Treball de fi de màster

Analysis of the digital divide in the mobility ecosystem of the Barcelona Metropolitan Area

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“Whose digital and whose mobility?” – Unknown author

Abstract

In the coming years, disruptive technological advancements and accelerated development of digital mobility tools is likely to lead to an important paradigm shift in travel. While such a change has a great potential to bring benefits for many, it can also exclude those who don't have access to digital tools or find it difficult to use them for various reasons. This could lead to greater social inequalities and limit sustainable urban development on different dimensions.

This study seeks to frame the digital gap related to the innovative mobility solutions in the region of Barcelona Metropolitan Area, trying to understand attitudes towards new digital technologies emerging in urban mobility and patterns of their use among the population. To that end, the study applies a mixed-method approach, combining a literature review and a quantitative survey data analysis. The project results allow to advance on the understanding of the factors leading to the existing digital gap between mobility service provision and uptake, by different users' groups within the current digital travel ecosystem.

The literature review provides insight into the digital mobility-related gap which affects mainly groups at risk of exclusion, aggravating situations of poverty and social injustice. Such a disadvantage concerning basic services such as public transport, limits reaching destinations and employment opportunities, influencing economic justice and affecting mainly the groups of people identified as vulnerable. Moreover, it identifies research gaps which should be bridged in order to advance on the understanding of the phenomena in question, as well as to promote more inclusive policies that better integrate social and technological aspects.

Furthermore, the project reports on findings from the user survey conducted in Barcelona, which forms part of the work done within the European project DIGNITY H2020. The results reveal gaps in the use of technology, attitudes towards digital mobility services and mobility limitations of vulnerable-to-exclusion groups, highlighting particularly low levels of access and use among older people and those with low education levels. The questionnaire outcomes highlight the difficulties that many residents have with digital technology and public transport, mainly due to lack of confidence in using technologies, lack of digital skills, as well as limitations regarding safety and cost of the transport services.

Finally, the study provides insights on the requirements that digitalisation in mobility imply for different types of users and its potentially exclusionary effects. Based on that, the study marks out some potential policy recommendations that can help urban planners, practitioners and transport services providers head towards sustainable, future-proof and inclusive urban mobility ecosystem.

Keywords: Sustainable mobility, digital divide, mobility poverty, social exclusion, digitalisation, vulnerable to exclusion groups

Resumen

En los próximos años, los avances disruptivos en la tecnología y el desarrollo acelerado de las herramientas de movilidad digital probablemente provocarán un importante cambio de paradigma en la movilidad. Aunque esta transformación tiene un gran potencial para aportar beneficios a muchos, también puede excluir a quienes no tienen acceso a las herramientas digitales o les resulta difícil utilizarlas por varias razones. Esto podría conllevar mayores desigualdades sociales y limitar el desarrollo urbano sostenible en diferentes dimensiones.

Este estudio busca enmarcar la brecha digital relacionada con las soluciones innovadoras de movilidad en la región del Área Metropolitana de Barcelona, tratando de entender las actitudes hacia las nuevas tecnologías digitales que están surgiendo en la movilidad urbana y patrones de su uso entre la población. Para ello, el estudio aplica un enfoque de método mixto, combinando una revisión de la literatura y un análisis de datos de una encuesta cuantitativa. Los resultados del proyecto permiten avanzar en la comprensión de los factores que conducen a la brecha digital existente entre la provisión de servicios de movilidad y su adopción, por parte de diferentes grupos de usuarios dentro del actual ecosistema de movilidad digital.

La revisión de la literatura proporciona una fotografía de la brecha digital relacionada con la movilidad que afecta principalmente a los grupos en riesgo de exclusión, agravando las situaciones de pobreza e injusticia social. Esta desventaja en relación con servicios básicos como el transporte público, limita las oportunidades de empleo y para llegar a los destinos, influyendo en la justicia económica y afectando principalmente a los grupos de personas identificados como vulnerables. Además, se identifica las líneas de investigación que deben ser abordadas para avanzar en la comprensión de los fenómenos en cuestión, así como para promover políticas más inclusivas que integren mejor los aspectos sociales y tecnológicos.

Por otra parte, el proyecto analiza los resultados de la encuesta realizada en Barcelona, que forma parte del trabajo realizado dentro del proyecto europeo DIGNITY H2020. Las respuestas revelan brechas en el uso de la tecnología, las actitudes hacia los servicios de movilidad digital y las limitaciones de movilidad de los grupos vulnerables, destacando especialmente los bajos niveles de acceso y uso entre las personas mayores y las de bajo nivel educativo. Los resultados del cuestionario ponen de manifiesto las dificultades que tienen muchos residentes con la tecnología digital y el transporte público, principalmente debido a la falta de confianza en el uso de las tecnologías, la falta de habilidades digitales, así como las limitaciones relacionadas con la seguridad y el coste de los servicios de transporte.

Por último, el estudio proporciona información sobre los requisitos que la digitalización de la movilidad implica para los diferentes tipos de usuarios y sus efectos potencialmente excluyentes. Sobre esta base, el estudio señala algunas recomendaciones para potenciales políticas que pueden ayudar a los planificadores urbanos, a los profesionales y a los proveedores de servicios de transporte a avanzar hacia un futuro ecosistema de movilidad urbana sostenible e inclusivo.

Palabras claves: Movilidad sostenible, brecha digital, pobreza y movilidad, exclusión social, digitalización, grupos vulnerables

Resum

En els pròxims anys, els avanços disruptius en la tecnologia i el desenvolupament accelerat de les eines de mobilitat digital probablement provocaran un important canvi de paradigma en la mobilitat. Encara que aquesta transformació té un gran potencial per a aportar beneficis a molts, també pot excloure als qui no tenen accés a les eines digitals o els resulta difícil utilitzar-les per diverses raons. Això podria comportar majors desigualtats socials i limitar el desenvolupament urbà sostenible en diferents dimensions.

Aquest estudi busca emmarcar la bretxa digital relacionada amb les solucions innovadores de mobilitat a la regió de l'Àrea Metropolitana de Barcelona, tractant d'entendre les actituds cap a les noves tecnologies digitals que estan sorgint en la mobilitat urbana i patrons del seu ús entre la població. Per a això, l'estudi aplica un enfocament de mètode mixt, combinant una revisió de la literatura i una anàlisi de dades d'una enquesta quantitativa. Els resultats del projecte permeten avançar en la comprensió dels factors que condueixen a la bretxa digital existent entre la provisió de serveis de mobilitat i la seva adopció, per part de diferents grups d'usuaris dins de l'actual ecosistema de mobilitat digital.

La revisió de la literatura proporciona una fotografia de la bretxa digital relacionada amb la mobilitat que afecta principalment els grups en risc d'exclusió, agreujant les situacions de pobresa i injustícia social. Aquest desavantatge en relació amb serveis bàsics com el transport públic, limita les oportunitats d'ocupació i per a arribar als destins, influint en la justícia econòmica i afectant principalment els grups de persones identificats com a vulnerables. A més, s'identifica les línies de recerca que han de ser abordades per avançar en la comprensió dels fenòmens en qüestió, així com per a promoure polítiques més inclusives que integrin millor els aspectes socials i tecnològics.

D'altra banda, el projecte analitza els resultats de l'enquesta realitzada a Barcelona, que forma part del treball realitzat dins del projecte europeu DIGNITY H2020. Les respostes revelen bretxes en l'ús de la tecnologia, les actituds cap als serveis de mobilitat digital i les limitacions de mobilitat dels grups vulnerables, destacant especialment els baixos nivells d'accés i ús entre les persones majors i les de baix nivell educatiu. Els resultats del qüestionari posen de manifest les dificultats que tenen molts residents amb la tecnologia digital i el transport públic, principalment a causa de la falta de confiança en l'ús de les tecnologies, la falta d'habilitats digitals, així com les limitacions relacionades amb la seguretat i el cost dels serveis de transport.

Finalment, l'estudi proporciona informació sobre els requisits que la digitalització de la mobilitat implica per als diferents tipus d'usuaris i els seus efectes potencialment excloents. Sobre aquesta base, l'estudi assenyala algunes recomanacions per a potencials polítiques que poden ajudar als planificadors urbans, als professionals i als proveïdors de serveis de transport a avançar cap a un futur ecosistema de mobilitat urbana sostenible i inclusiu.

Paraules claus: Mobilitat sostenible, bretxa digital, pobresa i mobilitat, exclusió social, digitalització, grups vulnerables

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1. Introduction

The 21st century has been marked by dynamic and disruptive advances in Information and Communication Technologies (ICT) which are every time more present in different aspects of our lives. What is more, the COVID-19 pandemic has further accelerated processes of digitalisation in the society. Apart from that, constant population growth and ever-expanding cities are the trends that can be observed in the last decades. Various experts and studies point out that the 21st century will be the century of the cities; a statement which is based on the series of premises (March, 2018). First of all, a proportion of the world's population living in urban areas - which today is of 55%, with Europe being one of the most urbanised regions (74%) - is expected to increase to 68% by 2050 (United Nations [UN], 2019). This implies that global problems like climate change, environmental pollution or the depletion of natural resources are closely related to the lifestyles, consumption and mobility patterns that we have in the cities, which occupy only 3% of the Earth, but account for 60% to 80% of energy consumption and 75% of carbon emissions (UN, 2019). These facts prove that although rapid urban growth presents an important opportunity, it also poses challenges to the implementation of an ambitious urban development agenda that seeks to make cities and human settlements inclusive, safe, resilient and sustainable; an objective defined by Sustainable Development Goal (SDG) 11 (UN, 2015).

In order to address the challenge of climate change the European Union has launched the European Green Deal (EGD) aiming to reduce at least its 50% of Greenhouse Gas Emissions (GHG) by 2030 compared with 1990 levels, and giving a lead as a first continent to become carbon neutral by 2050 (European Commission [EC], 2019). One of the pillars of the planned transformation towards a sustainable future within the EGD is the element of "accelerating the shift to sustainable and smart mobility", which overarching goal is to reduce 90% of transport emissions by 2050 compared with 1990 levels. (EC, 2019). Moreover, it also promotes going digital, projecting that automated and connected multimodal mobility, as well as smart traffic management systems will play an increasing role, making transport more efficient and cleaner, and smart applications and "Mobility as a Service" (MaaS) (ERTICO – ITS Europe, 2019) solutions will be developed.

The transport sector has contributed to around 14 percent of global GHG emissions on average over the last decade, with road transport – a sector that continues to have strong growth – primarily responsible (United Nations Environment Programme [UNEP], 2020). In the EU, there has been a steady overall reduction in greenhouse gas (GHG) emissions in recent years, however, the transport sector has not followed this general trend and, as a result, its relative contribution to overall GHG emissions in Europe has become more significant. In 2017, transport sector produced 23% of Europe's GHG emissions and 72% of them came from road transport (Figure 1). Therefore, although action is needed in all sectors if the EU is to meet emission reduction targets, this is particularly important in the transport sector which remains one of the key challenges to decarbonising the economy (European Environment Agency [EEA], 2020).

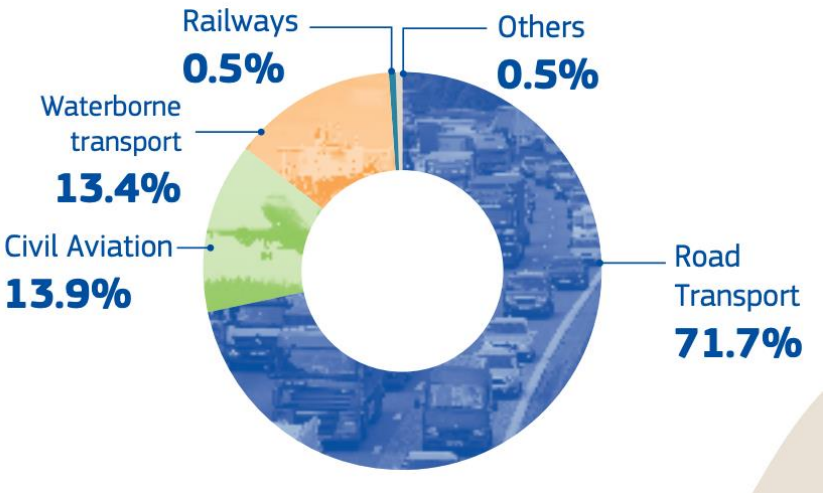

Figure 1. Share of Greenhouse Gas Emissions in the European transport sector (2017). Source: EC, 2019.

In order to meet the required goals and head towards more sustainable, clean, silent and liveable cities significant changes are needed especially in the urban mobility systems, accounting for 40% of all CO_2 emissions of road transport and up to 70% of other pollutants from transport (EC, 2021). In fact, the transformation of mobility systems is already undergoing, basically impacted by the threats of climate change, and ongoing digitalisation and its current acceleration during the pandemic. The complex system of mobility interlinks with other strategic and diverse areas also already under transformation like; new technologies, energy, placemaking, servitisation, working life etc. Therefore, there are a lot of arising requirements and opportunities for innovation which can shape a city's environment.

As stated in EIT Urban Mobility (2021); the main challenges that urban mobility is facing are climate change, urban health, social inclusion and cohesion, competitive economy, new models of governance and innovation technology (Figure 2).

Figure 2. Challenges & Requirements for Urban Mobility systems.
Source: EIT Urban Mobility, 2021.

Furthermore, the last technological advances in the transport and mobility sector, such as digitalization, availability of smart applications, and local digital services are radically altering mobility patterns and offer a range of mobility innovations that respond to rapid changes in lifestyles. New mobility concepts include a wide variety of elements, such as novel products, data-based processes, and services inspired by new transport dynamics e.g., Mobility as a Service (MaaS) or on-demand public transport, as well as new business models. However, many services are offered currently as an "online" mode or incorporate digital elements, and the lack of adequate digital literacy or of specific competencies/skills can be expected to generate situations of exclusion. This may exacerbate the conventional structural disadvantages due to the emergence of new systems and modes of transport that are not accessible to people with low digital sovereignty. This digital divide in mobility mainly affects citizens at risk of exclusion and encompasses different social dimensions which often accentuate situations of poverty and social injustice, such as: gender, poverty, low education level, age, reduced mobility, migrant status, ethnic minorities, etc. Till now, technology has not yet contributed to universal access and most of the new transportation technologies have more greatly benefited a specific demographic: urban, young, tech-savvy, and usually well-off (Vandycke, 2018).

Therefore, commuting and mobility produces new challenges for the political agendas and the development of the public and private sectors, with a strong presence of information and communication technologies. In this context, there are synergies appearing that can produce social exclusion in the field of mobility and the use of new technologies. More and more studies are examining the digital divide and transport poverty in greater depth; even so, the growing relationship between mobility and the use of new technologies, as well as the tendencies of governments and companies to move towards digitization, require further studies that relate the two concepts and give a precise overview of social exclusion and situations of inequality that are being generated in this area.

Bearing that in mind, this work will analyse the digital gap related to the innovative transport products and services in the mobility ecosystem of Barcelona Metropolitan Area. This research has been done in the framework of H2020 DIGNITY project (DIGNITY, 2020), which seeks to give answers for the highlighted problematics. The project is a backbone for the analysis carried out in this study, especially focused on Barcelona, one of the pilot cities within the initiative. In the first part of the study, a review of relevant literature regarding sustainable mobility, transport related disadvantages, mobility poverty and digital exclusion will be conducted in order to find gaps and weak points of research in those fields. Then, based on those insights and reinforced by the theoretical concepts relevant in the studied domain, a survey data will be analysed, with a goal to find tendencies and differences in access, perceptions and attitudes towards different technologies as well as in the daily mobility patterns among the population.

1.1. The DIGNITY project

Digital mobility services should be based on and promote inclusivity, taking into account the attitudes, skills and capabilities of users that might not fully benefit from mobility digital services. Understanding the aspects related to the integration of inclusiveness in digital mobility services is one of the research objectives of the DIGNITY project (DIGNITY - DIGital traNsport In and for society, 2020) a European initiative funded as part of the European Union's Horizon 2020 research and innovation programme. The overarching objective of DIGNITY is to foster a sustainable, integrated, and user-friendly digital travel ecosystem that improves accessibility, social inclusion, travel experiences, and daily life of all inhabitants. DIGNITY aims to contribute to the development of a transport system that is inclusive, digital, and interconnected, and that meets the needs of all residents. The project has fourteen partners from six European countries and selected four pilot studies in five EU partners' countries (Spain, Italy, Belgium, the Netherlands, and Germany) for their innovative proposals in sustainable and inclusive mobility solutions.

The project thoroughly examines the digital mobility ecosystem to understand the full range of factors that could lead to disparities in the adoption of digitized solutions for different user groups in Europe. Its aim is to propose solutions for an inclusive digital transport system that takes into account the needs and characteristics of all sectors of society, with particular attention to digitally excluded groups. The idea is to support public and private mobility providers in their conception of general digital products or services, to make these accessible and usable by the largest possible number of people, regardless of their income, location, social or health situation, or age. The challenges of digitisation are analysed from the perspective of users and suppliers, through a new approach that connects users' experiences with the available products and services, while analysing how transport policies and strategies can support a more inclusive digital transition. Further, results from DIGNITY should help policymakers formulate long-term strategies that promote innovation in transportation while responding to global social, demographic, and economic changes, including the challenges of poverty and migration. Four case studies on implementing inclusive mobility solutions have been selected as pilot projects, based on their ambition of working towards these types of solutions: Ancona (Italy); Barcelona (Spain); Flanders (Belgium), and Tilburg (the Netherlands). Table 1 presents the scheme outlined for the realisation of the project, with all the phases and partners responsible for leading each of them, as well as pilot cities where activities defined within the methodology developed will be applied.

Table 1. The DIGNITY project framework. Source: DIGNITY, 2021.

Phases	Understanding the digital gap	Building the Dignity Approach	Pilot demonstrations	Evaluation & Validation	Dissemination & Exploitation	Coordination & Management
Leading partner	UNIVERSITY OF CAMBRIDGE Engineering Design Centre	Breda University OF APPLIED SCIENCES	MOBIEL21 SETTING PEOPLE IN MOTION	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH	isinnova	
Pilot cities	-	Tilburg	Flanders	Barcelona	Ancona	

This work was carried out as part of the DIGNITY project and reports on research from one of these pilots, the one conducted in the AMB. The study based in Barcelona - a metropolis that is at the forefront in smart urban transformation – focuses on the co-design of inclusive digital last-mile services in industrial areas, paying particular attention to the needs of women, elderly and groups with lower education levels.

1.2. Barcelona Metropolitan Area

The Barcelona Metropolitan Area (Àrea Metropolitana de Barcelona – AMB), with a surface of 636 km^2 and more than 3,2 million people, is one of the largest metropolitan territories in Europe formed by 36 municipalities (Figure 3) (AMB, 2021). In fact, the actual metropolitan region, encompasses more municipalities and frames the daily lives of five million people. It is a network of dynamic neighbourhoods and cities shaped by diverse communities settled within high ecological value environments and a global economic activity space. However, due to transition processes developed over the last decade the metropolis faces some structural challenges: new socio-cultural and gender relations, migration, climate emergency and economic and technological transformations. (IERMB, 2020).

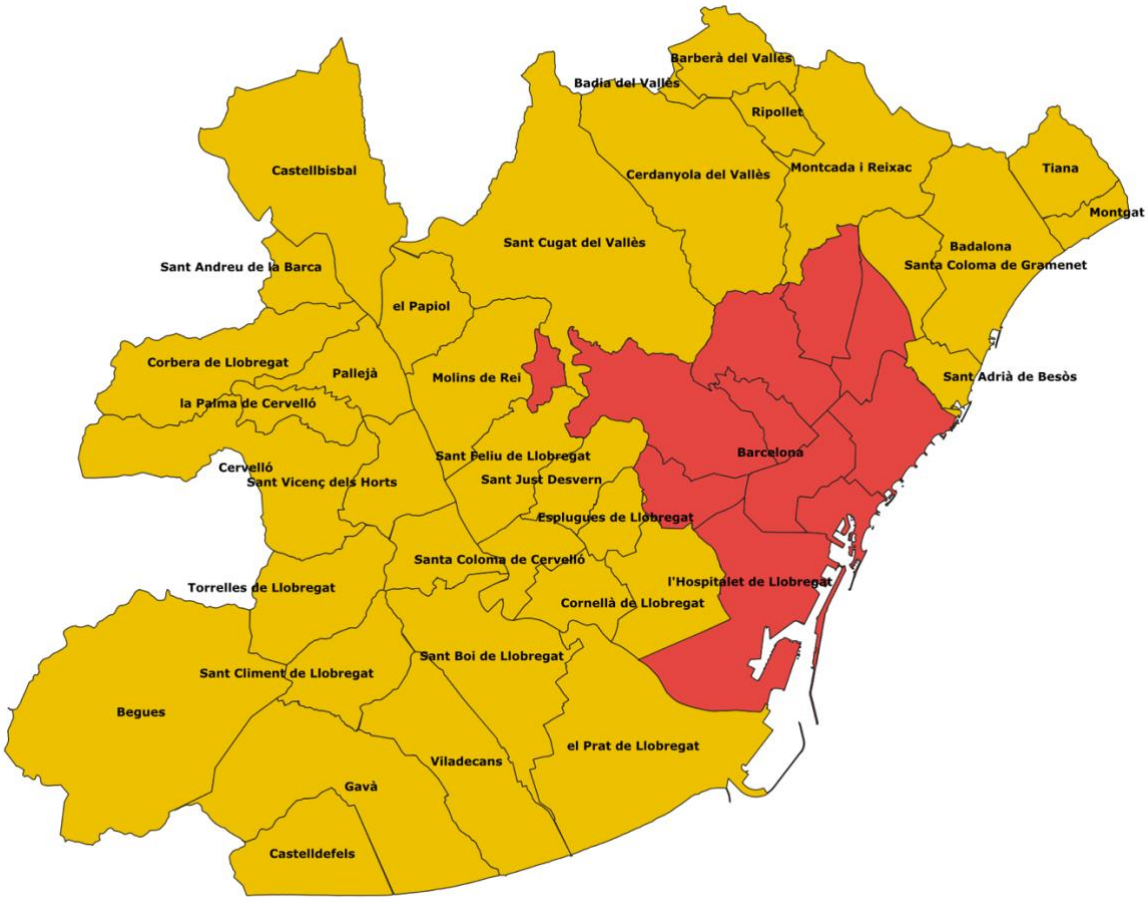

Figure 3. Barcelona Metropolitan Area. Source: ICGC, own elaboration.

In order to address these issues a powerful public policy agenda is needed and in the last years some plans have been already put in place. In regard to the technological transformation, the "Plan Barcelona Digital City: Transition towards Technological Sovereignty" (Pla Barcelona Ciutat Digital: Transició cap a la Sobirania Tecnològica) aims to solve the challenges of the city and the people through a more democratic use of technology. Moreover, the objective is to think Beyond Smart City ("Més enllà de la Smart City") and to ensure that technology and digital innovation act as facilitators in the pursuit of efficient, equitable public policies aimed at better meeting the needs of citizens to shape higher quality public services (Ajuntament de Barcelona, 2016). Such a longer-term digital plan for a city, where everyone could have access to information technologies is crucial, especially given that the COVID-19 pandemic has generated an unprecedented technological leap that has pushed to move towards a new urban model (Ajuntament de Barcelona, 2021).

In terms of mobility, the presence of inequalities and precariousness over the last decade affects the conditions and practices in the AMB. The study of poverty, social exclusion or inequalities from the point of view of mobility and transport are subjects which in the close Barcelona environment, have not been a notable line of study in recent years by those involved in its operation, organisation or planning. Consequently, there is still very little literature, data and policies concerning those concepts. Therefore, making this reality visible should allow to progressively introduce this still incipient dimensions into transport and mobility realm. On this basis, some challenges for the future are posed (IERMB, 2020):

- to advance the tools of knowledge (better parameters and indicators) and to introduce qualitative approximations;
- to strengthen the bid to break the binomial income-mobility;
- to place the inclusive policies of mobility in a cross-section between social rights and sustainable urbanism

With that perspective, Barcelona is currently working to improve urban mobility with traffic management platforms, applications to facilitate mobility, the introduction of electric vehicles, and the management of new forms of individual and collective transport such as shared vehicles and future self-driving. However, it is necessary to guarantee that the different modes of transport, as well as the digital tools that are being generated around them are accessible and non-discriminatory (Barcelona Urban Mobility Plan 2024 - Pla de Mobilitat Urbana 2024) (Ajuntament de Barcelona, 2021). It is necessary to establish proposals for reducing the digital divide in transport in order to build a fairer, more resilient and inclusive city, under the guidelines of Agenda 2030 (UN, 2015). For digital inclusion it is also essential to ensure that access to the online solutions and emerging technologies is effective and balanced in the territory and in the population in all its diversity. In this regard, the challenges of digitising mobility must be analysed from the perspective of users and suppliers while also analysing how transport policies and strategies can support a more inclusive digital transition (Ajuntament de Barcelona, 2021).

2. Objectives and scope

The main objective of this work is to analyse the digital divide related to the new mobility solutions in the region of Barcelona Metropolitan Area. What is more, the project aim is to advance on the understanding of the factors leading to the existing digital gap between mobility service provision and uptake, by different users' groups within the current digital travel ecosystem in order to mark out some policy recommendations.

To that end, this work builds on a mixed-method approach, combining a literature review and a quantitative survey data analysis, which marks the scope and aspects to be delved into. In turn, the study tries to achieve the following derived targets:

- characterize the context of digitalisation in mobility and its potentially exclusionary effects,
- identify research gaps regarding sustainable mobility, transport related disadvantages, mobility poverty and digital exclusion,
- understand the residents' patterns of use and their attitudes towards digital technologies in daily mobility.
- evaluate differences in access to the technologies and transport services uptake,
- provide insights on the requirements that digitalisation in mobility imply for different types of users that can bring awareness among policymakers and consequently help them formulate adequate strategies to mitigate the potentially exclusionary effects of digital transformation in transport.

Finally, this study will try to point out available alternatives and good practices examples in order to discuss and outline potential recommendations for urban planners, practitioners and transport services operators/providers on the way towards sustainable, future-proof and inclusive urban mobility ecosystem.

3. Opportunities and risks of digitalisation of transport services

In this section of the work, a background regarding the actual situation of urban mobility and emerging concepts related to digitalisation of transport services is presented. Firstly, notions of digital divide and sustainable mobility are provided. Next, ideas regarding innovation and inclusive design are introduced. Finally, taking into account the analysed problematics the vulnerable to exclusion groups are identified and defined.

3.1. Digital divide

As defined in (OECD, 2001), the term digital divide refers to the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities. Furthermore, the digital divide reflects various differences among and within countries, as well as cities, neighbourhoods, and socioeconomic groups.

The digital gap is a complex and dynamic phenomenon, currently reinforcing the existing social inequality (Van Dijk, 2020). What is more, various digital divides could be identified and they are constantly changing. Van Dijk (Van Dijk, 2020) describes access to digital technology as a multilevel process which starts with a motivation and a positive attitude towards use of the media (Figure 4). Subsequently, one needs physical access to get an appropriate device or/and an Internet connection. However, the case doesn't stop here since it is required to develop some digital skills in order to make proper use of them. If an individual has acquired due capabilities, he/she can use any application, digital product or service that suits him/her. Finally, it is expected that they can make benefit out of that use; the principal objective in this process.

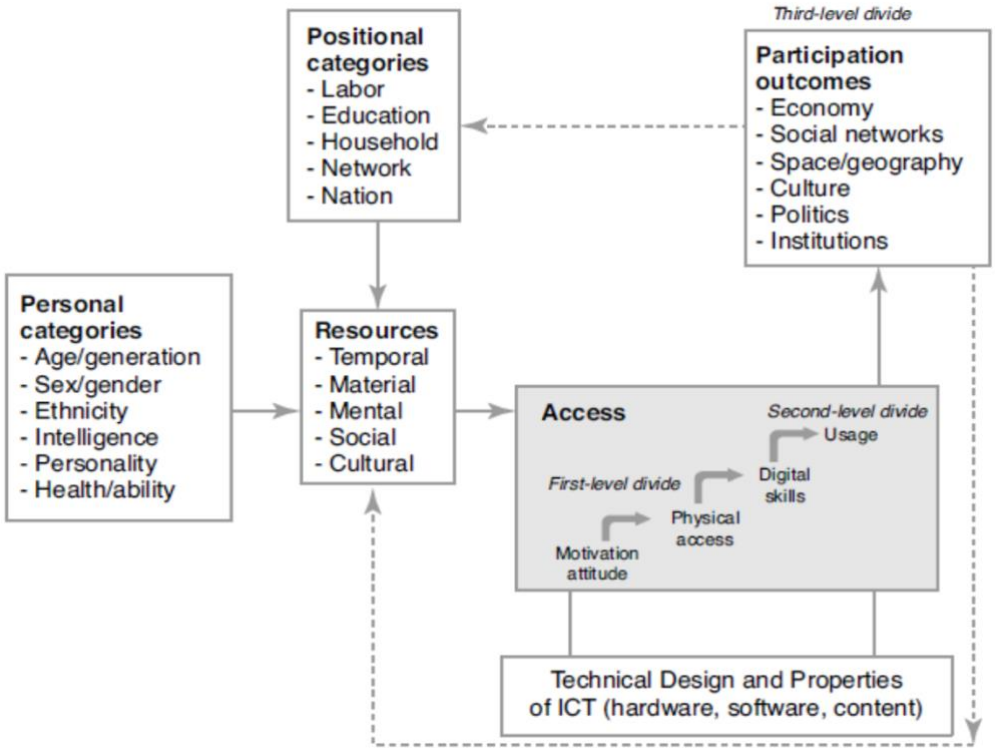

Figure 4. A causal model of Resource and Appropriation Theory of the Digital Divide. Source: Van Dijk, 2020.

Furthermore, the study author identifies the categories of age, gender, ethnicity, labour, education and nation or region as the most important factors in explaining digital inequality along this process, since their resources; material (income), mental (knowledge), social (relationships), and cultural capital are not equal.

In relation to mobility, the digital divide, inequalities and exclusion situations arise from technological and social developments in ICT. Specifically, they are triggered by the emergence of new forms of mobility (micromobility, new forms of public transport) and the way in which it is managed, both by the action of the administration and by the companies that design these technologies. Also, planning and management of transport mobility, increasingly based on constant technological advances, often fails to take into account the need of the user from a perspective of inclusion and social justice. In fact, some disadvantages are exacerbated by the emergence of these new systems and modes of transport that are often managed digitally and thus not accessible to people with low sovereignty in this area. Paradoxically, those who could benefit the most from these new solutions are at risk of being left behind due to their lower levels of digital literacy, because they are not affordable for them or not accessible (Kuttler & Moraglio, 2020). In large part, they are aimed at general public with digital skills and available in urban areas with a wide range of mobility. Consequently, this gap mainly affects groups of vulnerable citizens and encompasses various social dimensions.

3.2. Mobility poverty

From a social point of view, or in terms of what is understood by transport poverty or inequality in the study of people's living conditions, the concept has been studied in a segmented manner over the last few years, and various terms have been used to designate particularities with respect to this general situation, like mobility poverty, inequality in access, lower affordability, exposure to externalities, among others (IERMB, 2020). Some authors (Lucas et al., 2016) suggest that a person suffers from transport inequality in meeting their daily activities when they endure at least one of the following conditions:

- Lack of viable transport options according to the physical conditions and capabilities;
- an individual cannot access destinations where he/she can fulfil daily activity needs;
- the associated expense leaves the household with residual income below the official poverty line;
- the travel time is excessive leading to time poverty or social isolation;
- the current transport conditions are unsafe, unhealthy or considered dangerous.

This definition implicitly incorporates a close relationship between the personal environment characteristics of the people who suffer this inequality, and those that are expressed by their surroundings or by the design of the transport network. Thus, several pre-existing conditions are identified the that could accentuate these situations: low income, unemployment, poor health, unsuitable housing conditions or lower level of education. In any case, it should be taken into account that people who suffer severe poverty or are at risk of poverty do not necessarily experience any of the above disadvantages (IERMB, 2020).

In (Kuttler & Moraglio, 2020) transport poverty is defined as the combination of experienced social disadvantage and transport-related disadvantage, which can lead to social exclusion and enhance both transport and social disadvantages anew. Again, mobility poverty can be determined following the conditions; a) availability and accessibility of transport, b) locations and opportunities, c) affordability of transport, d) available time budget, and e) adequacy of travel options (Figure 5). Moreover, exposure to transport externalities – the environmental impacts and accidents generated by transport activities, such as air quality, emissions, urban congestion or noise – is another risk factor which could work to a person disadvantage while unequally distributed. Experiencing only one of those conditions could lead to a person suffering from transport poverty.

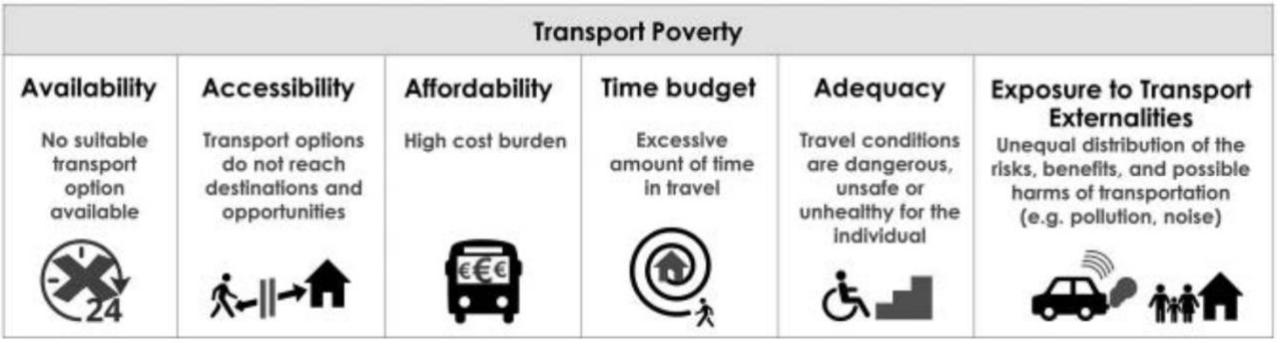

Figure 5. Transport poverty. Source: Kuttler & Moraglio, 2020.

Furthermore, some of the aforementioned conditions could play a more important role than others, depending on the different needs of each of the social groups. Therefore, the requirements for each vulnerable group have to be analysed and these basic transport necessities appropriately addressed in order to create inclusive mobility opportunities for vulnerable individuals (Kuttler & Moraglio, 2020). Residents who belong to one (or more) of these groups are seen to have a higher risk of social exclusion in terms of mobility. What is more, fieldwork, focus groups debates and end users confirm that in reality, everyone belongs to more than one group that experience mobility-related disadvantages (Kuttler & Moraglio, 2020). Therefore, mobility poverty should rather be considered as a multi-layered phenomenon. Nevertheless, in the academic debate, a focus tends to be on singular aspects, although important from an analytical perspective.

The gender dimension is particularly related to exclusion in terms of mobility and clearly impacts on greater job insecurity, exacerbated by the sexual division of labour. Gender differences in mobility are at risk of being exacerbated by the introduction of digital technologies into mobility services. In fact, transport and mobility are an area that has a huge impact on women, especially users who are part of different cultural backgrounds and vulnerable groups. For these reasons, the importance of integrating a gender perspective into the analysis and design of mobility plans to avoid barriers and gender inequalities is widely recognised. Importantly, women are not “typical” vulnerable group; they make up about half of European population and therefore it is necessary to understand gender mobility trends and characteristics. However, gender gap in mobility lacks literature and study and there is a need for systematic statistics on this topic (Kuttler & Moraglio, 2020).

Furthermore, it is also necessary to understand mobility poverty in a dynamic relationship with high mobility. Due to technological advances in communication and transport, constantly growing availability of options for travelling and interaction increase the mobility needs which are interrelated with social, spatial and technological change. A person's mobility patterns cannot be understood without understanding one’s use of communication tools. The use of communication tools may replace, supplement or create new needs of mobility or conditions of immobility respectively. The interactions between virtual and physical mobility may differ from person to person, with very different outcomes. Cognitive appropriation and understanding of mobility options is also very important. As described in (Kuttler & Moraglio, 2020) one group could be fully aware of, for example, the bicycle’s system, asking further for its improvement, and on the other hand, others can find it difficult to shift from private car to bus, arguing that they find it difficult to understand how public transport works. Therefore, new situations of transport disadvantages may occur or even be aggravated due to policies and markets focusing on the needs of the highly mobile and the most profitable transport connections. (Kuttler & Moraglio, 2020).

Ferreira and Bertolini (2017) mention literature sources that points out lacking knowledge about low mobility and localism which hampers policy-makers understanding on how to design strategies which are not oriented towards high mobility. Similarly, plans including only advanced, digitalised, high-tech mobility solutions do not cover the needs of the not-connected collectives. Therefore, in order to design inclusive policies for different transport users, policy-makers should be open to listen them and get to know their requirements.

The same study finishes concluding that transport researchers are too exclusively focusing their attention on making transport systems resistant to threats and disruptions. The authors argue that such an approach is limiting and restrains the progress to business-as-usual advancements, while preserving the existing problems related to transport unsustainability and its excessive costs. Consequently, the main focus it to create highly complex mobility systems, resistant to disruptions. However, increasing their complexity even further is not only costly, but can also be environmentally harmful and difficult to sustain. (Ferreira & Bertolini, 2017).

3.3. Sustainable mobility and Smart revolution

The concept of sustainable mobility as such derives from the broader idea of sustainable development - defined as one that "meets the needs of the present without compromising the ability of future generations to meet their own needs" - in the Brundtland Report (World Commission on Environment and Development [WCED], 1987). Then, the term sustainable mobility was firstly used later, and its principal objective is associated to sustainable transport which aim is to guarantee that transport systems meet society's economic, social and environmental needs whilst minimising their undesirable impacts on the economy, society and the environment (Gallo & Marinelli, 2020). There are different definitions for the wide concept of sustainable mobility and great part of them stress out that the three dimensions – economic, environmental and social, a so-called triple bottom line – have to be taken into account while implementing it (Foltýnová et al., 2020). Although in EC (2020) it is stated that augmenting significantly the uptake of clean vehicles and alternative fuels is crucial, the strategies for sustainable mobility cannot be limited only to creating and using less polluting transport systems (Gallo & Marinelli, 2020).

In order to meet the goals of the Paris Agreement (UN, 2015) and follow the guidelines of Agenda 2030 (UN, 2015) the transport sector needs to undergo some fundamental changes. In Europe, transport produces a quarter of the EU's greenhouse gas emissions and this proportion keep on growing since demand increase. Therefore, one of the goals of the European Green Deal is to reduce 90% of these emissions by 2050 (EC, 2019). Apart from that, transport activities give rise to the negative environmental and health costs of transport, also known as externalities. Cities and their residents are the ones that are exposed the most to the pollution. In order to address air quality, emissions, urban congestion and noise, a combination of measures is needed, including improving public transport and promoting active modes of transport such as walking and cycling. As described in (EC, 2020) moving to more sustainable transport means to put users first and to provide them with more affordable, accessible, healthier and cleaner alternatives.

On the way towards achieving the European Green Deal objectives, the digital technology can work as enabler. As argued in EC (2021), the uptake of digital solutions and the use of data can help in transition to a climate neutral, circular and more resilient economy. Videoconferences that replace business travels and other digital technologies that allow greener processes in different areas, such as agriculture, energy, buildings, industry or city planning and services, give wide range of opportunities which can contribute to Europe's targets regarding emissions reduction. However, ICTs and its infrastructures have to become more energy and resource efficient, what can be achieved thanks to innovation and ambitious eco-standards. Consequently, new digital products and services with lower environmental footprint and higher energy and material efficiency could be provided (EC, 2021).

Several opportunities of digital transformation are identified for the mobility ecosystem. Reduction of traffic accidents, enhancing quality-of-life, and improving the efficiency of transportation systems, including concerning their environmental footprint can be achieved thanks to a great potential of digital solutions for connected and automated mobility (EC, 2021).

Actually, in the transport and mobility sector, recent technological developments such as digitalisation, smart applications and locally-based digital services, are already altering mobility patterns, offering a wide range of novel solutions that respond to rapid changes in lifestyles. These new mobility concepts with a great potential to improve users' transportation options and experiences include a wide variety of new products and services such as Mobility as a Service (MaaS), public transport on demand, shared mobility etc. (EIT Urban Mobility, 2020).

The concept of MaaS has gained a lot of interest in the transport sector both from the public and private sector in the last years. Various studies have described this notion, however there is no universal definition of this idea. ERTICO – ITS Europe (2019) defines it as; "a user-centric, intelligent mobility management and distribution system, in which an integrator brings together offerings of multiple mobility service providers, and provides end-users access to them through a digital interface, allowing them to seamlessly plan and pay for mobility." Figure 6 illustrates the concept and its main elements.

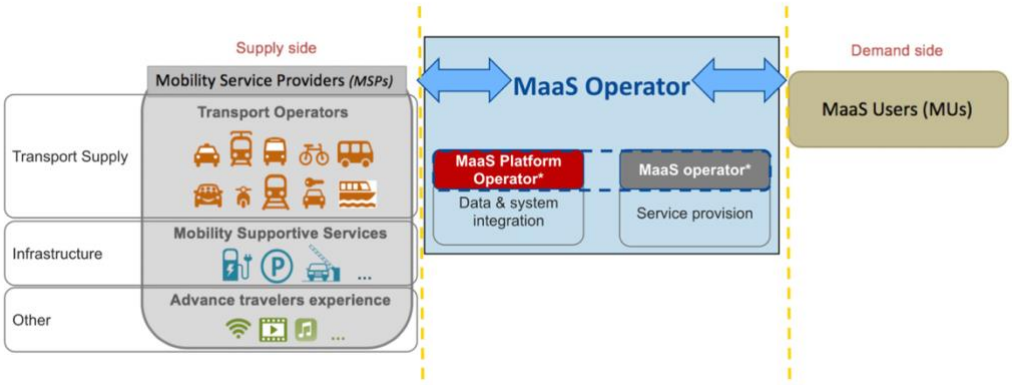

Figure 6. MaaS concept. Source: ERTICO - ITS Europe, 2019.

Furthermore, multimodal transport that combines various transport modes throughout a journey, digital technologies enabling automated mobility and smart traffic management systems are also identified as opportunities to improve efficiency across the whole transport system and increase the use of sustainable transport modes while also making transport cleaner (EC, 2019).

Another emerging concept that can be observed in the transportation politics for the future is the idea of Seamless Integrated Mobility Systems (SIMSystem), which marks a clear trend towards multimodal transport urban systems (World Economic Forum, 2020). These schemes try to combine different modes of transport in order to exploit the advantages of each one. If it becomes seamless, it can bring competitive advantages compared to personal car usage. "Seamless means efficient in planning the journey (from getting the information necessary to make our travel choices to booking services when needed), in travelling (with comfortable mobility services and smooth interchange between them) and in paying for it (with integrated ticketing)" (EIT Urban Mobility, 2021). What is more, the intermodal system can be tailored to the users' needs and wishes who can choose at any moment the travel combination following different criteria (i.e., the fastest, the cheapest etc.) It is stated that when efficient, intermodal solutions can become cheaper and consequently more affordable and inclusive. Nevertheless, development of such an integrated system needs a lot of innovation and currently the concept and its emerging implementations are still in the early phase of advancement. (EIT, 2020).

These novel mobility concepts can offer new opportunities for the transition to healthier and more sustainable modes of mobility. However, without a strategy attached to the inclusion of these technologies, it is not only not helping to promote universal access to transport, but it can also make the digital divide in transport more acute and reinforce the poverty related to mobility. In fact, most of the new transport technologies are benefiting mainly specific demographics: urban, young, knowledgeable and usually well-off. What is more, some groups in society do not fully benefit from the opportunities of digitalisation and situations of inequality in transport are widespread at global level. Various groups have been identified as being particularly vulnerable to digital mobility exclusion (Loos et al., 2020; Groth, 2019), and being more likely to be excluded from many services and facilities (Durand & Zijlstra, 2020), including older people, those with low levels of education, people with low income, rural inhabitants, migrants, disabled people and women.

From this perspective, and taking into account vulnerable groups' needs and barriers in digital mobility solutions up-take is crucial and indispensable to avoid expanding the digital divide and consequent mobility poverty and social exclusion. Such a sophisticated and technologically advanced solutions for sure can bring a lot of benefits to the society and drive cities into more sustainable and liveable future, but we have to bear in mind that not all individuals are connected to the Internet continuously and some collectives, even if they have access to the technology they don't know how to use it or don't feel comfortable doing it, and consequently can't take advantage of new innovative solutions in mobility, as does the majority.

Therefore, reducing the digital gap is really important, especially with regard to changes for future and priorities of policies to be implemented. In this sense, in the envisaged multimodal mobility system which would facilitates opportunities through digital services, equal access and potential to use them is crucial (Groth, 2019).

3.4. Innovation

Although innovation is a broad notion and complex concept to define, it can be described as a new product or process that has been improved by applying new processes, techniques or establishing successful ideas to create new value, and has been made available to potential users. However, currently innovation is too strictly and incorrectly associated with technological and digital-driven ideas and solutions, whereas innovation should be considered as and associated to the same extent to culture, leadership, financing, governance and people. It also varies widely between sectors and actors involved and their diverse nature. While in the private sector it focuses on enhancing competitiveness in new markets, in the case of the public sector, innovation seeks to create value and impact by addressing citizens' basic needs and improving the quality and efficiency of public services (OECD, 2019).

As stated in (OECD, 2019) cities that ensure the production, free flow, and utilisation of data and knowledge across the public sector are better positioned to improve their innovation capacity. Interestingly, the survey results presented in the study shows that cities collect more data on transport area (64%), law enforcement (57%) and land use/zoning (51%), while data on social welfare and inclusion (32%) are less extensive. It resonates in digital divide related to mobility where the data are still limited or not available.

Furthermore, although the requirements of more vulnerable collectives and the necessity to offer more differentiated transport services are gaining attention, and some stakeholders are aware of diverse social groups' needs, there are some obstructions that hamper the application of innovative policies. Firstly, it is the mind-set of many stakeholders who are still focused on users' physical impediment or low income as the main limitation in accessing public transport. However, there still remains concept of transport service addressed to physically healthy, fully aware of the service user who is fully able to take advantage of it. As a result, many transport providers approach their service with a product-driven attitude, without caring enough about customer needs. They also lack knowledge, resources and incentives to pursue innovation. Another important issue are budget constraints which push public transport suppliers to reduce services and keep common attitude. As a consequence, luck of supply by traditional transport operators leaves plenty of opportunities to develop innovative projects. Nevertheless, too often new transport solutions such as ride-hailing or bike-sharing address the needs of "strong" users, those with digital skills, great cognitive abilities, and ownig a credit card (Kuttler & Moraglio, 2020).

In order to leverage the full potential of innovation and promote policies and practices helping cities become places with shared prosperity, well-being and equal opportunities for all members of society, in 2019, the OECD Champions Mayors for Inclusive Growth Initiative created the Athens Road Map: Innovation for Inclusive Growth in Cities. The document collects several interesting strategies for social, technological and public sector innovation. It is highlighted that implementing the Road Map implies working together with communities, citizens, non-governmental organizations, business, academia, stakeholders and other levels of government in those three main areas (OECD, 2019).

Regarding social innovation the strategies recommendations include promotion of new ways to extend and deliver existing local public services and develop new relevant services that reach underserved areas of cities. Next, responding to the needs of new local businesses by developing targeted local employment policies that connect low-skilled individuals and disadvantaged groups is mentioned (OECD, 2019).

When it comes to technological and digital innovation the advises include; "exploring how to effectively embrace and plan for sustainable smart urban solutions across different sectors but also, to expand service delivery to underserved communities, leveraging digitalisation to deliver more efficient, sustainable, affordable and inclusive local public services and urban environments, and ensuring that new technology in public transport (e.g., app-based ride services and shared mobility) is both inclusive and sustainable, including to those with reduced mobility and those in underserved communities" (OECD, 2019).

3.5. Pandemic impact

The COVID-19 pandemic and restrictions it has involved affected urban mobility and citizens daily patterns of movement. Although those changes have been shaped in different ways among cities, some general trends can be outlined (EIT Urban Mobility, 2021):

- transition to private vehicles use,
- reduced use of public transport,
- decreased use of shared mobility.

What is more, reduced amount of mobility due to increasing share of people working from home and travel restrictions have reduced the environmental impact generated before, seeing NO_2, O_3 and PM2.5 concentrations in urban and rural areas decreased. Furthermore, the economic crisis provoked by the pandemic and consequent job losses affected various economic sectors and social groups differently. Small businesses, restaurants, retail, personal services, and arts and culture have been affected the most by closures while the others were able to telecommute. Therefore, it made even more visible the problematic of digital divide since low-skilled employees tend to work in the most affected sectors while high-income workers had problem to work from home. (EIT Urban Mobility, 2021).

Also, since the start of the pandemic shifts in reasons to select a transport mode have been observed; whilst before the health crisis the key reason for selecting a mode of transport was the time spent to destination, now the key reason is the risk of infection (McKinsey & Company, 2020). As a consequence, it can be observed that public transport ridership has decreased while private modes use has augmented (private car, private bike, walking). However, public transport may be crucial in maintaining active lifestyles. It is also very important as a support for older people's quality of life, improving their sense of freedom and autonomy guaranteeing access to basic services and decreasing social isolation (Kuttler & Moraglio, 2020).

Therefore, due to the changes in public transport demand and related fear to use it in the future there is a need to make public transport attractive again. The most prompted solutions seem to be flexible ticketing and digitalisation of services, which will play a major role in revitalising mass transit. Thereby, transport multimodality with more mobility options, apart from private vehicles and public transport, is being promoted (EIT Urban Mobility, 2020). In this context, integration of different transport modes powered by the need to reorganize public transit more flexibly and consumers' shift towards micro mobility brings cities opportunity for implementation of Mobility as a Service (MaaS) platform. In that sense, inclusive design of ticketing platforms, facilitating travel information and uptake of new digital mobility solutions is crucial in order to achieve a multimodal transport system that will leave no one behind. Therefore, new forms of public-private cooperation and partnerships are needed that would favour formation of new business models and involvement of start-ups in the mobility market to cover unserved needs (POLIS, 2019).

Furthermore, report issued by EIT Urban Mobility (2021) makes an overview of the measures implemented by different cities during the pandemic and tries to recollect the best practices that helped to address the challenges aggravated by the health crisis. The authors talk about the very important role of innovation as enabler for transition towards sustainable mobility. It is also stated that collaboration and experience sharing is very important to facilitate easier and faster decision making against the future problems and difficulties. Nevertheless, the study outlined that the actions of cities have been basically based on individual experiences and they differ substantially even between countries. The good side is that sharing of ideas and solutions for urban mobility in context of the pandemic management has been increasingly supported by a lot of resources, where successful cases, reports, research has been shared creating a sound knowledge base that cities can benefit from. In the perspective of actual cities practices and priorities which are focused on short-term measures, these sources will be valuable assets for future decision making towards sustainable mobility systems, which should be based on best practices and taking into account success factors for implementing them.

In the context of digital inclusion in mobility, cities experiences and lessons learned should serve as a guide to implement politics that will bear in mind requirements of the vulnerable-to-exclusion groups, facilitating uptake of new digital mobility solutions and providing non-digital alternatives for those suffering digital poverty. In the same sense, the set of effective measures aimed at vulnerable collectives that have eased their mobility during pandemic, should be highlighted and further analysed in order to derive from them for future inclusive policies regarding digital mobility.

Finally, the COVID-19 pandemic has forced cities to implement and develop sustainable mobility politics and measures. In order to create adequate strategies, working processes need collaboration for innovation in mobility. Nevertheless, it was observed that best conditions for participative environment created in live meetings, in-person workshops and using different tools and methods are harder to provide as social distancing and contagion risk is important factor that hamper such events, especially for groups like elderly people, which are the ones that suffers digital exclusion the most. (EIT Urban Mobility, 2020). Therefore, citizen participation and collaboration of diverse stakeholders in order to create trust during the process of urban mobility planning and innovation is impeded and could lead to development of solutions that would aggravate the problem of digital poverty in mobility amongst vulnerable-to-exclusion groups.

3.6. Inclusive Design

Policy makers and mobility services providers have to bear in mind that every design decision has the potential to include or exclude the end-user since every individual is characterised by its diverse capabilities, needs and aspirations. Although digital solutions are addressed all their target users, usually they meet requirements of limited part of the society. Therefore, users from outside of the target groups, such as often-underrepresented demographics like users with reduced mobility, migrants etc. should be taken into consideration. In that sense, inclusive design seeks to contribute to better understanding of users' diversity in order to allow to make better informed decisions, and thus to include as many people as possible (University of Cambridge, n.d.).

In the context of technologies and digitalisation, specific needs of different demographics such as users with physical impairments, elderly or residents of peripheral areas are widely missed out. Thus, it is crucial for new mobility solutions providers to integrate digital accessibility in their products. As described by Jin (2020), designing for accessibility means being inclusive and aware of the needs of users. Understanding their various perspectives is crucial to create more accessible and inclusive products. It becomes even more important in situations of multiple barriers/disadvantages, than an individual can experience, for instance a 65-year-old or more retired woman living in a suburban zone with physical disabilities.

Furthermore, although there are multiple inclusive mobility solutions that could benefit vulnerable groups, a great part of them is available in developed and urbanised areas where a specific infrastructure required by most of these mobility concepts is in place (Kuttler & Moraglio, 2020). Thus, it's crucial to integrate inclusive design into urban planning and design mobility systems for greater parts of the society. It not only makes it possible for services providers reach new markets, but also to create products and services that meet necessities of persons from diverse backgrounds. Therefore, designers, engineers, policymakers and technology providers should slow down and reflect on all collectives' requirements and impediments in order to foster future accessibility in mobility contexts (Jin, 2020).

3.7. Vulnerable to exclusion groups

Finally, based on the research done within the DIGNITY project and an examination of the literature (Durand & Zijlstra, 2020; Hoeke et al. 2020) seven groups that are more likely to be affected by digital mobility exclusion have been identified:

- Older people: This group has lower levels of technology use (EC, 2020) and digital skills and may also experience mobility issues, capability loss and psychological constraints (Loos et al., 2020).

- Women: Although many European countries report little gender gap in digital technology use, there are still noticeable gaps in some countries (OECD, 2018). In addition, women often have lower financial resources. Inherent biases and differences in attitudes towards technology also play a part (OCED, 2018). Women also often have different transport needs and patterns (Littman, 2021).

- People with low levels of education: Education attainment has been found to be highly correlated with a range of digital skills (Groth, 2019).

- People with low levels of income: Low income affects access to and ownership of technology devices, as well as car ownership and transport patterns (Arsenio et al., 2016; Martens & Golub, 2018).

- Inhabitants of rural areas: Transport provision and needs differ between rural and urban areas. Rural areas also often lack communication infrastructure (e.g., wireless communications services). (Kuttler & Moraglio, 2020).

- Migrants: This group may experience barriers to technology and transport use due to language and culture. Some may also have different transport needs. (United Nations Human Settlements Programme, 2020).

- People with disabilities: This group often experiences difficulties with transport use and may require additional information and assistance when travelling (Di Ciommo & Shiftan, 2017; Martens, 2018). They may have difficulty with certain interfaces.

There are many factors contributing to people in these groups being excluded from using digital mobility services. These factors include differences in digital capabilities, digital access and transport needs.

4. Methodology

As indicated before, this project applies a mixed-method approach, combining a literature review and a quantitative survey data analysis. In this part of the work, description of search for the relevant bibliography sources will be provided. Next, the methodological scheme for the analysis will be explained, followed by description of process for data analysis.

4.1. Literature review

The concepts presented in the previous chapter have been described following a search for relevant sources and are the main result of this process.

In order to find research gaps, challenges and trends in the context of sustainable mobility, with special focus on the new digital services, inclusive design and related problematic of digital exclusion and mobility poverty, the aforementioned themes have been investigated by conducting a literature review in English, Spanish and Catalan. The review has been carried out following the steps of;

- Choice of sources;
- keyword search;
- screening and selection of papers;
- in-depth analysis of the main topics covered.

The listed sources were used:

- Scopus, Science Direct, Research Gate and MDPI site, for scientific papers,
- Google search engine for other technical and policy reports,
- specific sites for some topics or data (Ajuntament de Barcelona, AMB, IDESCAT, UNEP, United Nations, Environmental European Agency, European Commission, Eurostat, OECD, etc.).

The great part of the research done till now in those matters has been focused on each of the topics separately and there is still lack of literature addressing digital gap in mobility in particular. Therefore, based on that, the identification of relevant studies has been done by looking for papers, reports, books, and other literature sources using the following keywords assigned to each of the main themes of the study:

- general keywords (“sustainable mobility”, “digital divide”, “mobility poverty”, etc.);
- specific keywords for each topic (“digitalisation”, “social exclusion”, “innovation”, “inclusive design”, etc.), combined with “transport”, “mobility”, “digital”, “inequality”, “disadvantage” etc.

The strategy has taken into account different terminologies that authors could use and consequently synonyms, homonyms and similar terms were identified in order to ensure finding the most recent and suitable sources possible. The number of papers found initially was very small. Subsequently, starting with the very first works found, the references and citations were analysed thoroughly and included in the bibliography when considered valid. Finally, the literature incorporated in this study is formed by the sources found initially using various keywords and derived relevant references tracked along the development of the work.

As a result, the literature review has allowed to identify the most adequate scheme for analysis of the survey data and interpret them properly thanks to the previous contextualisation of the main concepts relevant in the studied domain.

4.2. Analysis scheme

A scheme marked out in (Durand & Zijlstra, 2020) will be used as a framework for understanding the digital gap related to the new mobility services in the context of the AMB. The three principal areas of the analysis are digitalisation, social exclusion and mobility, along with the intersections between each of them. As shown in Figure 7, the target and core focus of this study is the central point formed by an interconnection of those main topics, namely digital inequality in transport services and its potentially exclusionary effects. Applying this approach is considered well-founded and reasonable as a great part of the past studies are mainly focused on one of those realms individually and there is still lack of scrutiny that would integrate the aforementioned themes. In addition, previous research has tended to focus on singular aspects of digital mobility exclusion, such as specific determinants that may cause and exacerbate mobility-related disadvantages of a particular vulnerable group. In contrast, this work takes a wider perspective by analysing those three interrelated areas and looking at a range of factors across the population as a whole. What is more, the fact that people at risk of exclusion typically belong to more than one specific group has to be taken into account. Therefore, it enables to consider digital exclusion and mobility poverty as a complex, interrelated and multi-layered phenomena, which requires in-depth research in order to be able to understand the nuances affecting it.

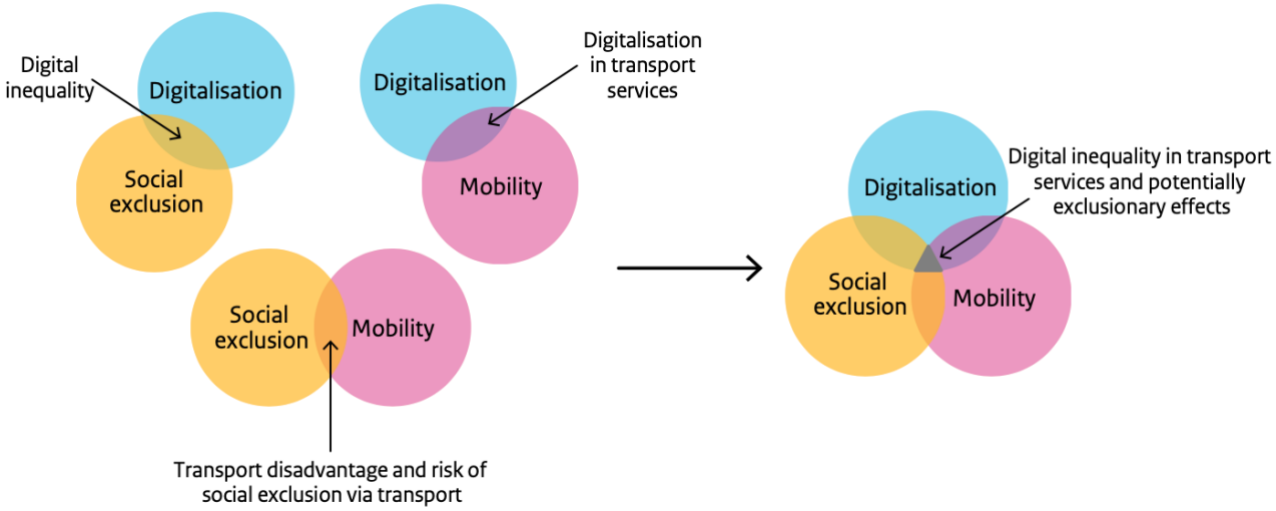

Figure 7. Project framework. Source: Durand & Zijlstra, 2020.

The intersections between each of the main areas of the analysis are extensive, however the research work already done within the DIGNITY project (DIGNITY, 2020) and available data from the user survey conducted in the AMB marks the scope and aspects to be delved into, concerning each of the topic:

- Digitalisation and Social exclusion crosscut (Digital inequality) – the main focus here is to measure level of access to the different ICTs among the population and how often do they use them.

- Digitalisation and Mobility intersection (Digitalisation in transport services) – here the research is based on attitudes towards the technologies used for mobility purposes and digital mobility services uptake.

- Social exclusion and Mobility crosscut (Transport disadvantage and risk of social exclusion via transport) – in this part of the study, daily mobility patterns of the population will be analysed with the focus on the main modes of transport used and reasons for the regular trips in the region, as well as main limitations in regular mobility experienced by the residents.

4.3. User survey in the AMB

The user survey used in this study forms part of the work done within the DIGNITY project (DIGNITY, 2020). The survey aims at improving the understanding of the patterns of use of digital technologies among the resident population in the AMB. It comes from the first phase of the initiative development called "Understanding the digital gap". The survey was conducted in Barcelona and other pilot cities. In the AMB, the fieldwork of collecting interviews was entrusted to the GESOP (Gabinet d'Estudis Socials i Opinió Pública - Cabinet of Social Studies and Public Opinion), an independent market and opinion research institute from Barcelona, who carried out a population-representative survey (n=601) conducted at the end of 2020. The survey questionnaire was adapted from a previous questionnaire examining digital exclusion (Goodman-Deane et al., 2020). It covers users' access to and use of digital technology, their digital capabilities, attitudes towards technology, current use of and attitudes to digital transport services and limitations in their regular mobility. Specifically, the survey objectives are to:

- measure level of accessibility and use of different technologies,
- measure use of digital mobility services,
- analyse characteristics that affect how a person interacts with the technologies,
- analyse daily mobility habits and its changes due to the pandemic.

Apart from that, this study provides an additional insight about the impact of the COVID-19 pandemic on the mobility patterns of the AMB residents and public opinion regarding measures for future urban planning. This info comes from the additional, last part of the questionnaire, not included in the case studies from other pilot cities of the DIGNITY project.

Regarding technical details of the survey;

- the technique used was; the computer-assisted face-to-face interviews (CAPI),
- the fieldwork was conducted during the months of November and December 2020,
- the universe of the study is population resident in the Barcelona Metropolitan Area aged 16 years old and more,
- interviews with 601 people have been carried out.
- two sub-samples have been defined; one for Barcelona city and the other for the rest of the metropolitan area. In the Barcelona city, interviews have been stratified by district and the people to be interviewed have been randomly selected, taking into account quotas of sex, age and nationality. In the rest of the AMB, interviews have been stratified according to a municipality dimension and geographic area; within each stratum, the municipalities to visit have been selected randomly. The individuals to be interviewed have also been selected randomly, taking into account quotas of sex, age, nationality and type of place of residence.
- The error margin quoted in the survey inform is of ± 4.0% for a confidence level of 95% and p=q=0.5.

The respondents to the questionnaire are residents of different municipalities in the Barcelona Metropolitan Area. They are presented below, on the Figure 8 indicating the spatial scope of the survey. The municipalities of residents that have participated in the survey are coloured in yellow; red colour represents the city of Barcelona and its districts. The bright yellow colour without labels features the municipalities of residents who haven't answered for the questionnaire.

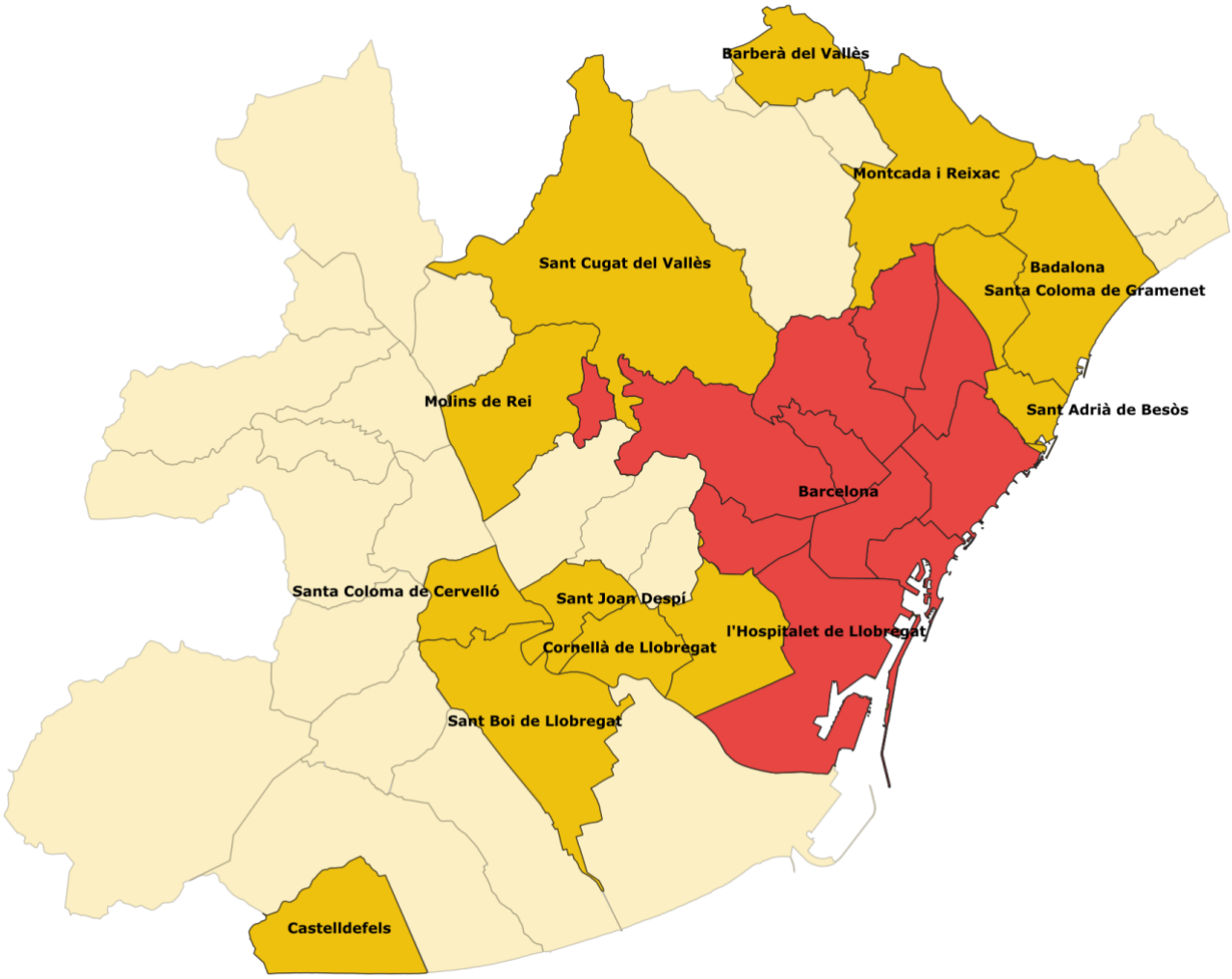

Figure 8. Spatial scope of the survey. Source: own elaboration.

As it can be observed on the graphic, some of the municipalities that forms part of the AMB are missing, what makes comparisons between the Barcelona city and the rest of the AMB municipalities not feasible. What is more, taking into account share of those territorial units and their built-up characteristics it was discussed and finally determined that distinction between urban and rural areas of residence is not appropriate in this case. Therefore, although two subsamples were initially defined (one for the city of Barcelona, and the other for the remaining metropolitan area), this work analyses only grouped data treating the sample as a whole in spatial terms, with two types of zones defined; urban and residential. Finally, it should be taken into account that lack of participation of residents from all of the AMB municipalities makes it vulnerable to bias in that sense.

4.3.1. Questionnaire content

Table 2 presents the survey content and distribution of its variables. The questionnaire includes 96 variables; 94 closed questions with 11 dichotomous, 81 single response, and 2 multiple choice questions. Moreover, there are also 2 open-ended questions, as well as additional 1 filter, 4 quota questions, and 4 ranking variables. It is divided into eight parts, each of which addresses specific issues related to mobility and technologies, such as: access to and use of technology; technology for public transportation; general computer and mobile device activities; attitudes toward technology, technology symbols, and interfaces; personal abilities / skills; demographics; and specific questions about daily mobility. The paragraphs highlighted in red are the ones to be considered for data analysis, taking into account this work objectives and the outlined analysis scheme. The last, underlined section G is the one carried out additionally in the AMB, not included in the other pilot cities.

Table 2. The questionnaire content. Source: own elaboration.

96 variables: • **Closed: 94 questions;** **- dichotomous: 11 questions,** **- single response: 81 questions,** **- multiple choice: 2 questions.** • **Open-ended: 2 questions.** • **1 filter question, 4 quota questions, 4 ranking variables.**	**A. Technology access and use**
	B1. Technology for public transport
	B2. General computer and mobile device activities
	C. Attitudes towards technology
	D. Technology symbols and interfaces
	E. Capabilities
	F. Demographics
	G. Specific questions about daily mobility

It is important to highlight the fact that carrying out face-to-face interviews was crucial in order to guarantee that residents in all types of situations could participate in the study. It prevents possible bias that could affect the results due to lack of participation from the residents without access to the technologies that cannot be reached and could not make the interview online.

As general commentaries for the field work and conducting of the survey, it can be outlined that the exceptional situation generated by the pandemic hindered the development of face-to-face interviews. In this regard, the interviews have been conducted using all the security measures recommended by health authorities to prevent coronavirus expansion. However, some people have shown reluctance to participate in the investigation, but, in general terms, people have been supportive of the interviewers.

The most difficult quotas to complete have been those related to the elderly people which is the population segment that probably applies most precautions in regard to the risks of the contagion. In addition, some older people, especially women, were not attracted to the subject of study, which has meant that they have been slowed down to participate. However, in these cases, the interviewers encouraged them to collaborate on the argument that all opinions are valid and necessary and eventually the interviews to this segment of the population have been completed. Apart from this, the main difficulty has been to administer some questions to the questionnaire, which for some people, who are less attracted to technology, were made to be weary. Some people, especially the older ones, have had some problems understanding some technological concepts included in the questionnaire. Despite some difficulties and thanks to strategies applied that would allow the person interviewed to keep their attention, the interviews have been completed successfully.

4.4. Data analysis

The analysis was conducted in SPSS v27 (IBM Corp., 2020) a software used within the DIGNITY project to process and explore the survey data obtained in all the pilot cities. For brevity and clarity, this work reports on selected summary results, calculated from the responses to individual questions. These were selected to cover key aspects selected from this extensive and comprehensive survey. Below, argumentation for the choice of targe questions, target groups and test for statistical significance of the results is described.

4.4.1. Target questions

Taking into account the amount of information that the gathered data provides, the work presented in this study will not embrace all the survey parts, and will mainly focus on its specific topics relevant to analyse the digital divide related to the digitalization in mobility within the defined framework. Therefore, variables from the following parts of the survey will be included in the study;

- "A. Technology access and use" - concerning access to and frequency of use of different devices;
- "B1. Technology for public transport" - addressing questions related to the digital transport services use;
- "F. Demographics" - describing the population social, educational, residential etc., characteristics
- "G. Daily mobility" - including questions regarding how the pandemic has affected daily mobility patterns of the residents and public opinion on measures for future urban planning.

The information provided by these parts of the survey links with the objectives of the study and allows to frame the digital gap within the defined context.

4.4.2. Target groups

Table 3 present sample distribution of the survey considering different socioeconomic groups. As described before the sample were stratified and the interviewed have been selected randomly, taking into account quotas of sex, age, nationality and type of place of residence. The three central groups, highlighted with orange shades are the ones that will be considered in the final analysis, and reasoning for that choice will be explained below.

Table 3. Sample distribution. Source: own elaboration.

	Group	Size	Percent
Residence area	Barcelona	306	50,9%
	The rest of the AMB	295	49,1%
Age	16-29	110	18,3%
	30-64	356	59,2%
	65 and more	135	22,5%
Sex	Women	312	51,9%
	Men	288	47,9%
	Prefer to self-describe	1	0,2%
Level of education	Low	185	30,8%
	Medium	209	34,8%
	High	206	34,3%
	Prefer not to answer	1	0,2%
Nationality	Spanish	506	84,2%
	Foreign	95	15,8%
Total		601	100%

Note: highlighted with orange shades are the ones that will be considered in the final analysis.

In regards to residence area, as already explained presenting spatial scope of the survey, the assignation of the municipalities from where the answers come do not allow to analyse the possible digital exclusion among the population living in the rural areas with difference to those living in urban/residential areas with usually better Internet coverage, transport infrastructure and provision.

For the purposes of the analysis three age groups have been defined, taking as a reference EMEF (L'Enquesta de Mobilitat en Dia Feiner - The Working Day Mobility Survey) 2019 – an annual report on daily mobility in the context of the AMB (IERMB, 2020) and its methodology;

- people aged 16-29; considered as those whose mobility patterns are related with their younger age lifestyle, schooling, studies, social life etc., as well as tech-savvy and used to digital interfaces.

- 30-64; assuming their professional activity, fully or almost completed education, social status possibly connected with building their own family and/or other social life patterns, possibly vulnerable to changes accelerated by digitalization revolution.

- 65 and more; as a group with little or no occupational and/or educational mobility, usually retired, possibly with some physical impairment, vulnerable to digital exclusion due to lack of skills and generational change.

This would allow to make comparisons and cross-validate obtained results with a representative and sound analysis already in place, and remains consistent with the objectives regarding looking for gaps related to the digitalization of transport services.

In the case of gender, the sample is formed in 51,9% by women, 47,9% by men and one of the interviewees preferred to self-describe (0,2%), what makes it representative only in the case of the first two groups. Therefore, while exploring the differences associated to different gender types, only the feminine and masculine sex will be taken into account.

Regarding levels of education, the sample have been divided into three groups;

- Low; no official studies completed and compulsory (primary, secondary),
- Medium; general post-compulsory, post-compulsory professionals (training cycles, modules, vocational training, trade),
- High; university students, degree, diploma, bachelor's, master's, postgraduate degree, doctorate.

What is more, one individual preferred not to specify its educational level (0,2%), which case will also be excluded from the analysis because of the very low percentage of the sample that is represents. Finally, it should be taken into account that those answers could be biased as individuals could tend to report higher level of attainment than the factual.

With respect to the nationality, the work done within the DIGNITY project and initial descriptive analysis of the sample from Barcelona have showed that the interviewed foreigners were rather short-term migrants, representing particular, usually tech-savvy and well-off profile and not all cross-section of diverse group of migrants residing in the AMB. Apart from the fact that this specific group is not really vulnerable to digital exclusion, it makes the sample biased comparing to the whole representative group in hand when it comes to digital technologies uptake in mobility.

Finally, it should be noted the questionnaire results do not provide information when it comes to some of the identified vulnerable-to-exclusion groups; namely people with low income, and people with disabilities. In the first case question about level of income was not included. In the dataset there is a variable describing employment status, however using it as a base to explore digital gap associated to wage tier is not consider viable, as this can vary along different status of employment and make it skewed. In the latter case, the parts of the survey that this study embrace do not include any variable providing information about disabilities that the interviewees could possibly suffer from. Although in the section E of the survey regarding capabilities there is a question asking about limitations in daily activities that could be connected with some disabilities, it will not be considered in this study, as it is not defined directly and additionally forms part of already pre-eliminated segment of the questionnaire.

4.4.3. Difference's assessment

In order to evaluate the results obtained and assess the differences between different target groups some statistical methods were used in data analysis of the survey. Therefore, significance testing was conducted using:

- Mann-Whitney-U test (Mann & Whitney, 1947) - a nonparametric test that allows to compare differences between two independent groups without making the assumption that values are normally distributed. The null hypothesis, H_0, is one of no difference between the two groups (McKnight & Najab, 2010; Neuhäuser, 2011).

The Mann-Whitney U test was used to compare proportions of females' and males' subgroups on each variable of interest and to check for significant differences between the genders.

- Kruskal-Wallis-H test (Kruskal & Wallis, 1952) - a nonparametric test used to determine if there are statistically significant differences between two or more groups. It is considered as an extension of the Mann-Whitney U test to allow the comparison of more than two independent groups (The Concise Encyclopedia of Statistics, 2008).

The Kruskal-Wallis-H test was used while exploring differences regarding proportions of age groups (16-29, 30-64, 65 and more) and levels of education (Low, medium, high) on each variable of interest.

The significance level $\alpha = 0.01$ was established.

5. Framing the Digital gap in the AMB

The results of the survey highlight interesting characteristics in the use of digital technologies and services related to mobility, as well as the main limitations and concerns of the main groups analysed in the AMB. The next paragraphs provide analysis based on the quantitative data gathered through the questionnaire and outline general gaps and trends among the studied population.

5.1. Digital inequality

First of the analysed intersection will be the digital inequality, which comes as an effect of digitalisation processes and could aggravate already existent social exclusion (Figure 9). This creates disadvantages for vulnerable groups which cannot take advantage out of new technological solutions in daily life because of lack of access and/or skills to use the ICTs. Results presented in this paragraph comes from the part A1 – "Technology access and use" of the survey.

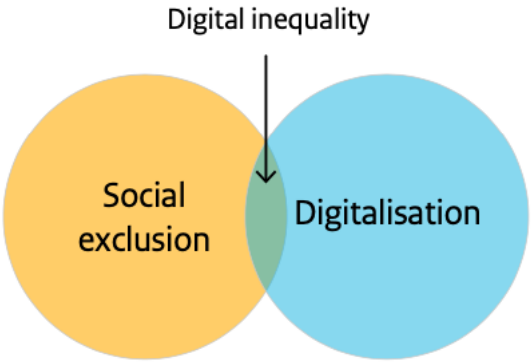

Figure 9. Digital inequality as an intersection between digitalisation and social exclusion. Source: Durand & Zijlstra, 2020.

5.1.1. Access to the technologies

Figure 10 presents the distribution of access to the different digital technologies. In the context of metropolitan area of Barcelona, the Internet is the most accessible technology, with almost 93% of the population being connected. This goes in line with the results presented in the (Ajuntament de Barcelona, 2020) where it is reported that 92% of households in Barcelona is connected to the Internet. This set the digital divide in Barcelona on the level of about 7%. If we would extrapolate this percentage to the total of about 3,3 million of residents living in the AMB (Ajuntament de Barcelona, 2020) - we will get more than 200.000 people without access to the digital world, and consequently without possibility to benefit from the digital mobility services.

Subsequently, Smartphone (85.2%) and Computer (77.4%) are reported to be less available among the citizens, which is compatible with the current trends observed in the society. Finally, less than 50% of the interviewees (45.9%) answered that has access to the tablet, which demonstrates that use of these kind of devices is not that popular in comparison to those mentioned earlier.

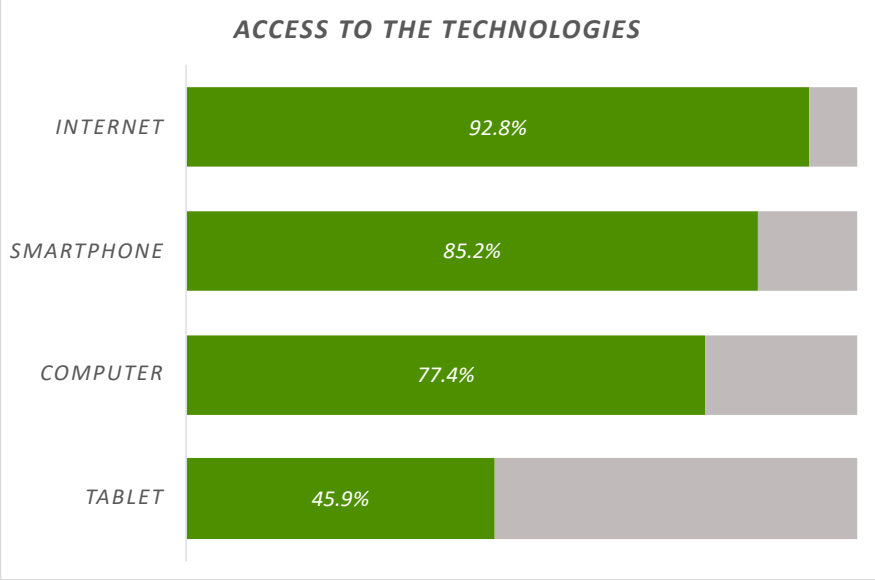

Figure 10. Access to the different technologies among the AMB population. [n = 601, error margin ±4%, significance level = 95%] Source: own elaboration.

If we study the differences in the access to the different technologies based on gender (Figure 11), the results suggest that greater number of men has access to the Internet (91.7% vs 94.4%, Mann-Whitney U, p = 0.183,), smartphone (82.7% vs 87.8%, Mann-Whitney U, p = 0.072) and computer (74.7% vs 80.6%, Mann-Whitney U, p = 0.085). On the other hand, more interviewed women indicated having access to a tablet, which could point out that this type of devices are more popular amongst the females (48.4% vs 43.4%, Mann-Whitney U, p = 0.220). However, those differences have been found not significant and therefore there is not enough evidence to conclude that level of access to the analysed technologies is different among those two genders.

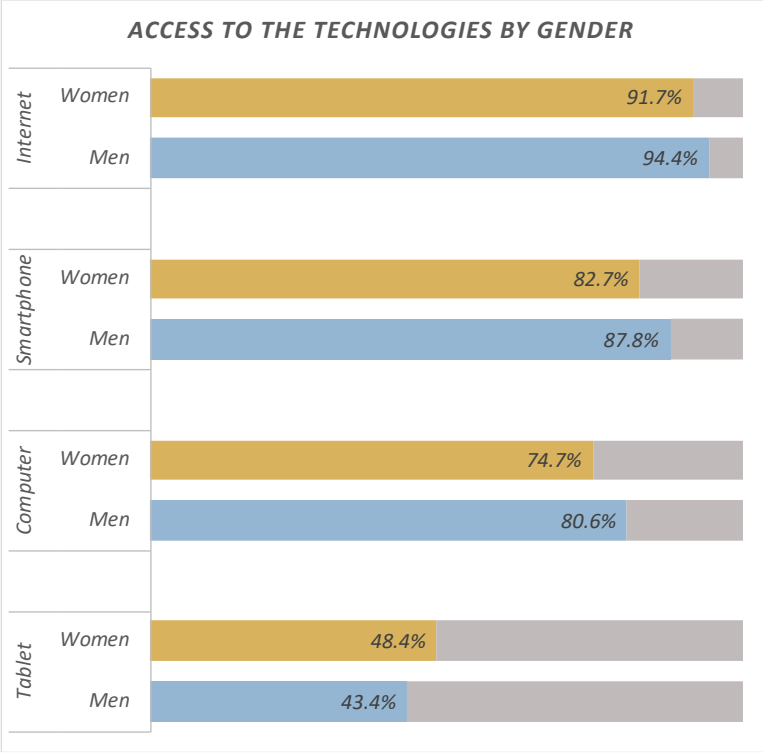

Figure 11. Access to the technologies by gender. Source: own elaboration.

When it comes to the age groups (Figure 12), interestingly, 100% of people aged 16-29 have access to the Internet, little less in the middle age 30-64 (97.8%) while more than 25% of the elderly (65 and more) are not connected and therefore cannot potentially benefit from the new digital transport services (Kruskal-Wallis H, $p < 0.001$). The same tendencies can be observed analysing two other technologies; namely smartphone (Kruskal-Wallis H, $p < 0.001$) and computer (Kruskal-Wallis H, $p < 0.001$), but with slightly lower percentages in general. Conversely, in the case of tablet the numbers are much lower, with middle age (30-64) having the biggest access to this kind of devices followed by young people (46.4%) and elderly (28.9%) (Kruskal-Wallis H, $p < 0.001$).

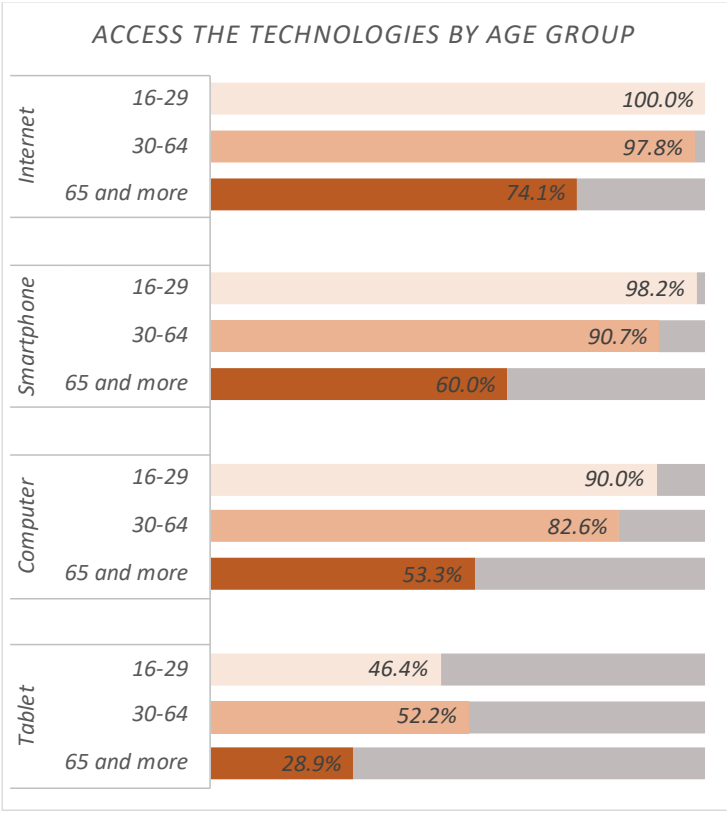

Figure 12. Access to the technologies by age group. Source: own elaboration.

Finally, taking into account education level (Figure 13), those with high education level stand alone with 100% access to the Internet, followed by medium (95.2%) and low (82.2%) education levels (Kruskal-Wallis H, $p < 0.001$). The same trend is observed in all of the analysed technologies (Kruskal-Wallis H, $p < 0.001$); the highest the education level the bigger number of people with access to the ICTs amongst the group.

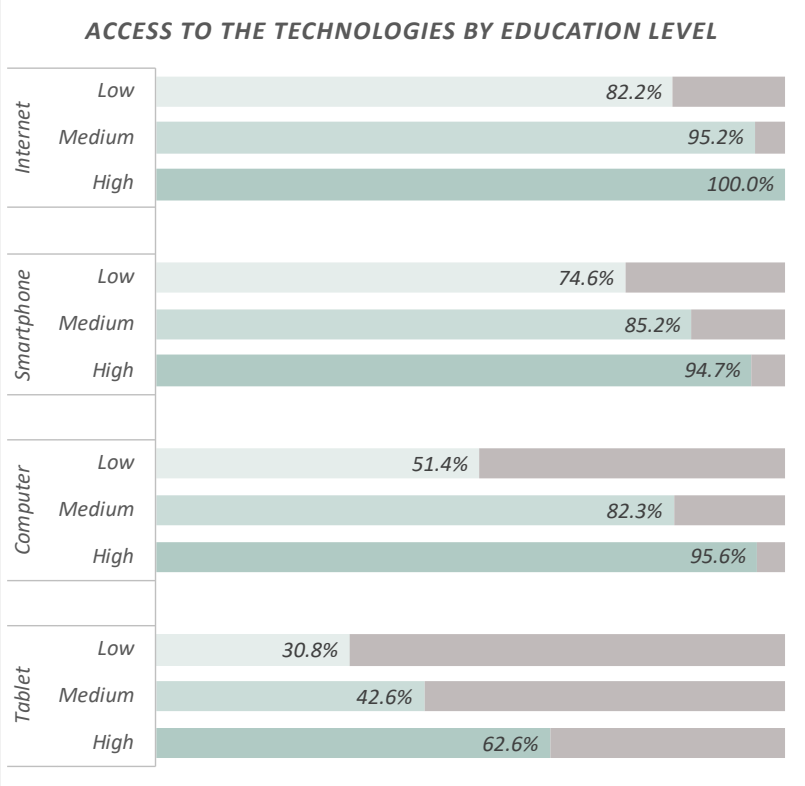

Figure 13. Access to the technologies by education level. Source: own elaboration.

To sum up, the results show that the Internet is the most available technology amongst the AMB population, followed by the tools from which one can access it; smartphones, computers and finally tablets. Moreover, age and education level are factors that in general influence level of access to the ICTs in population – the younger and the better educated a person is, the better access it has to all kind of the analysed technologies, apart from the tablet which is the most popular among the middle-aged group. Finally, the results suggest small differences in the level of access to the technologies between males and females. Nevertheless, those are not statistically significant and further studies exploring gender perspective when it comes to access to the different technologies are required that would investigate whether gender gap related to that actually exists.

5.1.2. Use of the technologies

Although one could have access to the different technologies it does not mean he/she use it on a daily basis and and/or without any limitations. There are numerous factors influencing appropriate use of the digital solutions resulting in different use patterns among the population. In the previous paragraph, it was proved that among the analysed technologies, the Internet is the most available one and smartphone is the most popular digital tool, both accessible for more than 85% of the AMB population, however with differences within the analysed target groups. Taking that into account and also bearing in mind that in order to use new digital mobility products and/or services usually it is required to use a smartphone to access the Internet, figure 9 presents the results regarding frequency of the technology use in those 3 scenarios.

The survey results (Figure 14) show that up to 85% of people use the Internet or a smartphone every day or almost every day. Next, 6.2% and 1% respectively use them at least once a week. On the other hand, 6.8% of the residents answered that they never used the Internet and 12.3% answered the same in the case of smartphone. In comparison, as reported in Digital Economy and Society Index (DESI, 2020) 88% of all individuals in Spain and 86% in the European Union are regular Internet users (using the internet at least once a week in the last 3 months) while 8% and 9% respectively have never used it. Those statistics indicates that the digital divide in terms of the Internet use in the AMB is slightly lesser that in those two reference populations.

In the specific context of accessing the Internet on a smartphone, the data proves that the uptake in that case is less frequent, with about 80% of people using it every day or almost every day. What is more, 3.8% of the interviewees answered that they used it at least once a week, while and 2.2% reported doing that less than once a week and 13.6% that they have never done it. This proves that on a daily basis, about 1 out of 5 individuals doesn't use a smartphone to access the Internet, for example to rent an on-street bike or check an alternative route for a journey while being on the move. This gap puts in question inclusiveness of the current transport services, and marks the needs of future work, especially thinking about future multimodal mobility.

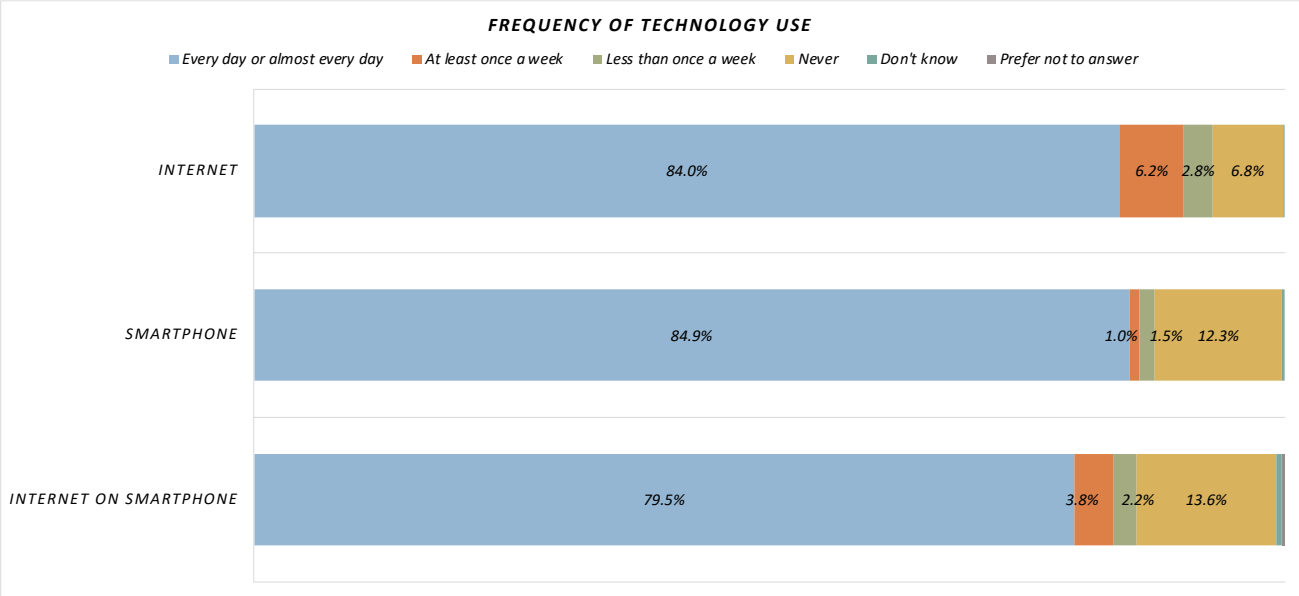

Figure 14. Frequency of use of the Internet and a smartphone in the past 3 months (at the time of the questionnaire). [n = 601, error margin ±4%, significance level = 95%] Source: own elaboration.

Furthermore, if we compare the frequency of use in the last scenario within the analysed groups (Figure 15), we can observe similar trends as in the case of previously described level of access to the ICTs;

- The results suggest that women use a smartphone to access the Internet less frequently than men. However, again, it is not statistically significant and there is not enough evidence to conclude that a gender gap exists in that case (Mann-Whitney U, $p = 0.398$).

- Frequency of that use decreases with age, with about 95% of individuals aged between 16 and 29, about 88% aged 30-64 and only about 46% aged 65 and more that reported using it every day or almost every day. What is more, 37% of people aged 65 and more, 8.7% aged 30-64 and less than 1% aged 16-29 answered that have never used it (Kruskal-Wallis H, $p < 0.001$).

- The higher the education level the more frequently a smartphone is being used to access the Internet among the population; 92.7% of the interviewed with high, 79.9% with medium and 64.3% with low education levels, answered that they used it on a daily basis. On the other hand, 3.4% of those with high, 12.4% with medium and 26.5% with low attainment levels indicated that they have never used it (Kruskal-Wallis H, $p < 0.001$).

Finally, in the comparison of the Digital Economy and Society Index (DESI, 2020) regarding internet access, use, and connectivity, the city of Barcelona is positioned among the European leaders, above the average for Europe, Spain (EC, 2019), and Catalonia (Orkestra, 2020). Therefore, it can be observed that the population of Barcelona is uniquely situated with respect to the use of digital tools in general, however there are important differences among the population which can hinder the equal and proper uptake of the innovative solutions emerging in the mobility sector.

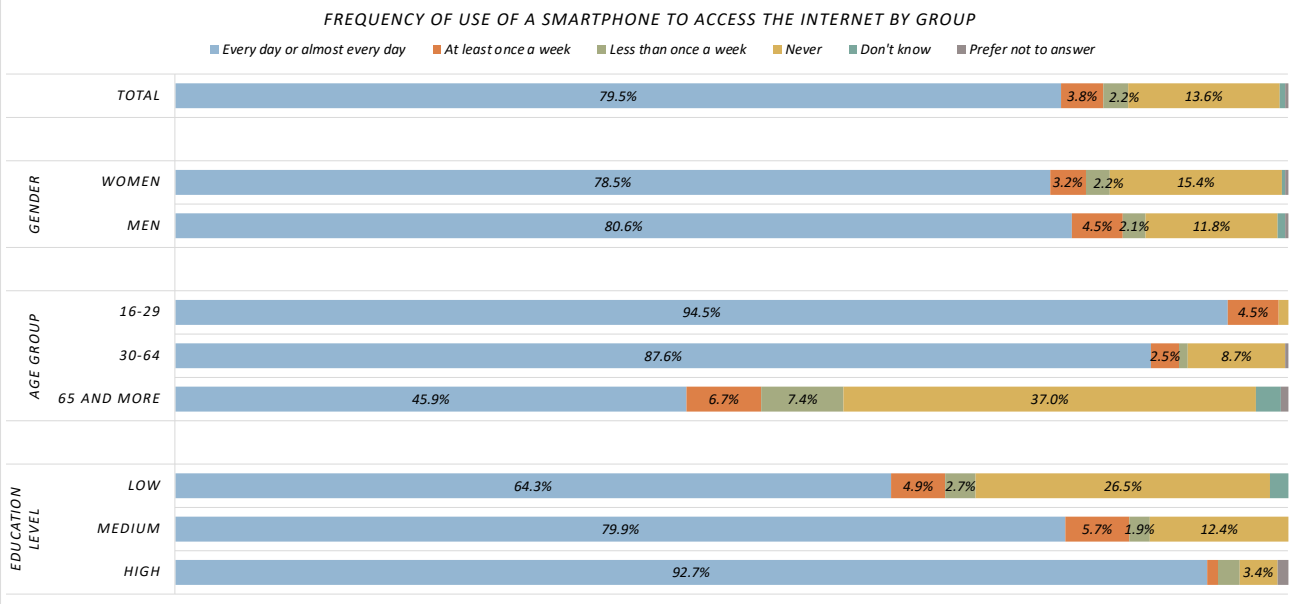

Figure 15. Frequency of use of a smartphone to access the Internet in the past 3 months (at the time of the questionnaire) by group. **Source: own elaboration.**

5.2. Digitalisation in transport services

The second intersection to be analysed will be the digitalisation in transport services (Figure 16). As mentioned before, thinking about the new digital mobility services, they usually require use of a smartphone with access to the Internet. Therefore, in this section it will be considered the most relevant in the context of digital mobility services use. This paragraph will analyse further attitudes and aptitudes towards technologies, and residents' uptake of innovative digital solutions in mobility. The answers below come from the part B1 – "Technology for public transport" of the questionnaire.

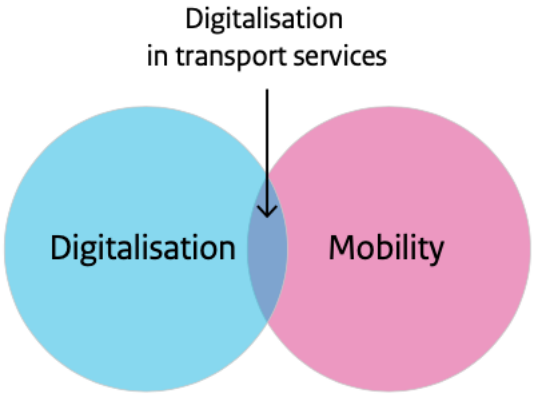

Figure 16. Digitalisation in transport services intersection.
Source: Durand & Zijlstra, 2020.

5.2.1. Confidence in planning a travel

Another important factor in the uptake of the new mobility solutions are the attitude and capabilities of users for whom they are designed. Although some groups have access to technologies and use them regularly a large part of them are not conscient about availability of new mobility products, feel insecure while using them, and/or experience limitations while planning (before the trip) and during the journey, related for example to the handling capacity of electronic devices.

Figure 17 presents perceptions of the interviewed persons regarding planning an unfamiliar local public transport journey using the Internet or an application on a smartphone. For clarity and visualisation purposes, the answers were categorised into High (8-10), Medium (4-7) and Low (1-3). It can be observed that about 64% of the respondents feel highly confident while planning such a trip, while almost 19% report medium and about 14% low confidence doing that. These results proves that big part of the population could be exposed to difficulties while using innovative digital solutions in transport or trying benefit from new mobility services. It is important to further study the aspect of attitudes towards technologies and digital competencies in order to be

able to design inclusive and user-friendly interfaces and platforms that will be crucial in the future mobility ecosystems based on multimodal platforms, such as MaaS (ERTICO – ITS Europe, 2019).

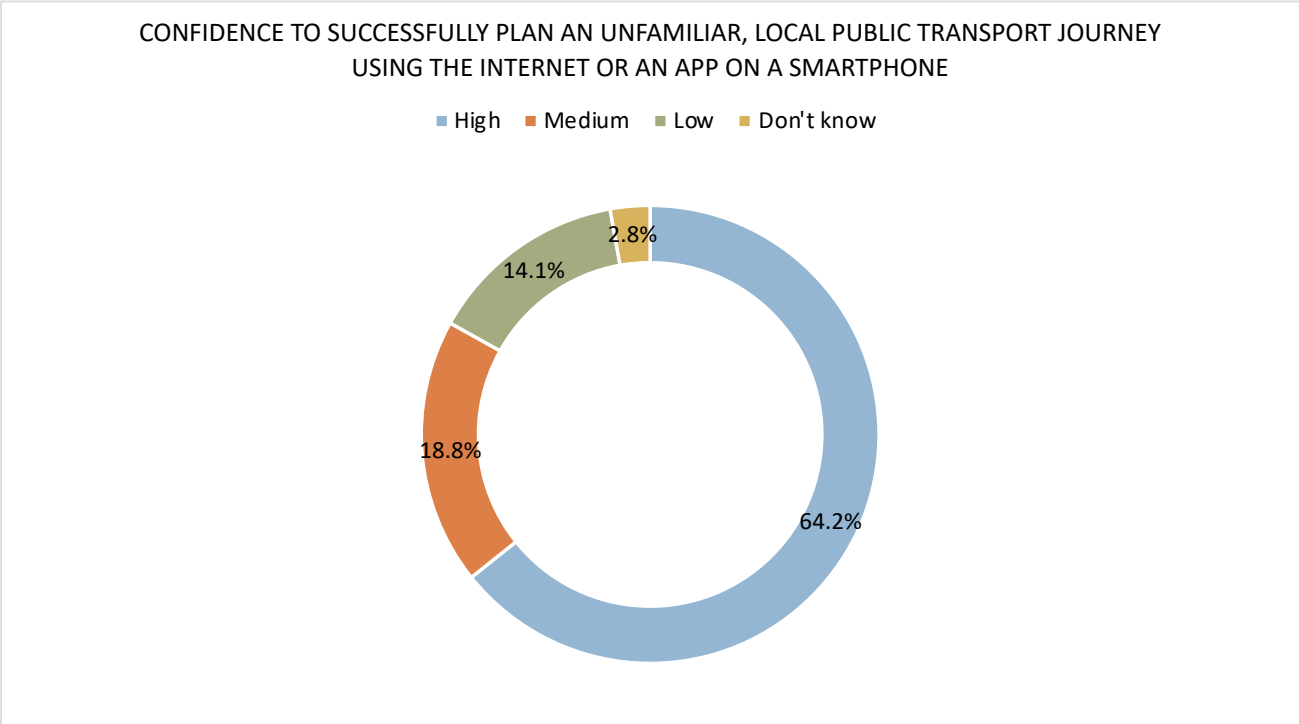

Figure 17. Confidence to successfully plan an unfamiliar, local public transport journey using the Internet or an app on a smartphone. [n = 601, error margin ±4%, significance level = 95%] Source: own elaboration.

The results presented in Figure 18 allow to make comparisons between different target groups regarding the confidence to planning a travel. When it comes to the differences between gender, higher percentage of men answered that they are highly confident to plan such a trip (67.7%) comparing to women (60.9%). Also, only 8.3% of men reported feeling low confident in contrast to higher proportion of women (19.6%) (Mann-Whitney U, $p = 0.020$). It proves that there is a gender gap when it comes to attitudes towards use of the technologies in mobility. However, it is important to highlight that the fact that in general women could feel less confident in that aspect doesn't mean that they have fewer digital skills. Furthermore, this lack of confidence could be caused by the existing social roles and therefore further studies exploring the topic of digital skills in mobility and possible differences based on gender are needed.

Analysing the age groups, there is a higher distrust among older people in the use of digital services for trip planning; 40% of older people feels insecure about planning a trip on public transport using the Internet or an application on a smartphone and only about one out of them feel very secure about that. On the contrary, almost 81% of the people aged 16-29 and 73.6% aged 30-64 feel highly confident doing that (Kruskal-Wallis H, $p < 0.001$).

Furthermore, about 25% of people with lower, 14.4% with medium and only 4.4% with high level of education answered that they experience similar limitations regarding planning such a trip. On the contrary, the highest level of confidence was observed in the case of people with high attainment levels, followed by 65.1% of those with medium and 44.9% with low attainment levels (Kruskal-Wallis H, $p < 0.001$).

Again, the observed tendencies are similar to the ones outlined in the previous paragraphs; feminine gender, older age and low education level are risk factors for digital exclusion, here, influencing the proper uptake of new mobility solutions.

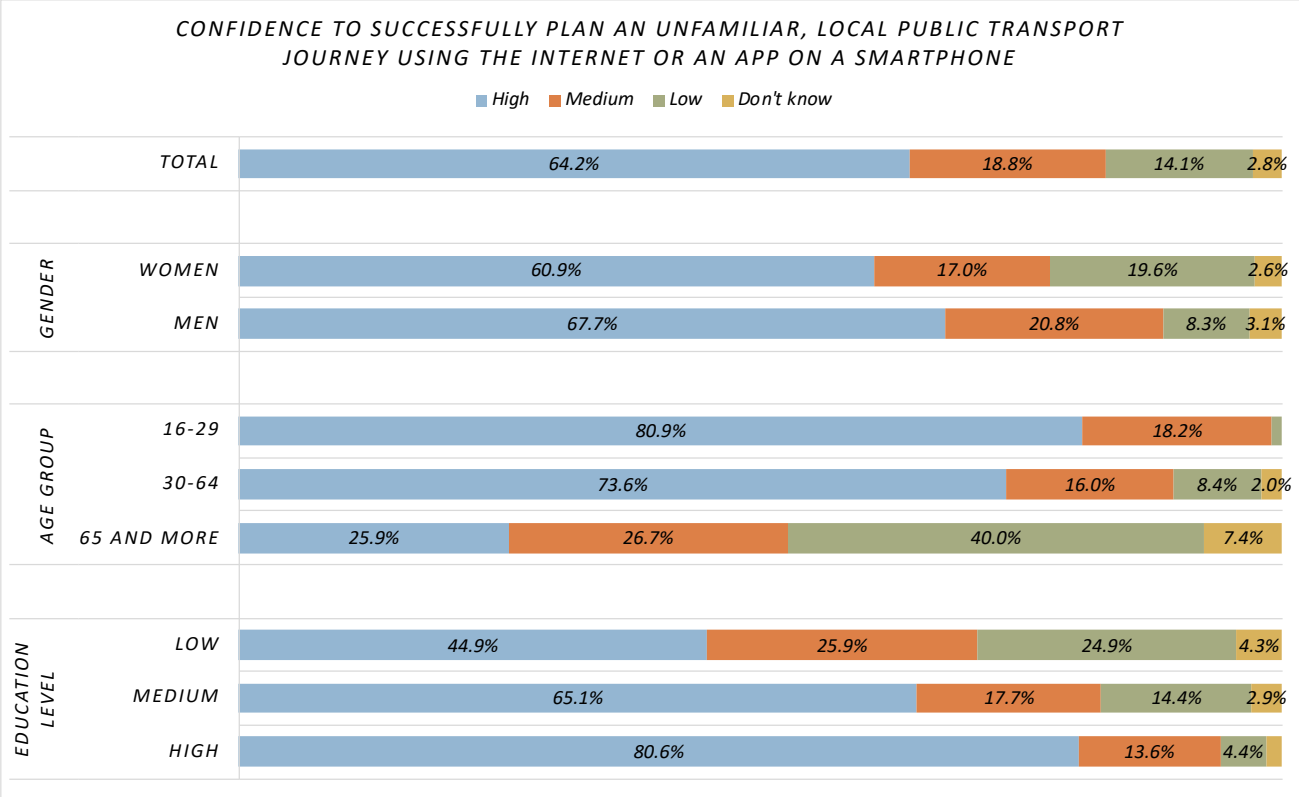

Figure 18. Confidence to successfully plan an unfamiliar, local public transport journey using the Internet or an app on a smartphone by group. Source: own elaboration.

5.2.2. Main sources of transport information

The results concerning use of main sources to find transport information are shown in Figure 19. Among those identified as the most popular are: search engine (39.8%), navigations applications (32.9%) and transport operator/service website or app (22%), as well as other sources (21%) and other websites or apps. On the other hand, social networks and radio/TV are the least used sources (below 1%). Moreover, very low percentage reported looking up for the info at a public transport stop/station (2%) or having their own paper copies of the info. Interestingly, high percentage of the interviewed (6%) didn't know how to specify the answer, and 7.7% of respondents answered that they use word-of-mouth as a way to gather information regarding transport. Furthermore, 2.2% answered that they don't know where to find it and 1.5% already know it and don't expect any additional issues.

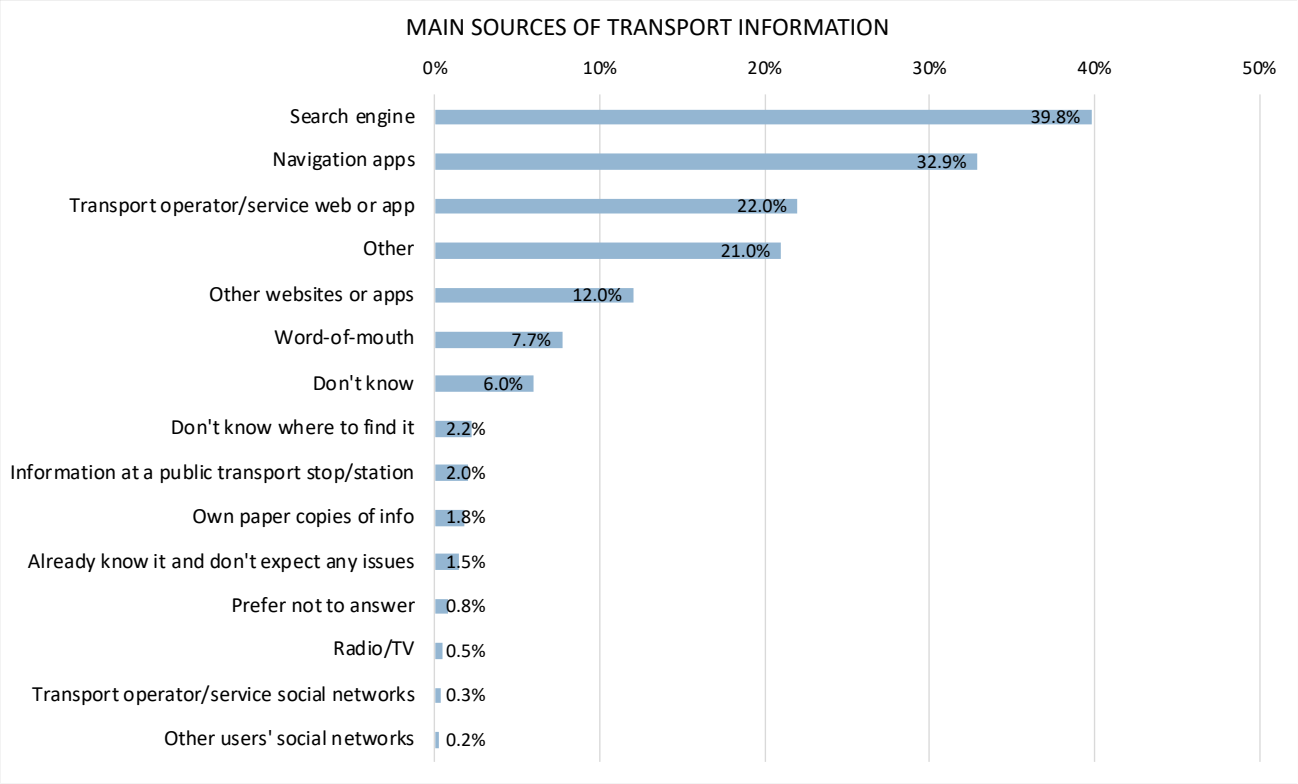

Figure 19. Main sources of transport information. The interviewed could select up to 3 responses [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

Analysing these different sources of information by category (Figure 20), the importance of using digital sources to find travel information is noteworthy. In general, a considerable percentage of the population (82.2%) uses at least one digital source to find travel information. On the other hand, 7.3% uses only non-digital sources to look up for that info. Finally, 10.5% of the respondents didn't indicated any travel information source, among which 6.8% don't report looking up travel information at all, 2.2% answered that they already know it and don't expect any additional issues, and 1.5% don't know where to find it.

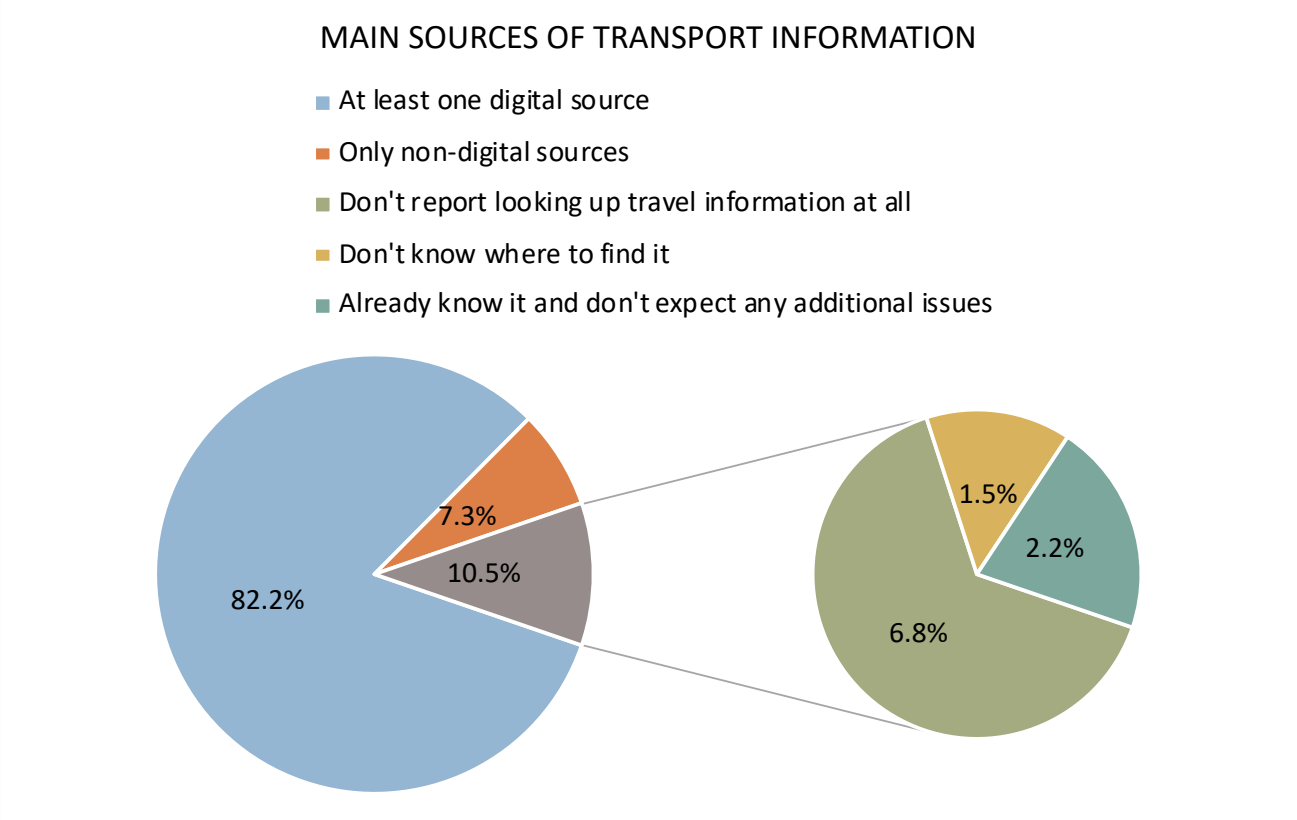

Figure 20. Main source of transport information by category. Source: own elaboration.

Results regarding main sources of transport information by different target groups are presented in Figure 21.

With respect to the analysis by gender, women indicated using any of the digital sources slightly less than men (80.1% vs 84.7%). On the other hand, they reported using only non-digital sources (9.0% vs 5.6%) and not using any of the sources (10.9% vs 9.7%) more than men (Mann-Whitney U, $p = 0.167$). Nevertheless, these differences are not statistically significant and therefore, there is not enough evidence to conclude that there is a gender gap regarding use of sources to look up for transport information.

What is more, the higher percentage of individuals indicated using at least one digital source within the group of those aged 16-29 (95.6%), followed by older collectives with ages between 30 and 64 (88.5%) and 65 and more 56.3%). Next, 20.7% of the elderly responded that they use only non-digital sources, while only 3.7% of the middle aged and 2.7% younger people answered the same. Finally, 23% of individuals from the oldest group, 7.9% of middle aged and only 3.6% of the youngest part of the population reported that they don't use any of the sources to find transport information. (Kruskal-Wallis H, $p < 0.001$).

Finally, 95.6% of the interviewed with high, 86.1% with medium and 62.7% with low education levels indicated at least one digital source as a tool for looking up transport information. On the other hand, 16.8% of those with low, 5,7% with medium and less than 1% with high attainment levels answered that they use only non-digital sources to find out about that. In the same order, 20.5%, 8.1% and 3.9% of them didn't report any source for looking up info for their trips (Kruskal-Wallis H, $p < 0.001$).

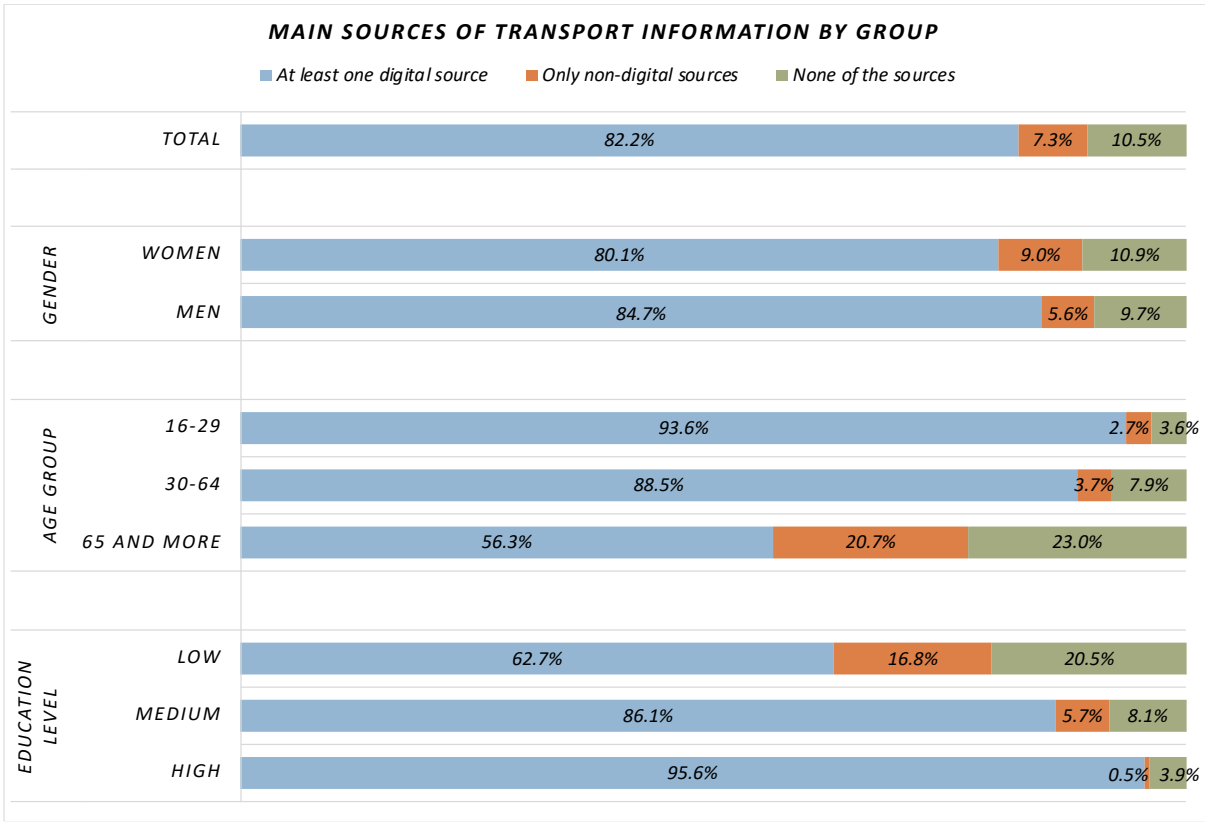

Figure 21. Main sources of transport information by groups. **Source: own elaboration.**

5.2.3. Use of digital transport services

The survey results regarding the use of digital transport services (Figure 22) revealed that, in general, those new solutions are still little used. The highest percentages are reported for digitally booked taxi services and digital payment for parking, although still much lower than 25% even considering longer period of time than 3 months before carrying out the interviews. Furthermore, use of carpooling, carsharing or on-street scooter/motorbike hire services is very low, which shows that these new forms of shared transport remain unpopular among the general population.

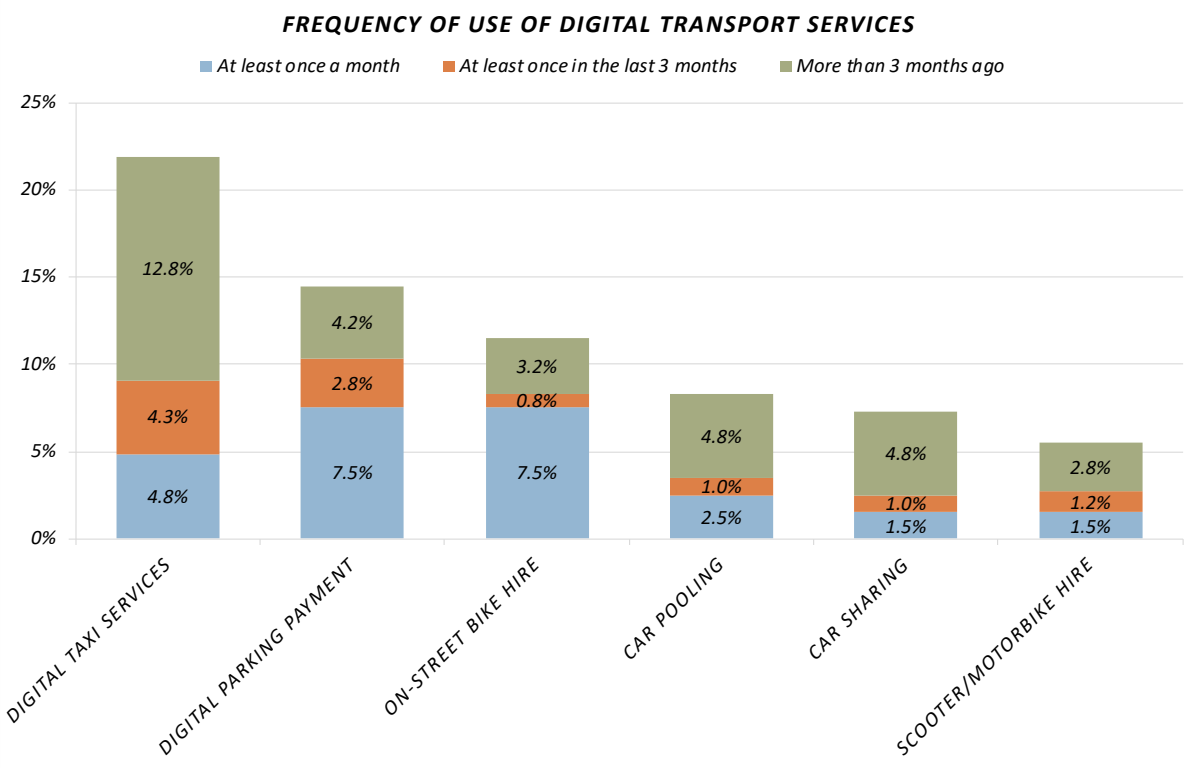

Figure 22. Frequency of use of digital transport services. [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

Therefore, as the uptake of carpooling, carsharing and scooter/motor bike hire options is at the very low level, with more than 90% of the residents who answered that they have never taken these solutions into considerations in order to move around, they will not be considered in the further analysis of differences among different target groups.

In general, the use of digital transport services is low among all the groups (Figure 23). Although the results suggest that uptake of these solutions is rather higher among males than females, significant difference has been found only in the case of on-street bike hire. Among women, 5.4% of them answered that they use it at least once a month, 1.3% at least once in the last 3 months and 1% more than 3 months ago. On the other hand, 9.7% of men reported using this digital solution at least once a month, followed by 0.3% at least once in the last 3 months and 5.6% more than 3 months ago (Mann-Whitney U, $p = 0.003$).

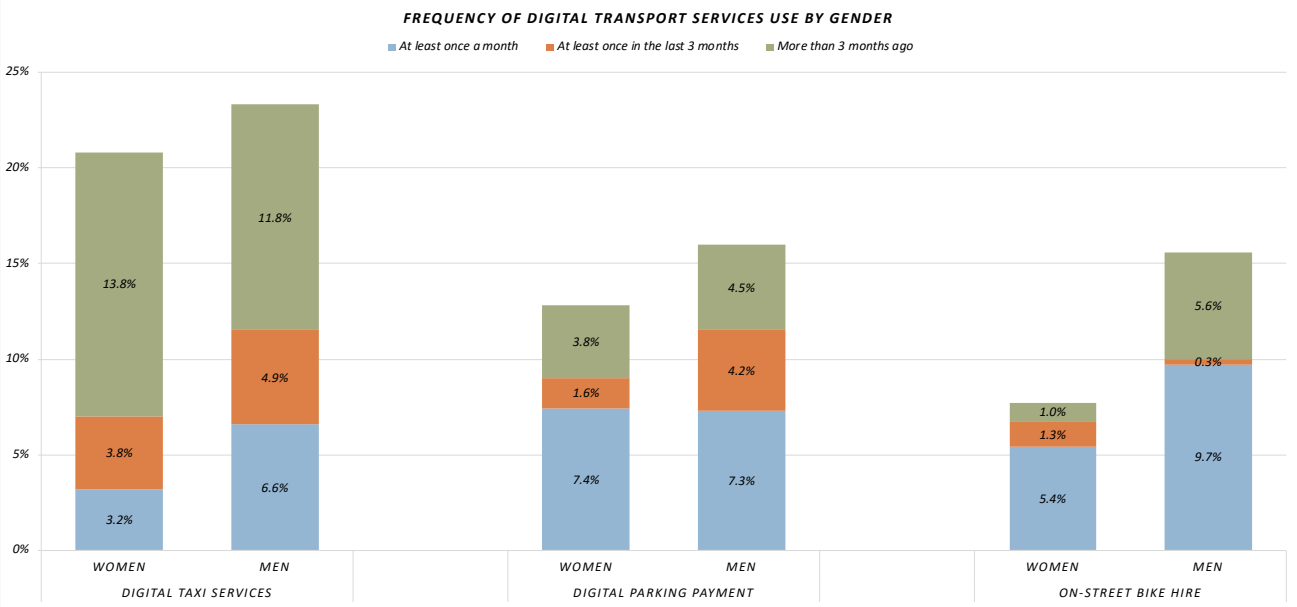

Figure 23. Frequency digital transport services use by gender. **Source: own elaboration.**

In figure 24 we can see comparison of frequency of digital transport services use between different age groups. First, those aged 16-29, use all of the listed services most frequently, apart from the digital parking payment, which is mostly used by those aged 30-64, a percentage affected simply by the fact that they have driving licence and use car more, in difference to some younger people who haven't gotten their driving licence yet and consequently don't even need to pay for parking. Significant differences have been found for all of the listed digital solutions (Kruskal-Wallis H; digital taxi services: $p < 0.001$, digital parking payment: $p = 0.002$, on-street bike hire: $p < 0.001$).

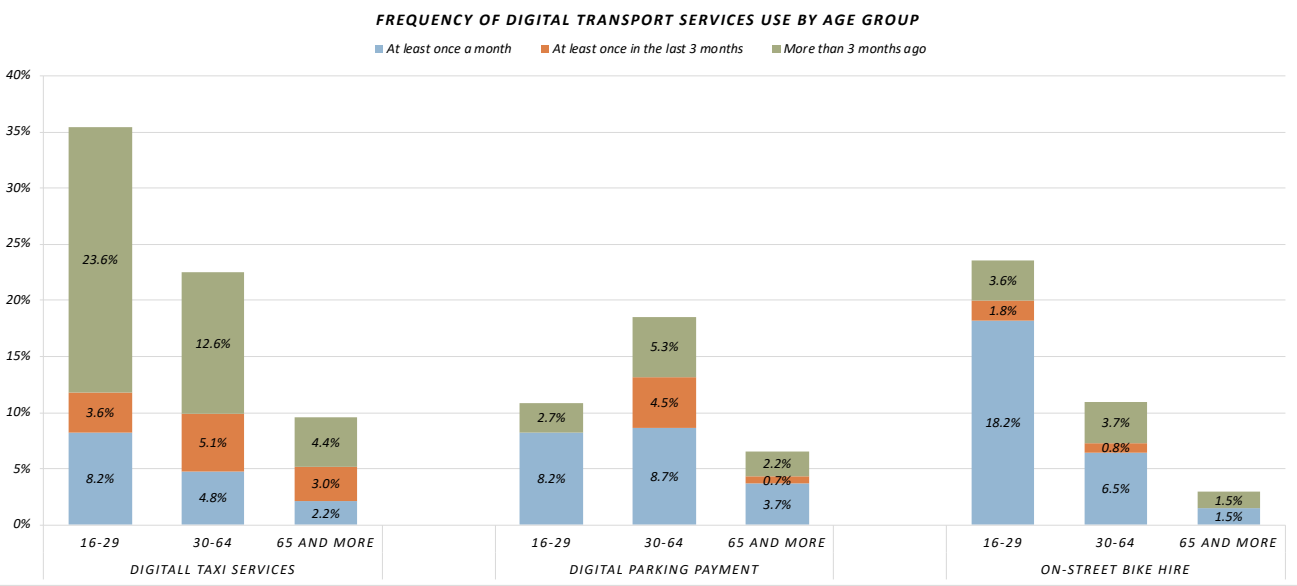

Figure 24. Frequency digital transport services use by age group. **Source: own elaboration.**

When it comes to differences in use among people from groups with different education level (Figure 25), it can be observed that those with higher education levels use all of the listed types of the digital transport services the most frequently and in general the lower the education level the lower the uptake of those services. Significant differences have been found for all of the listed digital solutions (Kruskal-Wallis H; digital taxi services: $p < 0.001$, digital parking payment: $p < 0.001$, on-street bike hire: $p < 0.001$).

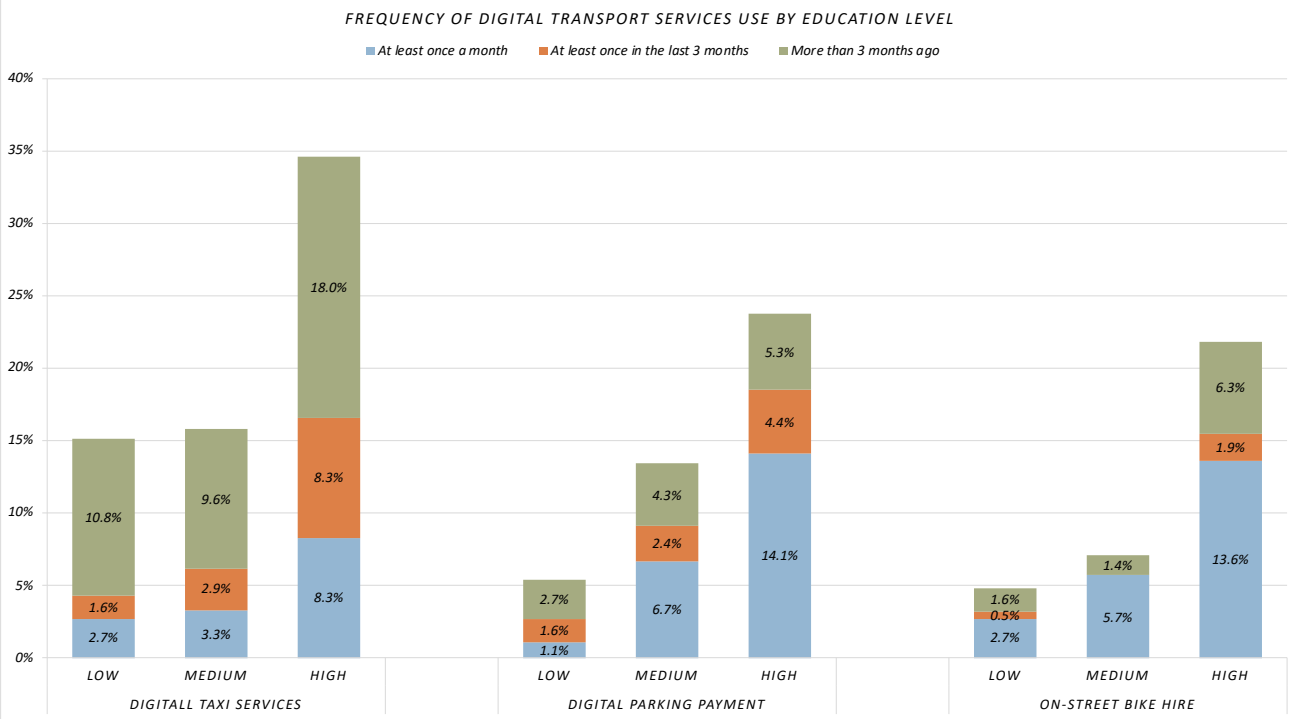

Figure 25. Frequency digital transport services use by education level. **Source: own elaboration.**

5.3. Transport disadvantage and risk of social exclusion via transport

Lastly, the third intersection within the marked methodology will be analysed, focused on transport disadvantage and risk of social exclusion via transport (Figure 26). In this paragraph the main means of transport used by the population in their regular mobility will be studied and comparison between the target groups will be made. Afterwards, the main motives for regular travel (work, studies, leisure etc.) among general population, as well as within various groups will be analysed. The results presented here comes from the part F of the survey called "Demographics". Answers for the question regarding limitations in regular mobility are also presented, included in the part B1 – "Technology for public transport" of the questionnaire.

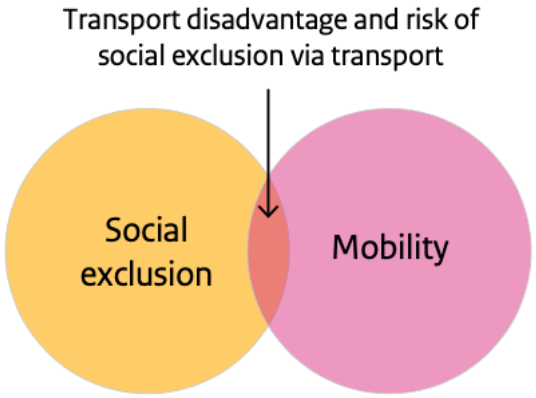

Figure 26. Transport disadvantage and risk of social exclusion via transport. Source: Durand & Zijlstra, 2020.

5.3.1. First mean of transport

Detailed distribution of the different means of transport used by individuals for their regular travel is presented in Table 4.

Table 4. First mean of transport for regular daily displacements. Source: own elaboration.

Mean of transport	Counts	Percentage
Walking	286	47.6%
Bike	23	3.8%
Scooter, Segway or other widgets	5	0.8%
Total active mobility	314	52.2%
Bus	63	10.5%
Metro	74	12.3%
Tram	9	1.5%
Generalitat Railways (FGC)	11	1.8%
Renfe Rodalies	20	3.3%
Total public transport	177	29.5%
Car as a driver	78	13.0%
Car as a companion	6	1.0%
Motorcycle as a rider	20	3.3%
Moped as driver	1	0.2%
Van	2	0.3%
Total private vehicle	107	17.8%
Prefer not to answer	3	0.5%
Total	601	100.0%

Furthermore, Figure 27 shows 3 main means of transport indicated by the respondents as primarily used for their daily displacements. In general, active mobility, which include walking, riding a bicycle, scooter or other low-speed transportation mode, is the most popular mean of transport for the daily displacements of the AMB residents (52.2%). Secondly, up to 30% uses public transport as the main mode for the daily displacements. Finally, about 18% of the population moves in private vehicle to reach their daily destinations. Similar results, respectively 50.3% for active mobility, 23.9% for public transport and 25.8% in the case of private vehicle, were obtained in the EMEF 2019 (IERMB, 2020) – the reference report regarding regular mobility conducted annually in the AMB. However, changes provoked by the pandemic should be taken into account while analysing this distribution.

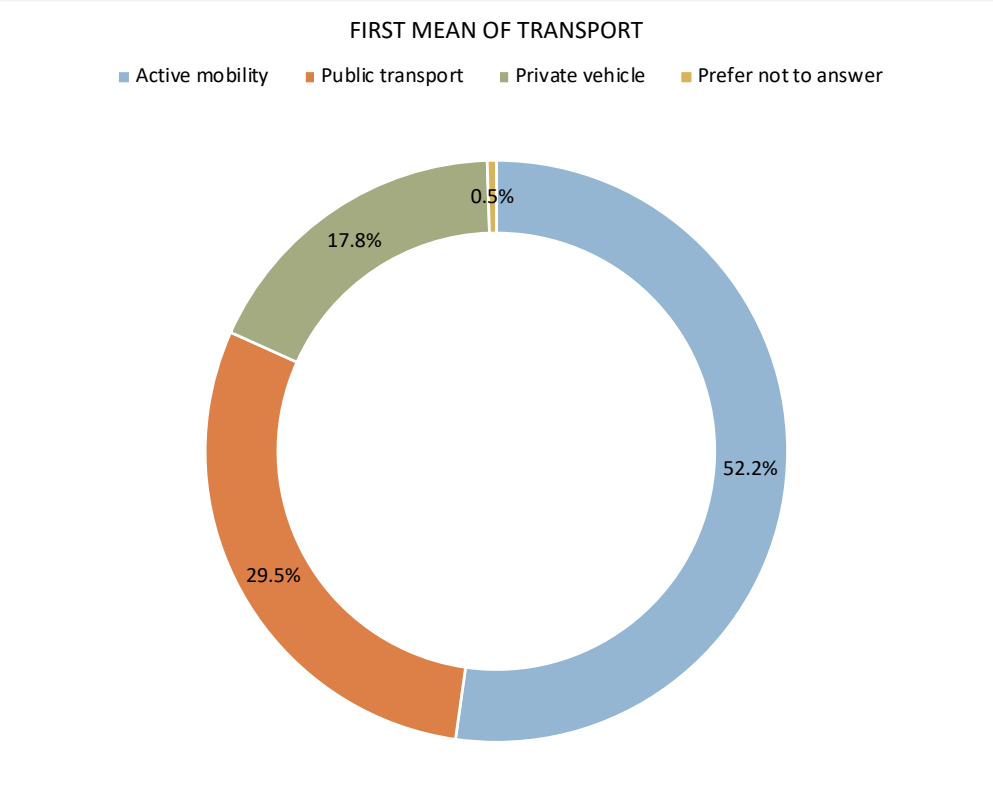

Figure 27. First mean of transport for regular daily displacement. [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

Figure 28 displays modal split in the AMB by the target groups. As regards gender differences, the results suggest that women use more often active means of transport (52.2% of women and 51.4% of men), such as walking. However, this difference is not significant (Mann-Whitney U, $p = 0.657$). In the case of public transport, 35.3% of women and 22.9% of men make use of it (Mann-Whitney U, $p < 0.001$), while men use more often private vehicles (10.9% of women and 25.3% of men) in their daily journeys (Mann-Whitney U, $p < 0.001$). These results prove that gender gap in mobility still exists in the AMB, especially when it comes to private mobility use, a fact reported also in other recent study regarding this topic (Jerònia Cubells, 2020). Therefore, in order to head towards inclusive and equal cities that achieve their climate objectives, efforts are needed to decouple gender convergence of travel behaviour from car-dependent built environments. It has to be taken into account that these differences are also consequence of the social roles and distinct mobility patterns of both genders. Women's daily mobility is more complex, diverse and sustainable since they tend to look for a workplace closer to home in order to be able to undertake other responsibilities, such as unpaid household chores or caregiving (Ortiz, 2019).

As regards to differences in daily mobility patterns among different age groups, it can be observed that older people move around actively (76.3%), and primarily by foot, much more often than the ones aged 30-64 (45.5%) and 16-29 (44.5%) (Kruskal-Wallis H, $p < 0.001$). Furthermore, public transport is the first choice to commute for 42.7% of younger people, followed by the middle aged (30.3%) and the elderly (16.3%) (Kruskal-Wallis H, $p < 0.001$). Finally, those aged 30-64 are principal users of private vehicle (23.9%), while only 12.9% of young people and 5.9% of the older ones use this mode of transport on a daily basis (Kruskal-Wallis H, $p < 0.001$).

Weighing up the mobility patterns among groups with different education level, it can be observed that active means of transport are used in large part by those with lower attainment levels (60.5%), followed by the individuals with high (54.9%) and medium (42.6%) education levels (Kruskal-Wallis H, $p < 0.001$). When it comes to public transport use the results suggest that it is principally used by those with medium education levels (34%), while less people with high (27.2%) and low (27%) education levels reported that they use this mode of transport (Kruskal-Wallis H, $p = 0.214$). However, these differences are not significant Finally, 23% of the interviewed with medium attainment levels answered that they commute in private vehicle, followed by 18% of individuals with high and 11.4% with low education levels (Kruskal-Wallis H, $p = 0.011$).

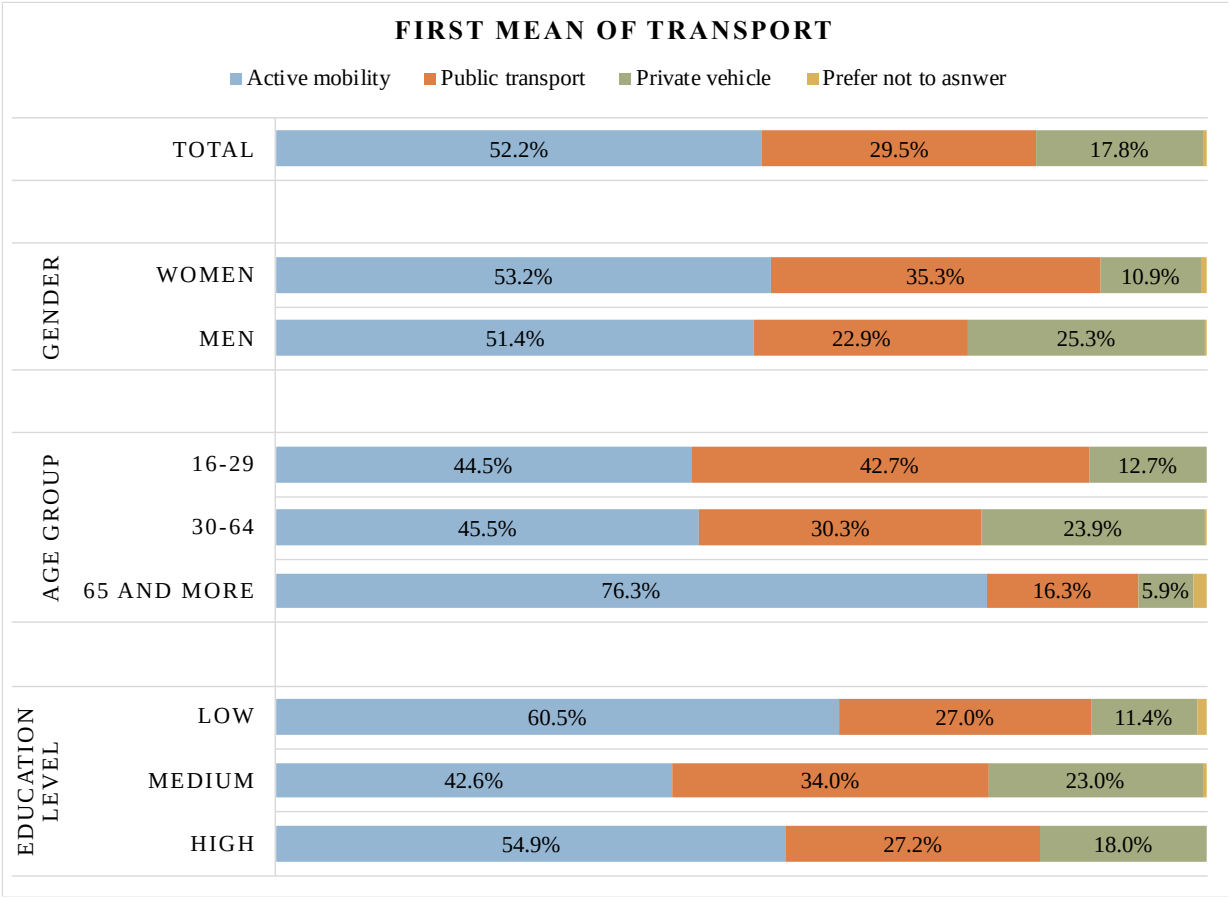

Figure 28. First mean of transport for regular daily displacement by target groups. **Source: own elaboration.**

5.3.2. Personal/Occupational mobility

People make their displacements with different kind of motives; reaching a place of work, going to study, walking, meet with the others etc. Figure 29 presents the distribution of those daily travels, where going to work or to study is considered as occupational mobility, and activities that have to do with mobility out of professional or educational matters, like daily shopping, walking, visiting other people etc. are categorised as personal mobility. In general, the residents of the AMB make more trips due to personal reasons (54.6%) than the occupational ones (44.3%). This result goes in line with the proportions reported in the (IERMB, 2020), namely 67.7% for personal and 32.3% for occupational mobility, although the difference between the two categories is bigger.

Furthermoe, considering individual motives, labour mobility is the first reason (35.6%) for regular trips. Afterwards, daily shopping (16.5%) and displacements with no fixed destination (15.3%), such as walking, are the next most popular reasons for regular journeys, followed by accompanying/picking up/looking up for people (9.2%), going to study (8.7%), leisure and fun (8%), visiting a friend or a family member (3.5%) or going to a doctor or a hospital (1.5%). Other unspecified motives reach up to 1% of all the daily displacements within the AMB.

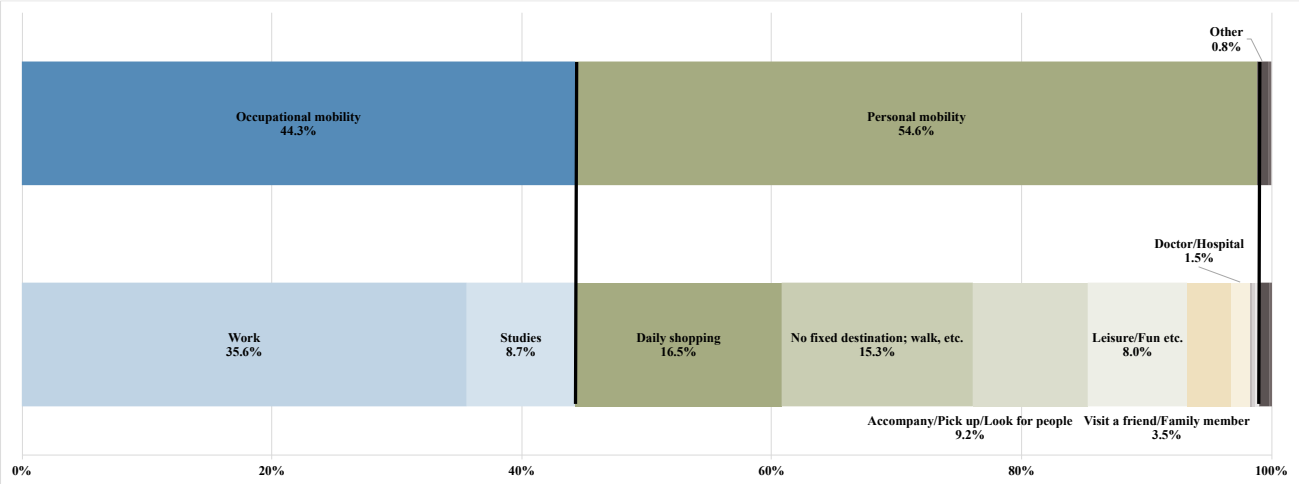

Figure 29. Personal/Occupational mobility. [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

Analysing the mobility patterns of the residents within different socioeconomic groups (Figure 30), based on the main reasons for making a trip, we can find some gaps that could provoke situations of social exclusion.

First, the results suggest that men move more than women due to occupational reasons (46.5% and 42.3%; Mann-Whitney U, $p = 0.299$), and on the other hand, that men make less displacements than women due to personal motives (52.4% and 56.7%; Mann-Whitney U, $p = 0.291$). However, those differences are not significant and there is not enough evidence to conclude that a gender gap is present when it comes to mobility motives.

Furthermore, when it comes to different age groups, it can be observed that young residents move primarily to a place of work or studies (70.9%), making only 29.1% of their movements due to personal reasons. Then, middle aged people (30-64), make less trips due to occupational reasons, but still more than a half of them (51.7%) and 47.2% due to personal motives. Finally, due to natural causes and because of the lack of professional nor educational activity, the elderly people make most of their journey for personal matters (94.8%), and less than 5% due to occupational motives. Therefore, a clear trend can be observed, namely that with age the reasons for regular trips move towards personal mobility and less occupational mobility (Kruskal-Wallis H, $p < 0.001$).

Finally, comparing groups with different education levels, the results show that 47.8% of the interviewed with medium and 47.6% with high education levels answered that that they move around on a daily basis due to occupational motives, while 36.2% of those with lower attainment levels answered the same (Kruskal-Wallis H, $p = 0.048$). Nevertheless, there are no significant differences between those groups to conclude that it is true in the overall population. On the other hand, 62.2% of the respondents with lower education levels answered that they move principally due to personal motives, followed by those with high (51.5%) and medium (51.2%) attainment levels who answered the same (Kruskal-Wallis H, $p = 0.033$). Again, the differences are not very significant. Therefore, although obtained data suggest that lack of education among the population impact the regular activity of the individuals and hinder their proper development and opportunities to access a job or an education further work is needed that would confirm if these differences are factual and exist among the population.

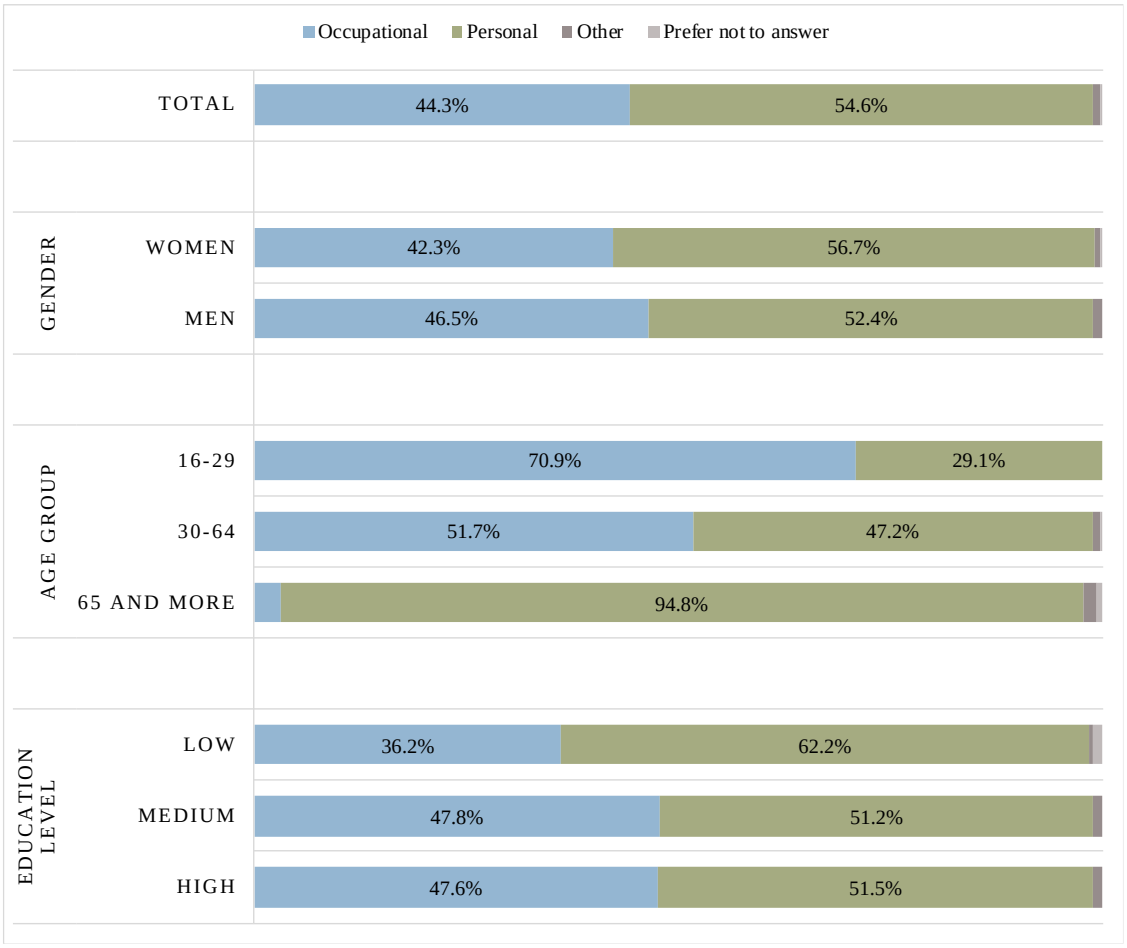

Figure 30. Personal/Occupational mobility by target groups. **Source: own elaboration.**

5.3.1. Limitations in regular mobility

Finally, the interviewees answered to a question; thinking about your regular travel within this region, to what extent do you feel limited in your travel by the following aspects? (Figure 31) In this question, "limited" is defined as wanting to travel more but feeling unable to.

Regarding perceived limitations in regular mobility, safety of transport services and cost of the travel are indicated as the most significant limitations. Next, limited availability of transport services and limited availability of infrastructure are the motives that limit users to some extent up to 39% and 33% respectively. Overall, the lack of digital skills required for planning travel, as well as during trip are not indicated as one of the most significant limitations (about 20%). Finally, difficulties using the available transport due to special needs or disabilities were indicated as the reason that limits the least part of the respondents (up to 16%).

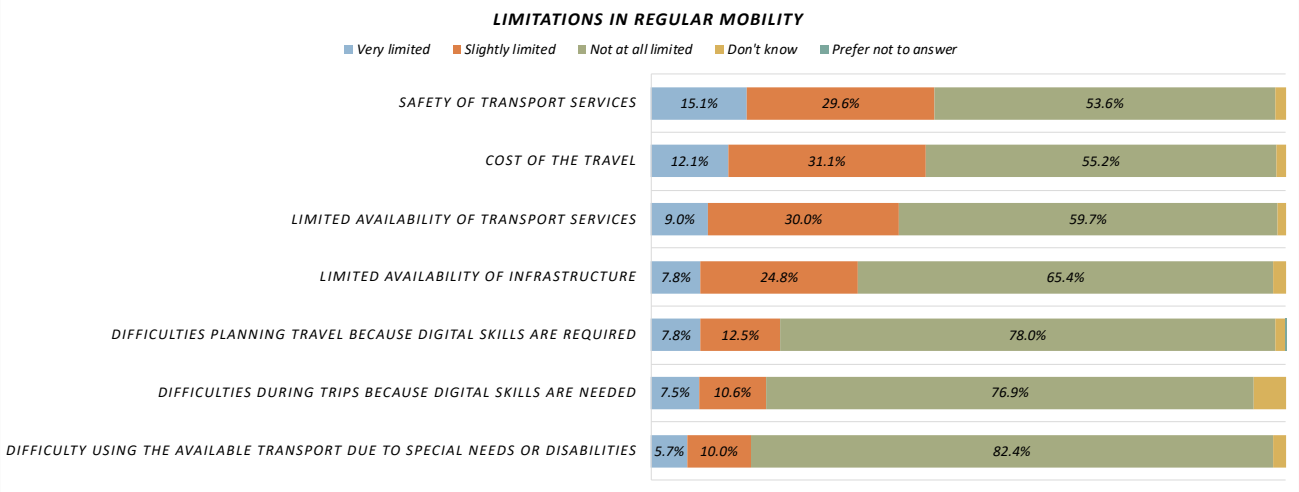

Figure 31. Limitations in regular mobility. [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

Analysing different categories of the listed limitations (Figure 32), in general about 19% of the population doesn't feel limited at all in their regular mobility. On the other hand, up to 81% indicated at least one of the motives that pose some limitations on their daily travelling, with 55% being limited by non-digital reasons, and about 26% being limited by the reasons that have to do with digital capabilities required for travelling.

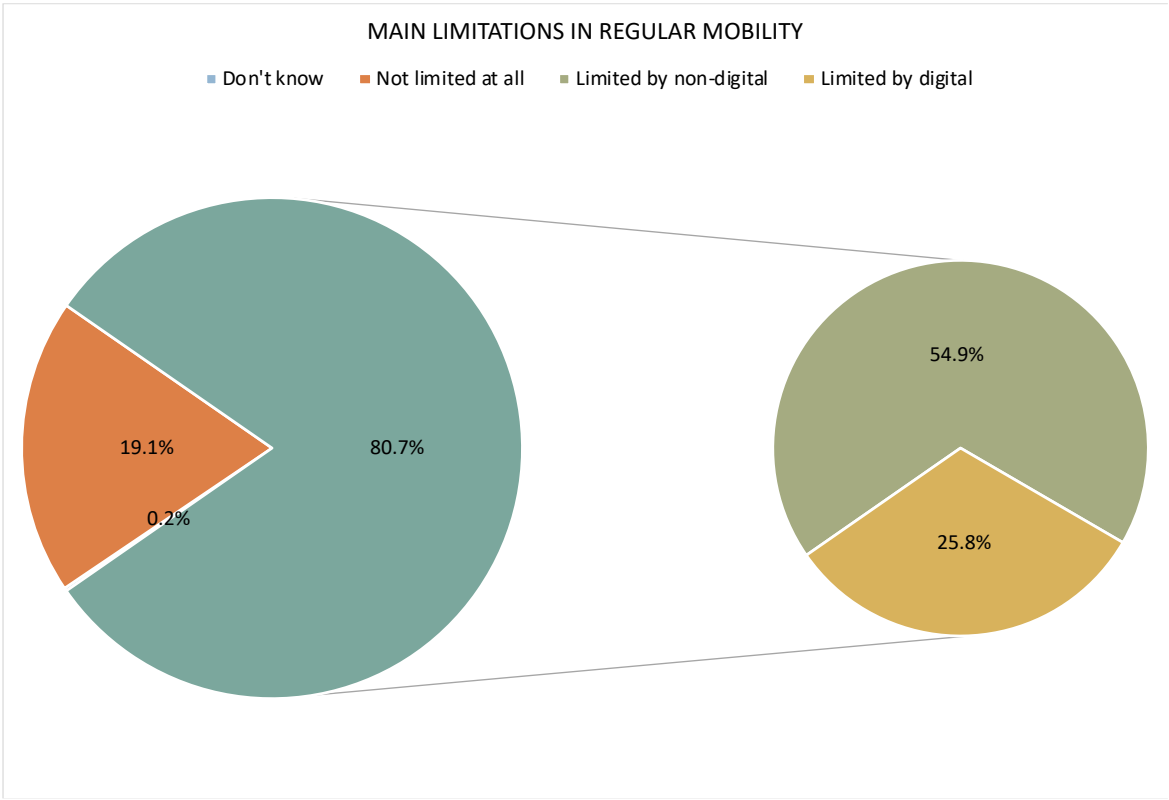

Figure 32. Main limitations in regular mobility by category. **Source: own elaboration.**

Figure 33 analyses the perceived limitations in regular mobility by gender. Safety is the most important of the perceived limitations, with a higher percentage of women very (19.9%) and slightly limited (30.1%) than men; 9.7% and 29.2% respectively (Mann-Whitney U, p = 0.001). On the other hand, 48.4% of females and 59.4% of male answered that they are not limited at all in terms of safety of transport services.

Similar differences can be observed when it comes to limitations due to the cost of the travel, however not that significant ((Mann-Whitney U, p = 0.010). 15.7% of women feel very and 31.7% slightly limited due to that, while 8.3% and 30.6% of men answered the same. On contrary, 51% of females and 59.7% of males reported not being limited by the cost of the travel.

When it comes to limitations which have to do with digital, namely difficulties while planning travel because digital skills are required and difficulties during trips due to digital skills that are needed, there aren't any significant differences that would indicate digital divide based on gender. (Mann-Whitney U, p = 0.642 and p = 0.765 respectively).

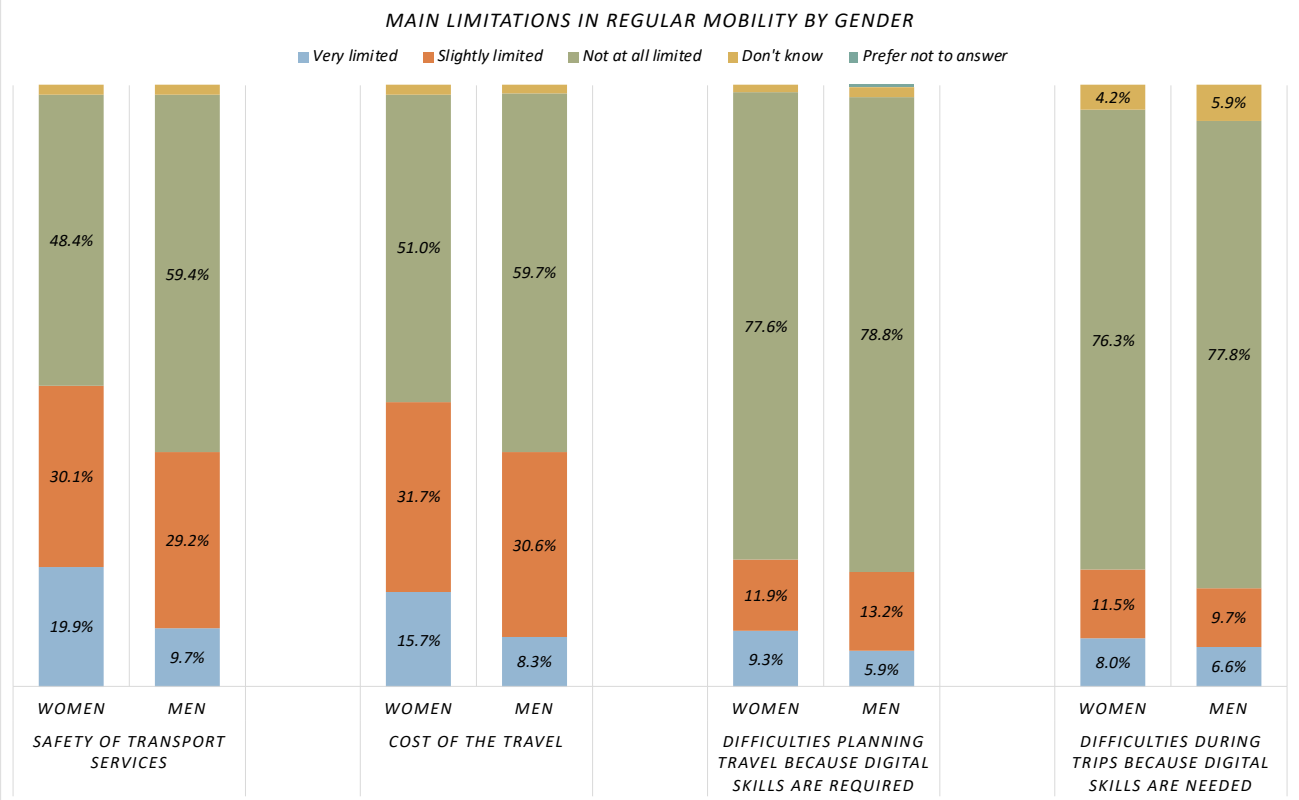

Figure 33. Main limitations in regular mobility by gender. **Source: own elaboration.**

While comparing different age groups (Figure 34), it can be observed that, in general, with age, the limitations increase regarding difficulties in planning (Kruskal-Wallis H, $p < 0.001$) as well as during trips (Kruskal-Wallis H, $p < 0.001$) due to digital skills that are required in order to do so. Conversely, the younger a person is the more it is limited because of the cost of the travel (Kruskal-Wallis H, $p < 0.001$). Interestingly, although the answers suggest that older people could feel more limited by safety of transport services, those differences have been found non-significant (Kruskal-Wallis H, $p = 0.075$).

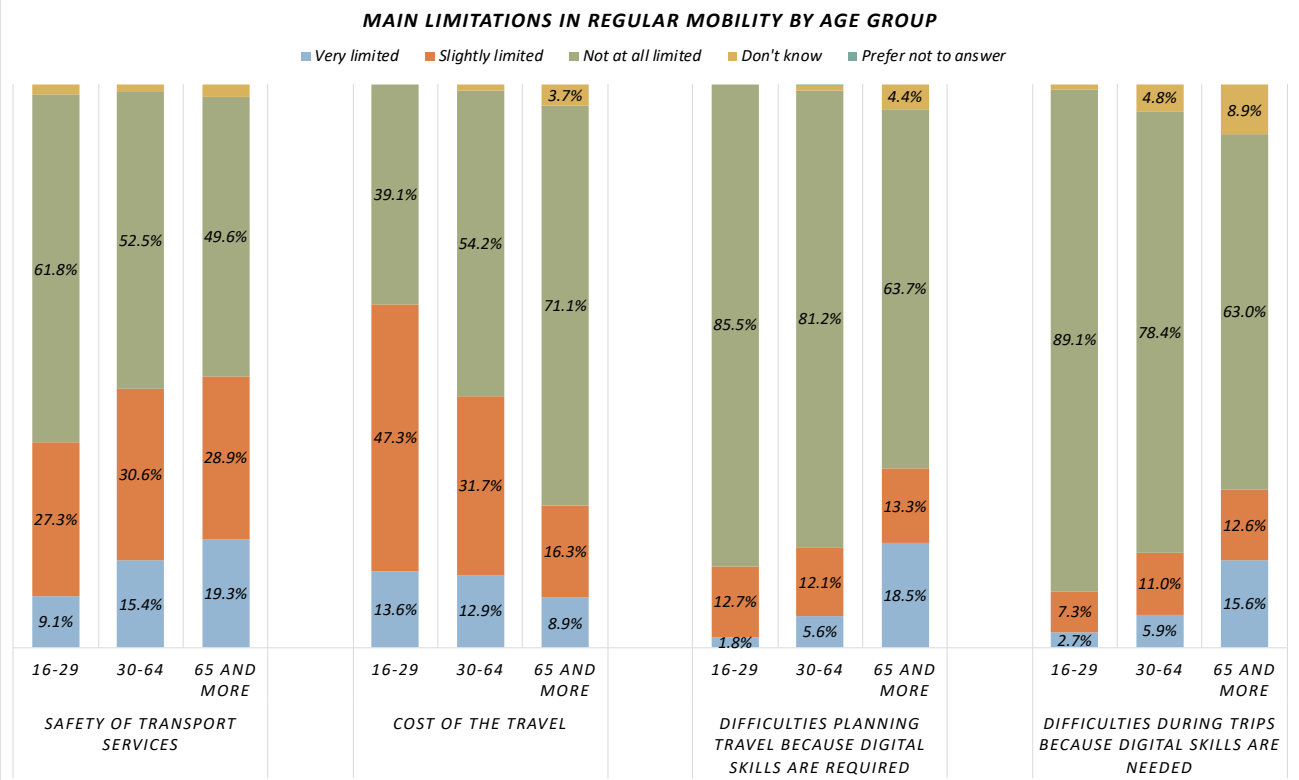

Figure 34. Main limitations in regular mobility by age group. **Source: own elaboration.**

Similarly, significant differences have been observed regarding difficulties in planning (Kruskal-Wallis H, $p < 0.001$) as well as during trips (Kruskal-Wallis H, $p < 0.001$) due to digital skills that are required in order to do so, among people with different education levels (Figure 35). Generally, individuals with lower attainment levels experience more limitations link to lack of digital skills required for using different mobility options than those with higher attainment levels. Secondly, the lower the education level of a person the biggest limitations it experiences regarding the cost of the travel (Kruskal-Wallis H, $p = 0.006$). Finally, there are no significant differences when it comes to limitations concerning safety of transport services among groups with different attainment levels Kruskal-Wallis H, $p = 0.985$).

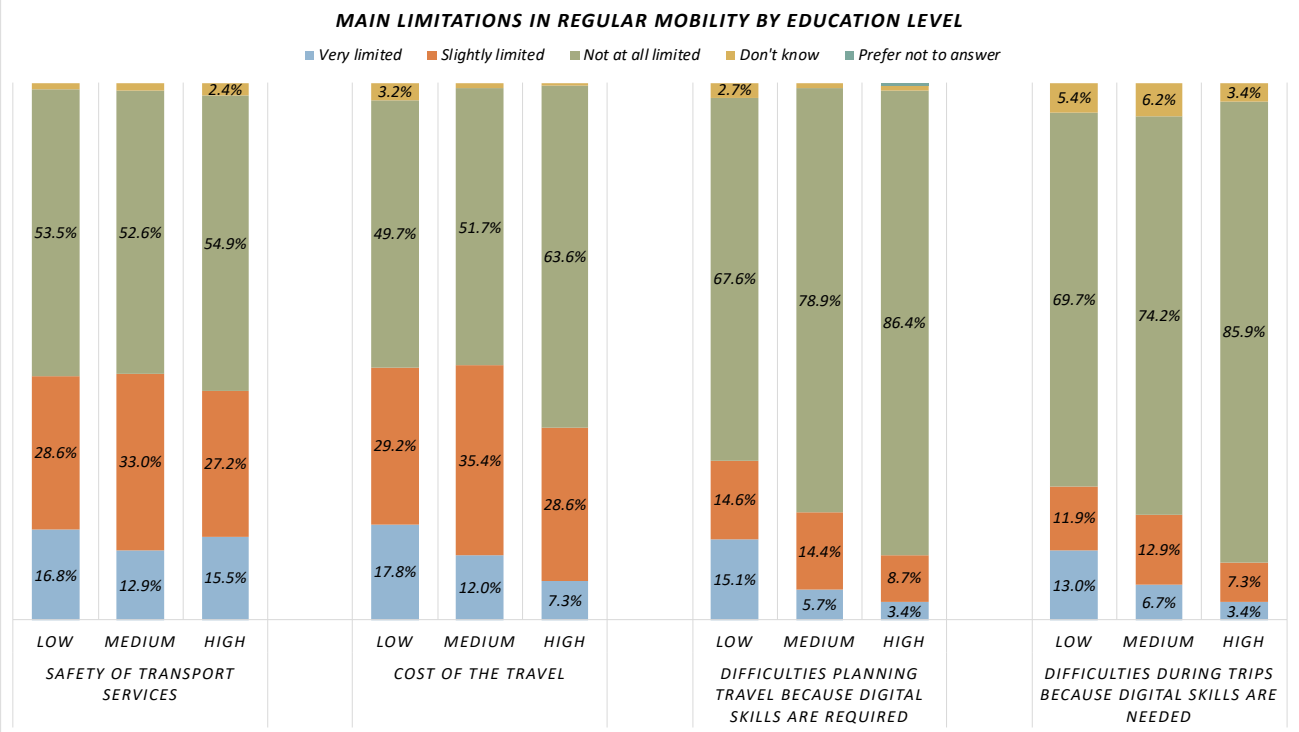

Figure 35. Main limitations in regular mobility by education level. **Source: own elaboration.**

5.4. Digital inequality in transport services and potentially exclusionary effects

Finally, this work analyses digital inequality in transport services and potentially exclusionary effects (Figure 36). Therefore, this paragraph will try to integrate the analysed three intersections, exploring how these dimensions link to each other and summarise the identified digital gaps.

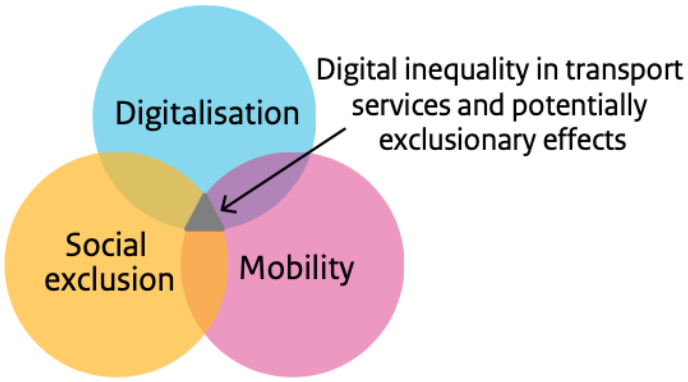

Figure 36. Digital inequality in transport services and potentially exclusionary effects. Source: Durand & Zijlstra, 2020.

First of all, it was observed that about 93% of the AMB population has access to the Internet and 85% owns a smartphone. Furthermore, taking as a base future scenario of digital multimodal mobility systems, which require to use Internet on a smartphone while being on the move, 80% of the residents answered that they do it on a daily basis, while about 14% answered that they have never done it. Moreover, only about 64% of them feel highly confident to plan an unfamiliar local public transport journey using the Internet or an application on a smartphone, while 14% expressed low confidence in doing so. When it comes to main sources of travel information, a considerable percentage of the interviewed answered that they use (82.2%) use at least one digital source to find travel information. On the other hand, 7.3% indicated only non-digital sources and 10.5% of the respondents didn't indicated any travel information source.

This proves that apart from need and motivation for use, and then physical access to technology the attitude and digital skills are crucial, influencing proper uptake of the digitalised mobility services. Consequently, very low levels of uptake of such services were observed, with digital taxi services, digital parking payment and on-street bike hire being among the most popular ones, however still rather infrequently used (only up to 10% of the respondents have used it at least once in the last 3 months preceding the survey). On the other hand, more than 90% have never used car-sharing, carpooling or scooter/motorbike hire. These results show that these novel solutions are still popular and accessible mainly for small part of the society, usually younger, tech-savvy and well-off individuals.

When it comes to the limitations in regular mobility indicated by the respondents, safety of transport services, cost of the travel, as well as limited availability of transport services and transport infrastructure was identified as the most problematic ones. However, up to 20% answered that they feel to some extent limited by difficulties while planning and during the travel because some digital skills are required for it.

Furthermore, regarding the modal split in the AMB, it was observed that about 55% moves actively, about 30% use public transport, but there is still considerable participation of private vehicle use (about 18%). It is stated (Kuttler & Moraglio, 2020) that insufficient availability of public transport is one of the main causes leading to the phenomenon called "forced car ownership" (FCO). It could be experienced by some groups that due to digitalisation in transport services and indicated digital gaps are not able to use new digital solutions and consequently opt for private vehicle instead of mass transit. What is more, in personal situations of low income, car dependency, without realistic alternatives, makes low-income groups highly vulnerable to policies that seek to limit car use (pricing, taxation or a ban on highly polluting old vehicles. Therefore, accessible information about public transport services and equal opportunities to benefit from new technologies is really important to alleviate digital-related disadvantages and at the same time reduce automobile use among vulnerable groups.

Gender

Regarding the differences based on gender; there is no evidence to conclude that women have lower level of access or use less frequently the analysed technologies. However, they indicated feeling less confident while using the Internet or an app on a smartphone to successfully plan an unfamiliar, local public transport journey. Nevertheless, this lack of confidence could be caused by the existing social roles and does not represent differences regarding digital skills. Therefore, further studies exploring the topic of digital capabilities in mobility and possible gaps based on gender are needed. As regards digital mobility services uptake, difference was found only in the case of bike sharing, which are used more frequently by men. Moreover, gender gap was observed concerning use of different transport modes. Women use more frequently public transport while men use more often private vehicle. However, these differences are linked with the social roles and distinct mobility patterns of both genders. Furthermore, women feel more limited than men by safety of transport services and cost of the travel. On the other hand, there is no difference between the two sexes regarding limitations due to digital skills required for planning or during travel.

Age groups

Age is a key factor influencing digital gap. In general, level of access and frequency of use of different technologies decreases with age. In case of accessing Internet on a smartphone, 37% of the ones aged 65 and more answered that they have never done it. In context of the AMB, it traduces to about 100 thousand elderly people, which won't be able to take advantage of some new digital solutions that require accessing Internet on a smartphone while being on the move. Moreover, with age the confidence to plan a trip using the Internet or an application on a smartphone declines, with 40% of the elderly feel very low confident about that. The same is true in the case of sources for transport information, where 21% of older people reported using only non-digital sources and 23% of them didn't indicated any of them. Equivalent tendencies were also observed when it comes to digital mobility services' uptake with more than 90% of elderly that have never used any of them. It proves that the end users of such solutions are still mainly younger residents with more digital capabilities, with higher confidence and better familiarised with the technology. In terms of modal split, the differences are mainly based on distinct roles and activities that people with different ages have. However, high share of active mobility (mainly walking) and low use of public transport can be influenced by digital divide and difficulties that the older people have to make proper use of digital transport services. In regard to their main limitations on regular mobility, they feel more constrained by safety of transport services and difficulties while planning as well as during the trips due to digital skills that are needed than the younger individuals. Conversely, with age perception of limitation due to the cost of travel decreases.

Education level

Just as in the case of age, education level is an important factor that can accentuate digital inequalities in mobility. On the whole, the higher the education level the better the access to the ICTs and the more frequent use of them among the population. The results show that up to 27% of residents with low education levels have never used a smartphone to access the Internet. Moreover, as confidence to plan a trip using the Internet or an application on a smartphone decreases with attainment level, about 25% of the respondents with lower education levels indicated feeling low confident about it. Furthermore, about 17% of those with lower education levels indicated that they use only non-digital sources to look up for travel information – a percentage much lower than among the other two groups. Finally, the uptake of digital mobility services follows the same trend, with the lowest percentage among the ones with lower attainment levels. Regarding the modal split and main motives for regular mobility, the results suggest that people with lower education levels use less private vehicle, more public transport and active modes, as well as make less occupational displacements. Therefore, lack of education among the population could be an important factor that impact regular activity of the individuals and hinder their proper development and opportunities to access a job or schooling. However, these differences are not very significant and further work is needed that would confirm if these differences are factual and exist among the population. Finally, it was observed that with education, limitations regarding cost of the travel, difficulties while planning and during the trip due to digital skills required decreases, while there are no significant differences in perceptions on safety of transport services among people with different education levels.

5.5. The COVID-19 pandemic impact on daily mobility patterns and public opinion on future actions for sustainable mobility plans in the Barcelona Metropolitan Area.

Adding to the already present issues in urban mobility and its diverse users' needs, the COVID-19 pandemic has brought new challenges for future-proofing urban mobility planning. Post-lockdown studies, for instance the one issued by EIT Urban Mobility (2021), report on the main trends: changes in mobility demand, shift in user requirements, and decreases in investments in mobility. However, questions still remain on how the pandemic has impacted the users' attitudes per se, and to what extent the observed changes in mobility demand will continue after this crisis. This paragraph will present the survey results regarding the changes of users' daily mobility patterns, as well as public opinions on the importance of promoting some selected actions for future mobility in the Barcelona metropolitan area. The answers come from the part G – "specific questions about daily mobility" of the questionnaire.

5.5.1. Changes in daily mobility patterns

The questionnaire results reveal that, due to the pandemic, a great number of the population increased their use of active mobility modes, and especially walking, which is good news in regard to future sustainable mobility within more liveable cities. However, some interviewees reported switching to private vehicle use. The most worrying fact is that around half of the respondents decreased their use of public transport. Furthermore, those changes in daily mobility varied depending on the age group and/or education level: in general, the well-off, better educated, and younger groups could afford to change to alternative modes of transport, while some less-advantaged individuals were forced to maintain or even increase use of some transport modes (such as public transport) despite concerns related to social distancing or risk of contagion.

New digital mobility services include carpooling, which aims to be an alternative for private car use and an option for integration into public transport. However, the results show that the great majority did not use, or decreased their use of those digital solutions due to the pandemic crisis. This demonstrates that reduced use of public transport and lack of alternatives could lead to changes towards private transport use and further aggravate the negative effects related to this mode.

Specifically, the results (Figure 37) show that, due to the pandemic, 41.1% of the people resident in the metropolitan area of Barcelona increased their active mobility modes, with 35.8% walking more and 12.1% more frequently riding a bicycle, scooter or other low-speed transportation mode. Conversely, 14% of respondents increased their use of a private car. Moreover, over half (50.2%) of the respondents have decreased their use of public transport. Notably, these changes differed amongst people within different socioeconomic groups.

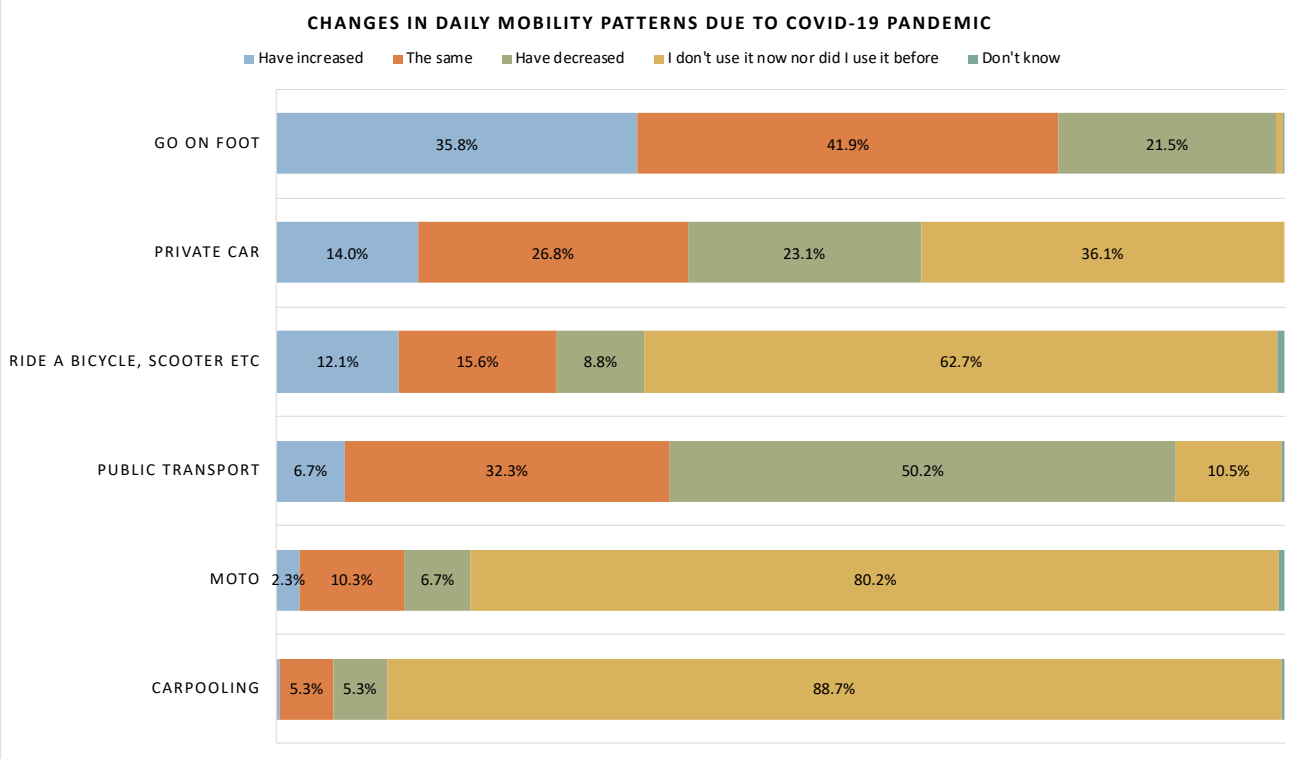

Figure 37. Changes in daily mobility patterns due to the COVID-19 pandemic. [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

5.5.2. Public opinion on future actions

The survey also collected information about the importance that the interviewees assigned to the promotion of different actions for the future, taking into account the crisis of COVID-19. An increase in the provision of public transport to avoid congestion stands out amongst the measures indicated as the most important. This is mainly related to perceived safety at the health level and concerns about the risk of contagion; these are important issues from now on in the context of public transport that have to be addressed with adequate measures, in order to regain the trust and reliability of this fundamental public service, which is essential for a sustainable urban ecosystem. Other future actions indicated as highly relevant were those addressing working conditions: specifically, the flexibility of working hours and an increase of teleworking. Less importance was assigned to measures such as the expansion of bike lanes or the promotion of new shared electric vehicle systems. Finally, the measure with the lowest perceived importance is the ease of driving to work by car.

These insights are very relevant for the post-pandemic life, as they can help authorities to make appropriate decisions on the way to recovery and to transition towards future sustainable mobility. However, the remaining question is how those perceptions will evolve in the longer-term, and to what extent they will shape our future cities.

Regarding the importance that the interviewees assigned to the promotion of different actions in the future (Figure 38), the post-COVID measure highlighted as the one most needed was an increase in the provision of public transport to avoid congestion (83.5%). Other measures considered as highly important were related with working conditions—specifically, the importance of having flexibility of working hours (75.7%) and increased teleworking (73.2%). The promotion of the implementation of contactless transport tickets or the expansion of pedestrian areas were also considered important for the future of cities, with percentages above 60%. The expansion of bike lanes (54%) and the promotion of new shared electric vehicle systems (51.4%) were also considered important, while less importance was given to the ease of driving to work by car (40.4%).

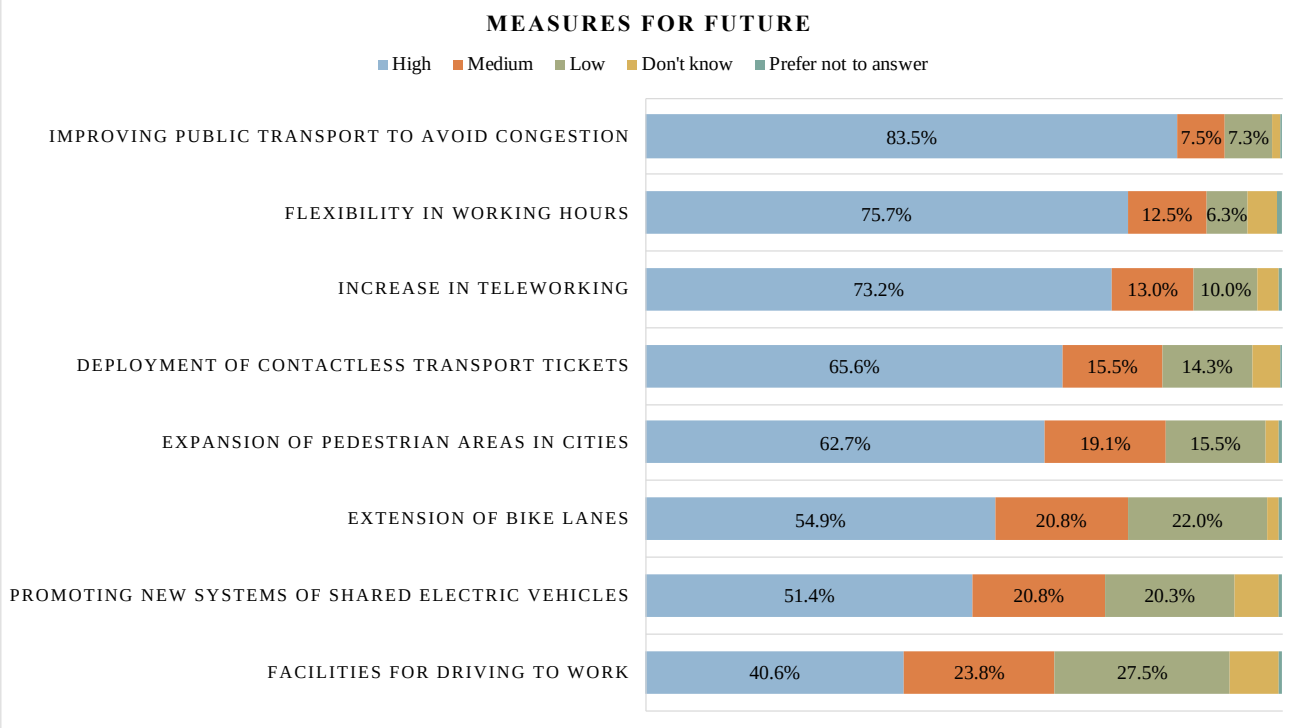

Figure 38. Measures for future. [n = 601, error margin ±4%, significance level = 95%] **Source: own elaboration.**

This case study gives a first overview of the changes in daily mobility of citizens of Barcelona metropolitan area during the pandemic. Public attitudes towards different actions give context-based insights to address future mobility policies for a sustainable transport ecosystem. The study provides interesting insights for policy-makers and transport operators with respect to what measures are considered important by the metropolitan population—valuable information for designing citizen-focused, future-proof urban mobility systems and crucial for sound strategic planning of transport policies.

The case study confirms the information reported in other works regarding changes in mobility demand, and especially, the strong decrease in public transport use. One lesson to be learned that should be highlighted is that shifts in regular travel during the pandemic did not affect all collectives equally and could have aggravated the already existent transport disadvantages amongst different socioeconomic groups. Interestingly, the feedback regarding the importance of promotion of different actions in the future shows that the great majority of respondents indicated that an increase in the provision of public transport to avoid congestion was important. This proves that, despite the strong decline in mass transit during the COVID-19 crisis, the citizens consider this mode of transport as valid, as long as its high level of safety, good quality, and good provision are guaranteed. Moreover, measures enhancing working conditions were considered more important than those related to promotion of new shared mobilities or contactless ticketing.

5.6. Policy recommendations

Based on the analysed literature, the main described concepts and the survey results regarding digital divide among the studied groups, some potential policy recommendations have been identified that could help urban planners, practitioners and transport services operators/providers to create more sustainable, future-proof and inclusive urban mobility ecosystems. What is more, these guidelines for strategies and good practices examples are also based on the work done within the DIGNITY project (DIGNITY, 2020), and insights from the workshops carried-out with representatives of vulnerable-to-exclusion groups, transport services providers and public agents. They are divided into some groups:

End-user:

Transition to sustainable and inclusive cities and mobility systems require initial user requirements and needs assessment. Therefore, it is crucial to put users in the centre, be open and prepare to listen to them and include their specific needs in designing of mobility products and services. It is also important to have strong stakeholder engagement and citizens participation during the planning process.

Policy makers have to ensure that the service provides equal access to all and does not discriminate anyone. However, they have to be aware that there are different groups with different needs, and it is difficult to fulfil all of them. Thus, adaptable solutions, meeting specific person's needs that would enhance accessibility for users are needed.

Urban planners have to understand travel patterns and habits of local users to provide worthwhile services that would meet their requirements and demands. In relation to that, - as indicated in the survey - expansion of pedestrian areas, expansion of bike lanes and promotion of new shared electric vehicle systems are important actions for future sustainable, liveable and inclusive cities.

The citizens have to be provided with clear, accurate and consistent information which would give them the power to make decisions. This info has to cover aspects at various stages of travel as well as before the trip including the fares of services.

Decision makers have to provide an easily accessible and available customer service channel, where different issues, complaints etc. could be addressed. It also should offer assistance at no additional cost for vulnerable collectives e.g., disabled passenger and passengers with reduced mobility.

Technical and business:

Currently, in cities and in the AMB specifically, there are too much agents that provide services. In this context, implementation of innovative solutions, such as Mobility as a Service (MaaS) platform gives policy makers an opportunity to reorganize public transport offer and facilitate use by integration of different transport modes.

However, plans for digital transition needs transparency, appropriate change management, as well as clear and helpful information for users about the predicted adjustments. Moreover, the newly introduced solutions have to be adaptable and accessible for all users. Policy makers have to take into account digital gaps existent in the society and include backup and analogic alternatives in their strategies.

Robust urban plans have to set standards, unify and simplify the information provided to the citizens and make it accessible for all. There is a need for dynamic, actualised, real-time information, which would allow data driven decision-making. This would facilitate supply of reliable services with mechanisms in place to deal with system failures.

Furthermore, it is important to have global vision of the transport service that would embrace all the travel phases that the user experience. Apart from access to the technology, provision of mobility options and awareness of their availability, the final user needs confidence and digital skills in order to make proper use of them. However, there is lack of literature/studies and information concerning this topic. Therefore, in-depth research and development of data collection is required to advance in understanding on different factors hampering universal and equitable uptake of mobility solutions, which would help make appropriate decisions regarding design and deployment of them.

Finally, new forms of public-private cooperation and partnerships are needed that would favour formation of new business models and involvement of start-ups in the mobility market to cover unserved needs.

Safety and security:

Digital mobility services have to be reliable and secure. Therefore, policy makers have to carefully select operators which to work with and make sure end-users are provided with a safe and secure service. Moreover, the privacy policy should be available and accessible to users and be in line with the relevant regulations in terms of data storage and protection.

Regarding user's personal data, regulation has to ensure that it is collected only after explicit and freely given consent. Furthermore, clear explanation of what data is being collected, who is collecting the data and what the data will be used for should be provided. Moreover, a possibility to opt-out from the data collection have to be offered. It is also important to simplify tariff system, implement contactless transport tickets and provide users with secure payment option. However, policy makers have to bear in mind the ones that don't have access to the ICTs or don't own a credit card and provide offline alternatives/low-tech tools that would facilitate use and don't exclude them because of that fact.

Taking into account the pandemic impact and user's concerns regarding risk of contagion, communication campaigns are needed in order to ensure public transport and micromobility recovery. Moreover, actions that would increase provision and improve quality of mass transit are needed. Policy makers should learn from global experiences and best examples of practices applied due to the pandemic, but adapt them to specific local context. They should collaborate and give support to the other cities, by sharing experiences that would facilitate easier and faster decision making against the future problems and difficulties.

Contribution to Sustainable Development Goals (SDGs)

On the way towards sustainable and digitalised mobility ecosystems in the cities, which seek meeting the Paris Agreement, European Green Deal and Agenda 2030 goals it is crucial to integrate the outlined policy recommendations. Their implementation has great potential to contribute to (Figure 39) (UN, 2015):

- SDG 5; achieve gender equality, especially in relation to Target 5.b: Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women.

- SDG 9; build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, especially when it comes to Target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

- SDG 10; Reduce inequalities among societies, in reference to Target 10.7: Facilitate orderly, safe, regular and responsible mobility of people, as well as to Target 10.4: Adopt policies that would contribute to progressively achieve greater equality.

- SDG 11; make cities and human settlements inclusive, safe, resilient and sustainable, relating directly to Target 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons.

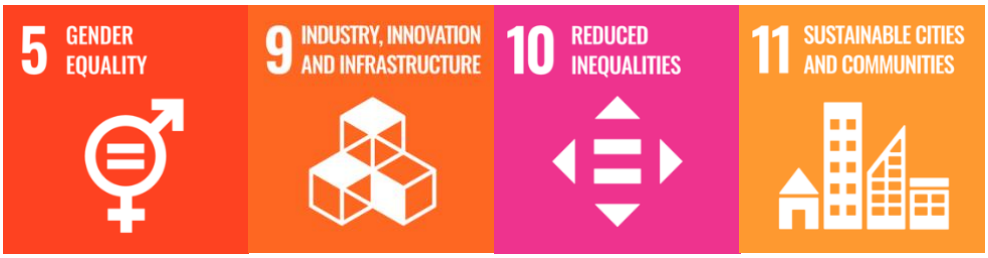

Figure 39. Selected SDGs potentially affected by policies for sustainable and inclusive digital mobility ecosystem. Source: UN, 2015.

6. Conclusions

The main objective of this work was to analyse the digital divide related to the new mobility solutions in the region of the AMB. To that end, the study applied a mixed-method approach, combining a literature review and a quantitative survey data analysis. The project results allow to advance on the understanding of the factors leading to the existing digital gap between mobility service provision and uptake, by different users' groups within the current digital travel ecosystem.

While carrying out literature review it was observed that the great part of the research done till now regarding the matters in question has been focused on each of the topics separately and there is still scarce literature addressing digital divide in mobility in particular. What is more, in context of the AMB, poverty, social exclusion or inequalities from the point of view of mobility and transport are subjects which have not been a notable line of study in recent years by those involved in its operation, organisation or planning. Consequently, there is still very little literature, data and policies concerning those concepts. Therefore, there is a need to make this reality visible and progressively introduce this still incipient dimensions into transport and mobility realm.

Revision of the relevant studies has revealed that the urban ecosystems are complex and interconnected networks where multiple stakeholders, actors and their diverse perspectives and interests makes transition processes complicated. Therefore, interrelated and multi-layered phenomena of digital exclusion and related mobility poverty requires in-depth research in order to be able to understand the nuances affecting it and cannot be solved without collaborative participation of diverse agents. What is more, the actual and also upcoming challenges are putting pressure on local governments to address complex problems with limited resources. Thus, it should be addressed considering a multitude of perspectives and engaging multidisciplinary competencies within a collaborative learning process in order to find alternatives and decide on the most appropriate ones. In the context of mobility challenges, especially when it comes to digital inclusion, it implies that the stakeholders involved looking for innovative solutions must bear in mind all the persons perspectives and requirements, and consider vulnerable collectives needs.

Furthermore, analysis of the qualitative information from the user survey confirmed the problem of potential exclusion related to the mobility in the AMB. Identification of several digital gaps proves that there are large parts of population that cannot access the digital world or lack required knowledge and skills, and consequently they are not able to take advantage of novel transport services. Consequently, very low levels of digital mobility services' uptake were observed which proves that solutions such as carpooling, carsharing etc. are still popular and accessible mainly for small part of the society; usually younger, tech-savvy and well-off individuals. Therefore, in the process of urban mobility planning and design of digital services, it is important to take into account that apart from access to the technology, provision of appropriate mobility options and awareness of their availability, the final user needs confidence and digital skills in order to make proper use of them.

What is more, there are diverse individuals with different needs, patterns of use and attitudes towards digital technologies in mobility. Hence, adaptable solutions, as well as non-digital and low-tech alternatives are needed that would meet specific person's requirements and make mobility ecosystem more inclusive and sustainable.

Furthermore, main groups at risk of digital mobility exclusion have been identified. In the context of the AMB, older people and people with low level of education have been found to be the most affected groups with regard to access to the ICTs and their use, and consequently, the changes that may result from the development of new modes of transport. In addition to that, gender may be an aggravating factor for digital mobility exclusion since women indicated feeling less confident in using technology, and more limited by safety of transport services and cost of the travel than men. On the other hand, no differences between the two sexes have been found regarding limitations due to digital skills required for planning or during travel. Also, females tend to use more sustainable modes of transport what is linked with the social roles and distinct mobility patterns of both genders.

On that account, a better understanding of the relationships among digitalisation in transport services, digital inequality and mobility poverty is required in order to address the exclusion situations that different vulnerable groups might experience. The identified gaps affect the groups that could be the main beneficiaries of new innovative products/services such as transport on demand or shared mobility. However, these solutions are not accessible to vulnerable persons or in excluded areas, but are mostly addressed to general public with digital skills and available in urban areas with a wide range of mobility. Without adequate measures to make new digital means of transport accessible to greater parts of the population exposed to transport related disadvantages and/or mobility poverty, and to empower the most vulnerable, new technological solutions will continue to increase the digital dichotomy between sustainable mobility and social inclusion.

In addition, urban mobility needs adequate actions for future, taking into account its current challenges, as well as the COVID-19 pandemic impact. In this sense, it will be important to address certain aspects, such as improvement of public transport, with particular attention to categories such as women and older persons, who represent a significant percentage of users. Regaining the trust and reliability of this fundamental public service is essential for a sustainable urban ecosystem since reduced use of public transport and lack of alternatives could lead to changes towards private transport use and further aggravate the negative effects of externalities related to this mode. Other important measure for future is the promotion of working conditions that recognize the flexibility of working hours and the possibility of working remotely. These factors will in turn lead to important changes in the design of services to be offered and in the conditions of provision of the public transport service.

Finally, the project results provide valuable insights on the requirements that digitalisation in mobility imply for different types of users and its potentially exclusionary effects. In order to mitigate them, strategies for bridging the digital divide need to be multidimensional, including technological, economic, educational, social and persuasive aspects. Moreover, they have to reduce social and digital inequality at once. Therefore, based on the carried-out analysis, some policy recommendations for urban planners, practitioners and transport services operators/providers have been outlined, which have a great potential to help create a sustainable, future-proof and inclusive urban mobility ecosystem.

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