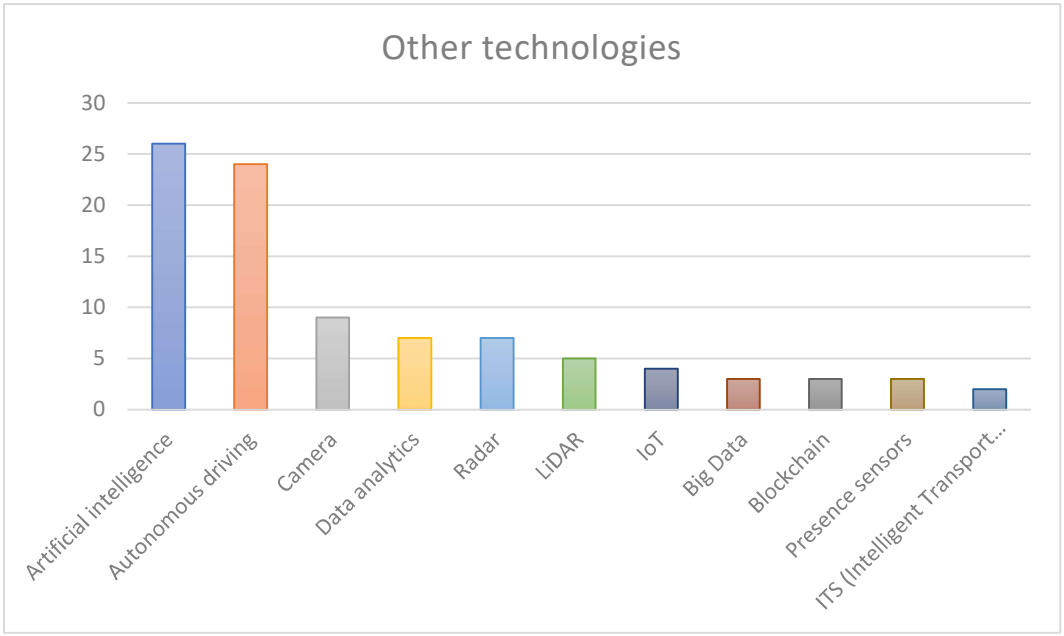

Figure 35. Other technologies used in the various projects analyzed

As a result of the analysis and statistics of the initiatives, there is a significantly greater incidence in the use of two technologies, which are artificial intelligence and autonomous driving, with a presence in 26 and 24 projects, respectively.

In this sense, the use of artificial intelligence means is evident considering that one of the premises of Smart Mobility is to optimize the operation of means of transport as much as possible. In this way, algorithms based on artificial intelligence allow to provide efficient and technologically superior solutions to those made by conventional methods.

Specifically, these technologies have a very wide application within the mobility sector, as they allow to improve both the vehicles themselves, and the means that manage them, through the infrastructure itself. Thus, it is common to find this type of technology in projects focused on traffic management, road infrastructures or the internal management of the vehicles themselves.

In relation to vehicles, the technology related to autonomous driving comes into play, which has presented a high incidence in the initiatives analyzed. This technology is complemented by artificial intelligence and together they make up their own sector with infinite possibilities, applications, and advantages. Specifically, these technologies can be seen in car assistance systems and in proposals with fully autonomous vehicles that fulfill certain functions within the field of Smart Mobility.

At the same time, and with a significantly lower incidence, there are other types of technologies that have appeared in multiple projects and are considered important within the Smart Mobility paradigm.

In the first place, the presence of data analytics technologies in general is distinguished (with an impact on 7 projects), this implies that the projects categorized here have specific technologies that together seek to perform data analysis to find patterns and trends that allow applying action strategies in various applications of Smart Mobility.

Associated to this technology, there are complementary technologies that are focused on the extraction of data from the environment, specifically, there are optical technologies (camera), Radar, LiDAR, and presence sensors with incidence of 9, 7, 5 and 4 projects, respectively. This type of technology has been detected within the database associated with functions of analysis of the environment of some initiatives, in this sense, these types of technologies are able to analyze the environment with

different purposes to extract information and apply certain actions that allow to improve in general the dynamics of mobility.

Next, within the ecosystem of connected things that is closely related to Smart Mobility, there is an impact on 4 projects with IoT (Internet of Things) technologies. These types of technologies are based on the concept of the connectivity of things, understanding things as any element or component that, without human interaction, can contribute to a common network with the rest of things. In this way, a connected ecosystem is achieved with a large amount of information that can be used for any purpose. For this reason, the IoT is a very broad concept with application and significant advantages in almost any technological field.

At the same time, the presence of Big Data technologies has been distinguished in 3 of the projects analyzed in the database. It should be noted that in general, a large number of projects are based on the collection and statistical processing of mobility data with the aim of looking for patterns and trends that allows applying measures and action strategies in order to improve the mobility system as a whole. However, it has been detected in 3 projects the presence of the concept of Big Data as such, which seeks the massive processing of all types of data, structured and unstructured, with the aim of making an analysis of all this data and looking for certain behaviours and trends that allow to improve the way of understanding a certain process, so that its operation can be optimized and improved, and even subsequent events can be foreseen.

Likewise, with an incidence of 3 projects, the use of Blockchain technologies has been distinguished. This technology is based on the existence of a shared and immutable larger book to record virtual transactions, track assets, and generate trust in them. In this sense, Smart Mobility has been crossed with economic aspects and, considering the nature of Smart Mobility projects, there is no remarkable potential in this type of technology within the Paradigm of Smart Mobility, so the incidence of this technology is not remarkable.

Finally, in certain projects mention is made of ITS (Intelligent Transport Systems) technologies that have already had their appearance within the dedicated communication protocols that exist. In this sense, the two projects in which this technology is mentioned include the use of means of transport integrated within the

paradigm of Smart Mobility, therefore connected, integrated within a centralized mobility system and with an efficient and sustainable operation.

Once this introductory analysis has been concluded, it should be borne in mind that the results obtained in this analysis are indicative, since as in the case of communication technologies, the technical information available in a large part of the initiatives is limited and does not allow proper analysis. In this way, the results obtained allow to differentiate those technologies that are of interest within the paradigm of Smart Mobility and identify those that present an outstanding in their incidence, and therefore are of special interest.

3.2.2 Other technologies per application area

In an equivalent way with the analysis carried out for communication technologies, in this section a cross-correlated analysis will be carried out where the data corresponding to the alternative technologies detected and the different application areas in which the initiatives have been characterized will be combined.

First, according to the chart footer that can be distinguished in Figure 36, the different technologies detected within the traffic management initiatives are analyzed.

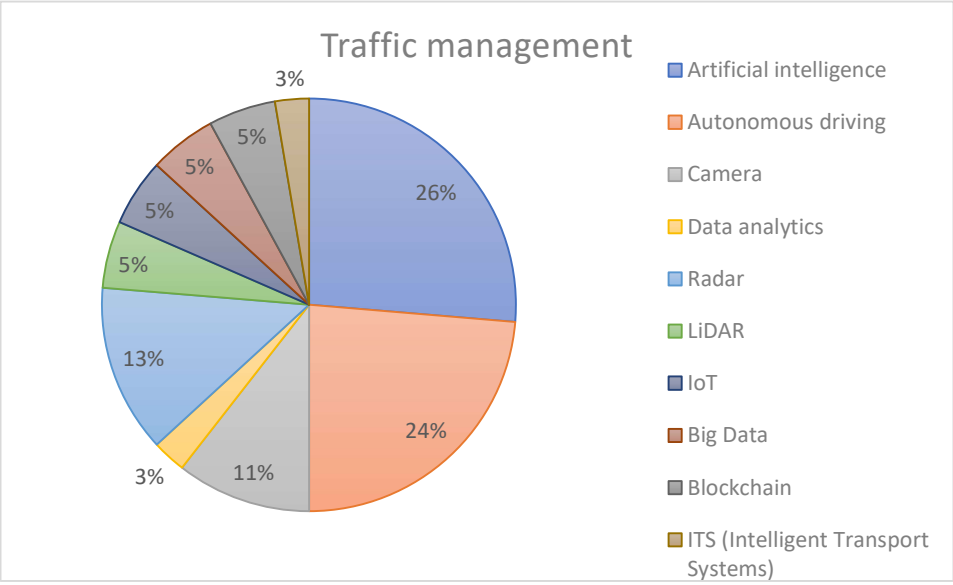

Figure 36. Other technologies distribution for traffic management initiatives

According to the results, a high presence of projects with artificial intelligence and autonomous driving can be distinguished, comprising 26% and 24%, respectively. These results are consistent considering the high incidence of these technologies compared to the rest, in general.

Additionally, technologies focused on obtaining data are distinguished, such as radar, LiDAR and optics (cameras), with a distribution in 13%, 5% and 5% of the projects included in the database. These results are consistent considering that a large part of the traffic management projects are based on data analysis technologies on traffic circulation in order to make more efficient use of the control infrastructure, requiring elements that act as input within the system.

It should also be noted that in this field of application it is distinguished that there are, with a reduced incidence, Internet of Things, Big Data/Data analytics and Blockchain technologies.

The analysis proceeds with the alternative technologies for the next application field, which is the Smart Road. Figure 37 a graph specifying the distribution of technologies in this category.

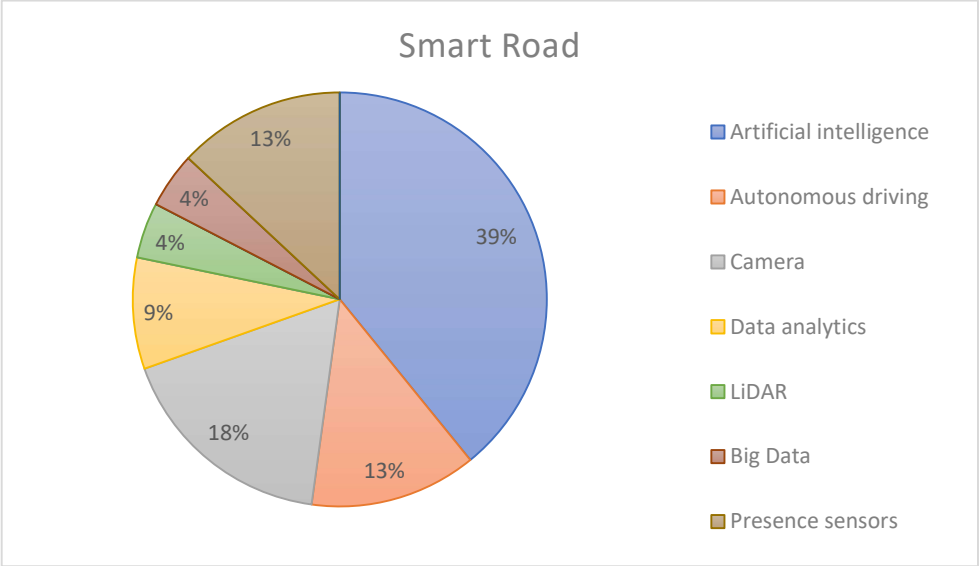

Figure 37. Other technologies distribution for Smart Road initiatives

According to the results, there is a significantly greater presence of projects with artificial intelligence technologies (39% of the total), than with the presence of

autonomous driving technologies (13% of the total). This result can be explained considering that a large part of the projects pigeonholed within this application framework seek precisely to offer a more sophisticated infrastructure and road services for cars and road users, so it does not consider the presence of autonomous vehicles as such. In this sense, it should be borne in mind that projects related to the Smart Car sector have not been incorporated into the database, where there are many initiatives to evolve the autonomous driving of cars, which is outside the scope of this project.

Moreover, an important presence of data analytics and Big Data technologies can be distinguished, with a distribution of 9% and 4%, respectively. This type of technology is important because this application area focuses on the incorporation of technologies directly on the roads, a fact that directly promotes the study and analysis of data to provide more technologically sophisticated solutions, requiring specific data processing.

Likewise, there are technologies that act as inputs in the data analysis and management system, specifically there is optical technology (camera), presence sensors and LiDAR, comprising 18%, 13% and 4% of the sample, respectively.

The analysis proceeds with the technologies associated with the logistics application area, as can be distinguished in the graph in Figure 38.

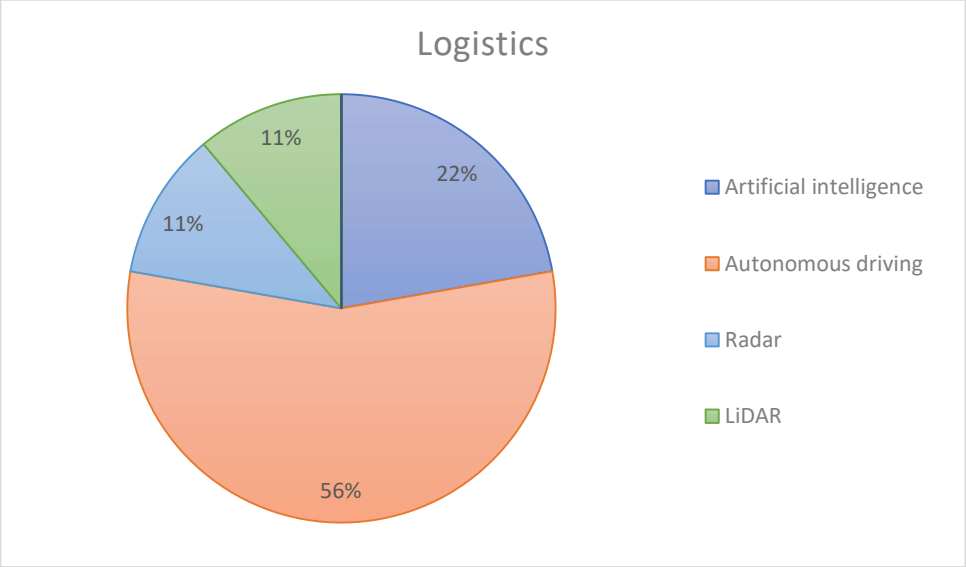

Figure 38. Other technologies distribution for logistics initiatives

It is distinguished from the graphic a majority presence of autonomous driving technologies, which cover 56% of the projects within this application framework. This result is closely associated with the main problem presented by logistics systems today, which is the last mile delivery. As already mentioned, this problem concerns the last section of transport, which takes place in urban centers and requires several stops at the destination homes, a fact that significantly increases the price per kilometer. It is in this context that a multitude of initiatives appear where autonomous driving is introduced through specific vehicles dedicated to covering this last mile delivery in an autonomous, efficient, and sustainable way.

Naturally, there is also a notable presence of artificial intelligence (accounting for 22% of the projects) that ranges from the algorithms of the initiatives themselves to part of the autonomous operation of the vehicles previously defined.

Next, and closely related to autonomous vehicles, it is possible to distinguish with a presence of 11% the use of radar and LiDAR technologies that, in most cases, are used as input to the autonomous driving system of the vehicles proposed in the initiatives.

Thus, the study proceeds with the analysis regarding the application area of software and platforms, where, according to Figure 39, the most significant technologies can be distinguished.

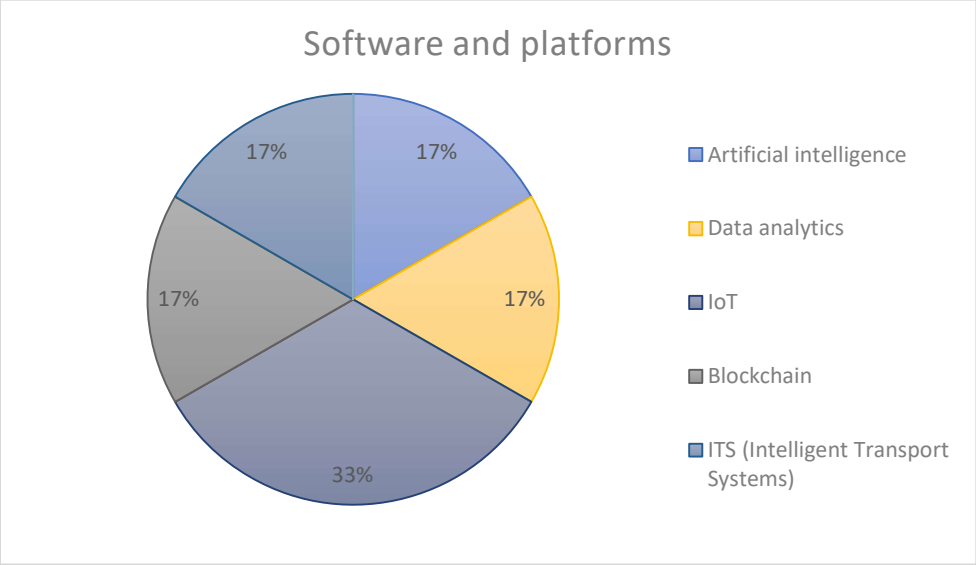

Figure 39. Other technologies distribution for software and platforms initiatives

This graph shows a majority presence, in this case, of IoT technologies that cover 33% of the projects introduced in this category. This result is justified considering the nature of digital software and platform initiatives, where the systems of networks of devices connected to each other fit perfectly, giving rise to favorable ecosystems for Smart Mobility scenarios.

In this sense, the absence of autonomous driving technologies and a relatively small presence (17% incidence) of artificial intelligence technologies are distinguished, with respect to the rest of the technologies. In this sense, the fact that this category is not necessarily focused on vehicles as such, gives rise to artificial intelligence appearing as a tool for the generation of specific algorithms on which to build the various initiatives included in this category.

On the other hand, data analysis technologies are distinguished, intrinsic to the development of digital platforms, as well as Blockchain or ITS technologies, all with an incidence of 17%.

Once this analysis is concluded, the paragraph proceeds by defining the technologies framed within the application framework of green technologies. In this sense, the chart footer that can be distinguished in Figure 40.

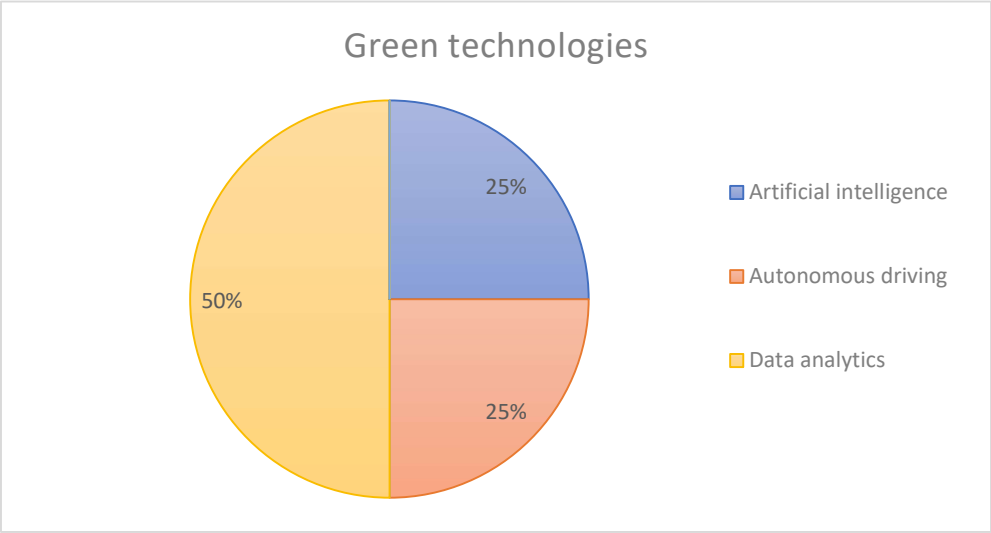

Figure 40. Other technologies distribution for green technologies initiatives

In this case, there is a predominance of data analytics technologies, which covers 50% of the projects taking into account that this sector comprises multiple projects directly

focused on the measurement of environmental parameters to consequently modify the methods of traffic management and mobility infrastructure in general, to achieve better results.

Also, considering the predominance of artificial intelligence and autonomous driving technologies, they can be distinguished in this application area with an incidence of 25%.

Finally, an analysis is carried out on the alternative technologies detected within the scope of security, as shown in the graph that has been obtained from the database and that is represented in Figure 41.

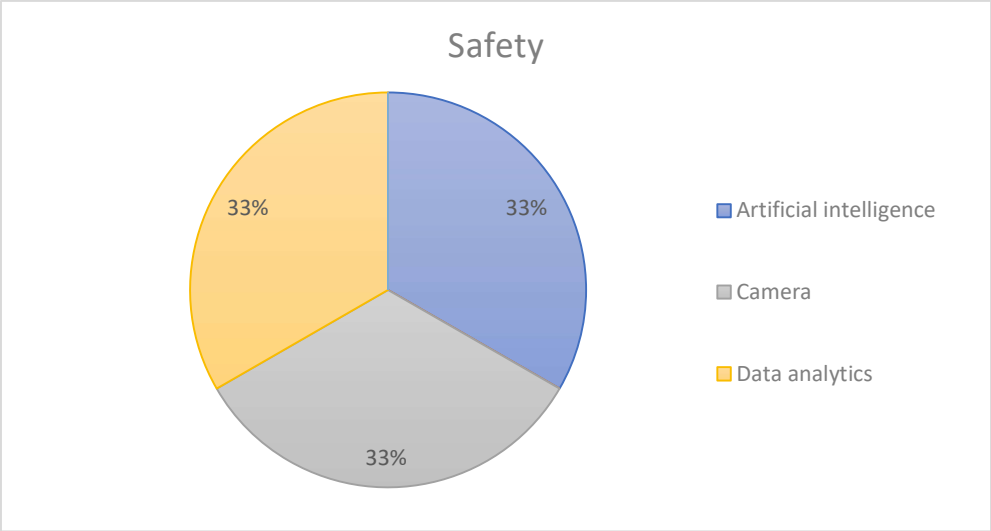

Figure 41. Other technologies distribution for safety initiatives

In this last category, the presence of optic technologies (cameras), data analytics and artificial intelligence differs with an equal incidence of 33%. This result is consistent with the nature of this type of project, which mainly seeks to act on the most fragile point in terms of security within the mobility paradigm, which is the private vehicle.

In this sense, by strategies of data analysis and artificial intelligence, it seeks to make an intelligent management of the data obtained from the rest of the vehicles, and the environment in general, which allows to improve the safety conditions of the vehicles that users drive. In addition, for this purpose it is distinguished that the main input used in the new initiatives that have been included in the database, makes use of optical technology (cameras) mainly.

Once the analysis of the technologies for each application area has been concluded, it should be noted that the analysis on the category of sharing mobility has not been carried out as it is lacking in this type of technology considering the nature of this type of applications.

The paragraph proceeds with a conclusion on the results obtained from this analysis using Table 3, which includes all the technologies that have been analyzed in this section presented against the different application areas, in such a way that the results extracted from this analysis can be summarized.

Table 3. Summary of the distribution of other technologies for each of the application areas

	Artificial intelligence	Autonomous driving	Camera	Data analytics	Radar	LiDAR	IoT	Big Data	Blockchain	Presence sensors	ITS (Intelligent Transport Systems)
Traffic management	10.8%	9.7%	4.3%	1.1%	5.4%	2.2%	2.2%	2.2%	2.2%		1.1%
Smart Road	9.7%	3.2%	4.3%	2.2%		1.1%		1.1%		3.2%	
Logistics	4.3%	10.8%			2.2%	2.2%					
Software and platforms	1.1%			1.1%			2.2%		1.1%		1.1%
Green technologies	1.1%	1.1%		2.2%							
Sharing mobility		1.1%									
Safety	1.1%		1.1%	1.1%							

From this table it is possible to distinguish highlighted in a gradual chromatic scale the percentage of incidence of each technology for each application area. In this context, artificial intelligence technologies for application areas of traffic management and Smart Road, as well as autonomous driving technologies, can be differentiated with a high frequency (between 9% and 11%), as well as autonomous

driving technologies have an important relevance in traffic management and logistics projects.

On the other hand, with a significant but not very high incidence (between 4% and 6%), the cross correlations of artificial intelligence technologies for logistics projects can be highlighted, as well as optical technologies (camera) in initiatives framed within traffic management and Smart Road. Finally, there is a remarkable incidence of radar technologies in initiatives related to traffic management.

3.2.3 Communication technologies per other technologies

The last of the analyses considered within the section of alternative technologies is precisely their cross-correlation with the communication technologies themselves that have been analyzed in section 3.1.

Thus, the realization of Table 4, where all the technologies analyzed are collected in a summarized way that helps interpretating the results.

Table 4. Distribution of communication technologies for each of the other technologies

	Artificial intelligence	Autonomous driving	Camera	Data analytics	Radar	LiDAR	IoT	Big Data	Blockchain	Presence sensors	ITS (Intelligent Transport Systems)
Wired technologies			1.4%							1.4%	
DSRC	2.8%	1.4%	2.8%	1.4%	2.8%						1.4%
Wireless technologies	1.4%	2.8%			1.4%						
Cloud platform	9.9%		4.2%	1.4%			4.2%		1.4%		
Cellular network		4.2%									1.4%
Vehicle communications (V2V, V2I, V2X)											
GPS	7.0%	9.9%		2.8%	4.2%	1.4%	1.4%		1.4%		
Smartphone app	5.6%	7.0%	2.8%	1.4%			4.2%		2.8%		

According to the results of the table, there is a particularly significant presence, with a 9.9% incidence, in technologies based on cloud platforms that complement their use through artificial intelligence technologies. This result is consistent considering that initiatives based on cloud platforms use the data extracted to make an intelligent analysis of the information obtained to apply measures and strategies that favor the use of sustainable and efficient mobility.

Likewise, with an incidence also of 9.9%, the use of GPS communication technologies within the autonomous driving technologies of vehicles can be appreciated. This result is evident and does not provide particularly relevant information, as it is a combination of technologies intrinsic to the very nature of the autonomous vehicle.

Next, an incidence of 7% can be seen between GPS location technologies and artificial intelligence technologies. This combination allows us to determine that a large part of technologically sophisticated projects at a technical level, due to the use of artificial intelligence sequences that must be adapted to each specific application, make use of location technologies that can be associated with both vehicles and pedestrians.

Additionally, the combination of smartphone applications with autonomous driving technologies is differentiated, with an incidence of 7%. Although it may seem like an erroneous combination, this combination presents a high frequency considering the widespread presence of last-mile deliveries initiatives where, vehicles with autonomous technologies are in turn able to interact with users, in such a way that a more personalized and sophisticated service can be offered, avoiding incidents due to the absence of a recipient, among other advantages.

Moreover, with an incidence also of 5.6% distinguishes the combination of smartphone applications with artificial intelligence technologies. This combination is mainly justified in the Mobility as a Service models introduced in the database. Taking into account that this type of mobility is already currently implemented and operational in initial phases with basic services, the new initiatives propose the use of sophisticated algorithms that make an analysis not only of the available means of transport, but of the general conditions of each mobility ecosystem in particular to be able to provide a more precise and efficient service that, through artificial intelligence algorithms and statistical analysis, it can offer a substantially more efficient and sustainable service.

On the other hand, mention is made of other crossed correlations that, although they are not so relevant given their incidence of 4.2%, should be highlighted against the rest. In this sense, the presence of cellular network technologies in autonomous vehicles can be differentiated, as the main method of data transmission. Likewise, the presence of optical technologies (cameras) in cloud platforms is appreciated, in such a way that optical technologies act as input for data that is uploaded, stored, and processed on cloud-based platforms.

Finally, GPS positioning technologies in conjunction with radar systems differ with the same incidence of 4.2%, which can be justified as a complementary system to positioning, so that elements can be located more accurately within specific environments that are detected by radar. In addition, for IoT technologies there is an obvious coincidence with cloud platform technologies, where information inputs corresponding to the paradigm of connected things (among which cameras are included) are generally included. IoT technologies also converge with smartphone applications, where smartphones are distinguished as one more "thing" within the paradigm, which can provide a large amount of efferent information to users within IoT networks.

In this way, this chapter concludes having carried out an analysis that allows to respond to the second of the research questions raised in section 0, having thus determined the emerging technologies within the growing paradigm of Smart Mobility, and concluding the research development object of this project.

4. Chapter 4: Conclusions and future work

Finally, this last chapter of the project presents the conclusions reached as a result of the research carried out in the Smart Mobility sector.

In this sense, this project has included the analysis of new initiatives related to the different areas that make up Smart Mobility in such a way that it has been possible to cover enough initiatives to carry out an analysis of the state-of-the-art and the most outstanding technologies that make up the different proposals.

Specifically, this section aims to determine both the conclusions obtained from the analysis carried out, broadly speaking, as well as the limitations detected in the research carried out and the future directions of the research that would seek to obtain more precise results and extend the level of knowledge in the paradigm of Smart Mobility that, progressively, is gaining greater relevance.

4.1 Analysis conclusions

The analysis carried out in this project seeks to determine the state-of-the-art and emerging technologies for the Smart Mobility sector and, through the results obtained, interesting information has been obtained in reference to the directions that the most recent developments in the market are taking.

Specifically, throughout Chapter 2, a study has been made of the most outstanding initiatives of the database for each of the differentiated application areas and, likewise, an analysis has been carried out of both the characteristics of the partners behind the initiatives, as well as the initiatives themselves.

In this sense, it has been possible to distinguish a remarkable variety in the nature of the partners behind the initiatives, since there are 46% of established companies, 32%

of Startups and 22% of projects with the participation of the public administration. In this sense, it can be distinguished that initiatives and, in general, Smart Mobility is an area of general interest for the public and private sector.

Likewise, in this same chapter it has been possible to differentiate that year after year, a greater number of proposals arise, especially in the European continent, which give rise to an exponential growth of Smart Mobility technologies.

At the same time, it has been determined that, with a great difference, the application area of greatest interest within Smart Mobility is traffic management, followed by Smart Road and logistics initiatives.

In this way, it has been possible to establish the context of the state-of-the-art today, and thus respond to the first of the research questions raised, from which it can be extracted that Smart Mobility is gaining an increasing importance within the mobility paradigm, especially affecting those areas that involve urban cores and mobility in logistical terms.

Next, the analysis carried out continued with the analysis of emerging technologies within the sector, obtaining the results reflected in Chapter 3.

Thus, from this analysis it has been possible to determine which are the main communication technologies within Smart Mobility. Among them, the most significant taking into account the wide range of possibilities it offers, is the technology implemented in smartphone applications, which allows making use of all the sensors of smartphones and interact with mobility users in a simple and accessible way.

It also highlights the presence of GPS positioning technologies, which are intrinsic to the very nature of mobility. It can also be distinguished a remarkable presence of vehicle communications with other vehicles (V2V), with infrastructure (V2I), with the cloud (V2Cloud) or with all the previous ones (V2X).

On the other hand, in reference to the various distinguished communication protocols, there is a very notable higher incidence of the cellular communication protocol by 5G, which is of recent creation and significantly expands the capabilities compared to previous similar technologies. In this sense, there is also a notable

presence of ITS protocols for communication between vehicles, specifically C-ITS and ITS-G5 protocols.

From the analysis of communications technology, it has been possible to distinguish a high incidence of smartphone applications and vehicle communications for traffic management initiatives, as well as smartphone application and GPS technologies in sharing mobility projects.

In addition, in this analysis, other innovative technologies independent of communications were analyzed, among which a superior presence of artificial intelligence and autonomous driving technologies has been detected. In this area, the presence of artificial intelligence technologies in traffic management and Smart Road initiatives stands out, while autonomous driving is more distributed in traffic management and logistics projects. Finally, a notable incidence has been distinguished between artificial intelligence technologies and cloud platforms, as well as autonomous driving with GPS.

Thus, it has been possible to establish the main emerging technologies in the field of Smart Mobility, responding to the second of the research questions being able to distinguish the importance of communications in mobility, specially V2X communications based on 5G, and of other trendy technologies such as artificial intelligence and autonomous driving, whose application also includes the field of mobility.

That way, it has been possible to conclude with the objective of this research project. After the developments made, there is a more precise perspective on the trend that new developments in this sector are following, being able to differentiate the initiatives and technologies with the greatest potential.

4.2 Limitations

Due to the very nature of the research, a series of limitations have been detected associated with the procedures carried out to obtain the data that have been analyzed in the database carried out. In this sense, the scope of the project does not allow to extend the level of detail of the analysis.

Specifically, the main limitation has been the difficulty of differentiating initiatives, at any stage of development, which had established a project with specific application in a real environment. Likewise, to this fact has been added the presence of a multitude of initiatives that did not have an innovative technological component strong enough to be included in the database, because it was not of interest for the analysis.

At the same time, this difficulty has been a problem for the identification of initiatives in the Asian continent mainly associated with the cultural and language leap that exists with this continent, as well as by the IP region itself from which the search for initiatives has been carried out. In this sense, there is a much greater presence of projects within the European and North American continent.

Likewise, another limitation of notable relevance for the correct development of the project has been distinguished in the identification of technologies in general, which is why the data obtained in this part of the analysis are only indicative and serve to make a low-level analysis of the technologies present in the latest Smart Mobility initiatives, as well as to differentiate those that have a significantly higher incidence than the rest. This limitation is directly associated with the lack of technical sources of information for a large part of the initiatives, in which no relevant information is provided at a technical level. This information, in addition, in a large part of projects cannot be found because many of the initiatives that have a strong technological component maintain a conservative position against the competition in terms of the publication of technical data of their projects.

Despite the limitations that have been found in the research carried out in this project, it is concluded that the results obtained are consistent and robust. Considering the limitations presented and interpreting the data accordingly, information of interest has been provided to know in greater detail the current situation of Smart Mobility.

4.3 Future directions of the research

Finally, and thus concluding this chapter and therefore the whole project, a series of guidelines are proposed to continue the research carried out in this project,

expanding the information extracted with reference to the state-of-the-art of Smart Mobility and its most relevant emerging technologies.

In the first place, to act directly on the limitations detected in the previous section, a deeper analysis should be done in the state-of-the-art of the Asian continent, trying to obtain in various ways Smart Mobility initiatives of Asian origin that meet the requirements established for their introduction into the database.

On the other hand, in order to distinguish the application in real environment of the initiatives, as well as the technologies on which they are based, the analysis could be extended through direct contact with the partners associated with the development of the initiatives, trying to extend the information entered in the database, in order to have more information and more accurate, improving the results obtained and their accuracy.

Likewise, the developments carried out include only initiatives carried out until December 2021, so it should be both to monitor the state of development of the projects introduced, and to extend the search over time, so that a wider database can be built and, therefore, with greater capacities.

In the same line of introducing exchanges of information with the developer partners of the alternatives introduced in the database, an analysis of the concerns of technology companies in reference to the Smart Mobility paradigm would be of special interest. In this sense, a survey of a few questions could be prepared where companies can answer if they are interested and propose to develop initiatives in the field of Smart Mobility and which of the application areas and technologies in general are of greatest interest for their development.

Finally, it is considered that within the Smart ecosystem, the analysis carried out could be extended to sectors closely related to Smart Mobility. Specifically, it is considered that the analysis of Smart Car and Smart City initiatives would be of interest within this ecosystem, which would allow contextualizing, in the same way, the state-of-the-art and the emerging technologies of these sectors.

References

[1] Verizon Communications, "What is smart mobility and why is it important?," Verizon Connect, 4 June 2021. [Online]. Available: https://www.verizonconnect.com/resources/article/smart-mobility/.

[2] DR2 Consultants, "Smart mobility within cities: benefits and challenges," 2022. [Online]. Available: https://dr2consultants.eu/smart-mobility-within-cities-benefits-and-challenges/#:~:text=The%20main%20objectives%20of%20smart,between%20different%20modes%20of%20transportation..

[3] RideAmigos, "Smart Mobility in the Smart Cities of Tomorrow," [Online]. Available: https://rideamigos.com/smart-mobility-in-smart-cities#:~:text=Smart%20cities%20are%20making%20IoT,them%20get%20to%20work%20efficiently..

[4] S. H. Shafana A.R.F., "A Survey: Smart Cities for Sustainable Future," *Researchgate,* 2018.

[5] Deloitte, "The future of mobility. How transportation technology and social trends are creating a new business ecosystem," 2015. [Online]. Available: https://www2.deloitte.com/content/dam/Deloitte/tr/Documents/manufacturing/future-of-mobility.pdf.

[6] H. T. Natasa Tandir, "Perceived satisfaction with public transport service: Case study of Gras," Sarajevo, 2016.

[7] El Confidencial, "Movilidad inteligente, en el foco de europa ¿es buen momento para invertir en ella?," *Cotizalia,* 2021.

[8] L. H. F. Y. L. G. Longyu Shi, "The evolution of Sustainable Development Theory: Types, Goals, and Research Prospects," *MDPI,* 2019.

[9] ACEA - European Automobile Manufacturer's Association, "Fuel types of new passenger cars in the EU," 2021. [Online]. Available: Fuel types of new passenger

cars in the EU - ACEA - European Automobile Manufacturers' Association.

[10] SmartCitiesWorld, “London borough makes school streets healthier and safer,” 2021. [Online]. Available: https://www.smartcitiesworld.net/news/london-borough-makes-school-streets-healthier-and-safer-6886.

[11] AlternativaSostenibile, “E-GAP: l'operatore mobile di ricarica veicoli elettrici,” 2018. [Online]. Available: http://www.alternativasostenibile.it/articolo/e-gap-loperatore-mobile-di-ricarica-veicoli-elettrici.

[12] Regione Lombardia, “Mobilità, Regione presenta scatola nera anti inquinamento. Da ottobre con 'Move-In' deroghe chilometriche veicoli 'datati',” 2019. [Online]. Available: https://www.regione.lombardia.it/wps/portal/istituzionale/HP/lombardia-notizie/DettaglioNews/2019/07-luglio/29-31/fontana-cattaneo-mobilita-regione-presenta-scatola-nera-anti-inquinamento.

[13] WiTricity, “Move-in,” 2020. [Online]. Available: https://witricity.com/.

[14] ShargeMe Electric Vehicles, 2021. [Online]. Available: https://www.shargeme.com/new/.

[15] Auto Rental News, “Bluebird, Autofleet, and ABeam Partner to Optimize, Scale One of Asia’s Largest Taxi Fleets,” 2020. [Online]. Available: https://www.autorentalnews.com/10143059/bluebird-autofleet-and-abeam-partner-to-optimize-scale-one-of-asias-largest-taxi.

[16] e-Novia, “YAPE - Low-contact delivery droid,” 2019. [Online]. Available: https://e-novia.it/startup/yape/.

[17] Dezeen, “Amazon to deliver purchases by drone "within months",” 2020. [Online]. Available: https://www.dezeen.com/2019/06/06/amazon-prime-air-drone-news/.

[18] Motor1, “Ford sviluppa il robot per la guida autonoma,” 2021. [Online]. Available: https://it.motor1.com/news/351225/ford-digit-robot-guida-autonoma/.

[19] SmartCitiesWorld, “EHang trials parcel delivery drone flights in Estonia,” 2021. [Online]. Available: https://www.smartcitiesworld.net/news/ehang-trials-parcel-delivery-drone-flights-in-estonia-6879.

[20] SmartCitiesWorld, “Logistics company plans to scale zero-emission delivery solutions across US,” 2021. [Online]. Available:

https://www.smartcitiesworld.net/news/logistics-company-plans-to-scale-zero-emission-delivery-solutions-across-us-6875.

[21] ForoCochesEléctricos, "Zoox. Así funciona el taxi autónomo de Amazon capaz de alcanzar los 120 km/h," 2021. [Online]. Available: https://forococheselectricos.com/2021/02/zoox-asi-funciona-el-taxi-autonomo-de-amazon.html.

[22] Damon Motorcycles, "CoPilot™: Advanced Guide to Our Award-Winning AWSM," 21. [Online]. Available: https://blog.damon.com/copilot-advanced-warning-system-for-motorcycles/.

[23] SOLOMOTO, "Ducati presenta el sistema de comunicación coche-moto en Las Vegas," 2019. [Online]. Available: https://solomoto.es/sistema-comunicacion-coche-moto-ducati/.

[24] AmsterdamSmartCity, "FindMyBicycle," 2019. [Online]. Available: https://amsterdamsmartcity.com/products/find-my-bicycle.

[25] TechCrunch, "Tampa offers first demo of its connected vehicle technology project, launching with 1,600 cars in 2018," 2018. [Online]. Available: https://techcrunch.com/2017/11/13/tampa-offers-first-demo-of-its-connected-vehicle-technology-project-launching-with-1600-cars-in-2018/?guccounter=1.

[26] Marshmallow, "We're rebuilding insurance. For goodMarshmallow specifically targets underserved segments of the insurance market, using tools and analytics that focus on customers that traditional insurers struggle with. The company began in 2018 by insuring ex-pat driv," 2019. [Online]. Available: https://www.marshmallow.com/.

[27] TIER, "Dublin to host innovative e-scooter AI research pilot project," 2021. [Online]. Available: https://about.tier.app/dublin-to-host-innovative-e-scooter-ai-research-pilot-project/.

[28] BePooler, "Move together," 2019. [Online]. Available: https://www.bepooler.com/?lang=en.

[29] MVMANT, "REINVENTING Urban Mobility," 2018. [Online]. Available: https://www.mvmant.com/.

[30] Electrive.net, "Chargery benennt sich in Surve Mobility um," 2020. [Online]. Available: https://www.electrive.net/2020/12/11/chargery-benennt-sich-in-surve-mobility-um/.

[31] TOYOTA, “Toyota Woven City,” 2022. [Online]. Available: https://www.woven-city.global/.

[32] CORCOM, “L’Autobrennero diventa smart road, sul piatto oltre 18 milioni di euro,” 2019. [Online]. Available: Implementation of 5G technology on a 600km stretch of motorway from Munich to Bologna. All this will serve to improve the performance of connected cars and the management of traffic and certain situations.

[33] I. Spectrum, “Colorado Prepares to Install “Smart Road” Product by Integrated Roadways,” 2019. [Online]. Available: https://spectrum.ieee.org/colorado-prepares-to-install-smart-road-product-by-integrated-roadways.

[34] A. D. Academy, “City Brain Lab,” 2020. [Online]. Available: https://damo.alibaba.com/labs/city-brain.

[35] Securaxis, “Do you listen to the City? Sound is information,” 2021. [Online]. Available: https://www.securaxis.com/.

[36] EETimes, “Infineon and Reality AI Teach Cars How to Hear,” 2020. [Online]. Available: https://www.eetasia.com/infineon-and-reality-ai-teach-cars-how-to-hear/.

[37] TOMP-WG, “City Data Standard - Mobility (CDS-M),” 2021. [Online]. Available: https://www.amsterdam.nl/innovatie/mobiliteit/city-data-standard-mobility/.

[38] ConnectedMobilityHub, “iomob,” 2020. [Online]. Available: https://connectedmobilityhub.com/portfolio-item/iomob/.

[39] ICT4CART, “A connected future for automated driving,” 2018. [Online]. Available: https://www.ict4cart.eu/.

[40] ThinkBig, “La alianza de Volkswagen y Microsoft: cuando el coche encuentra a la nube,” 2020. [Online]. Available: https://blogthinkbig.com/coche-conectado-nube.

[41] COORD, “Curb management for fast-changing cities,” 2018. [Online]. Available: https://www.coord.com/#delivering-digital-curb.

[42] Transdev, ““Whim”: one subscription for all your transport needs,” 2020. [Online]. Available: https://www.transdev.com/en/solutions/whim-maas/.

[43] Peek Traffic, “Adaptative Traffic Control,” 2021. [Online]. Available: https://www.peektraffic.eu/what-we-do/adaptive-traffic-control/.

[44] European Comission, “Innovative data analysis to cut urban traffic congestion,”

4] 2020. [Online]. Available: https://ec.europa.eu/research-and-innovation/en/projects/success-stories/all/innovative-data-analysis-cut-urban-traffic-congestion.

[45] SmartCitiesWorld, "Intelligent infrastructure solution chosen for New Jersey smart city project," 2021. [Online]. Available: https://www.smartcitiesworld.net/news/news/intelligent-infrastructure-solution-chosen-for-new-jersey-smart-city-project-6407.

[46] Indra, "Transforming Transport," 2020. [Online]. Available: https://www.indracompany.com/en/indra/transforming-transport.

[47] SmartCitiesDive, "Sacramento to transform historic train station into people-first mobility hub," 2021. [Online]. Available: https://www.smartcitiesdive.com/news/sacramento-valley-station-area-plan-mobility-hub/598512/.

[48] AITHORITY, "Commercialized Vehicle-To-Everything (V2X) Solutions Arrive to Fast-Track Emergency Movement," 2020. [Online]. Available: https://aithority.com/robots/autonomous-vehicles/commercialized-vehicle-to-everything-v2x-solutions-arrive-to-fast-track-emergency-movement/.

[49] ETSI, "Intelligent Transport Systems (ITS);," [Online]. Available: https://www.etsi.org/deliver/etsi_en/302600_302699/302663/01.02.00_20/en_302663v010200a.pdf.

[50] European comission, "Specifications for the provision of cooperative intelligent transport systems (C-ITS)," 2017. [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/1381-Specifications-for-the-provision-of-cooperative-intelligent-transport-systems-C-ITS-_en.

[51] D. Jiang and L. Delgrossi, "IEEE 802.11p: Towards an International Standard for Wireless Access in Vehicular Environments," in *VTC Spring 2008 - IEEE Vehicular Technology Conference*, Marina Bay, Singapore, 2008.

[52] 3GPP, "The Mobile Broadband Standard," [Online]. Available: https://www.3gpp.org/about-3gpp.

[53] What is LoRaWAN?, "LoRaWAN," [Online]. Available: https://lorawan.es/.