Gender, Smart Mobility and COVID-19

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Abstract.

The COVID-19 pandemic has strongly impacted people's main routine, which certainly includes their mobility habits. This paper aims to assess the pandemic's mobility impacts and whether these may have increased the already existing inequality between men and women. In particular, the variation of mode choice in a pre-COVID and post-COVID scenario is investigated, focusing on the use of transport mode defined as Smart Mobility. The analysis is performed on data collected in thirteen European countries between July and September 2020 through a survey designed using an intersectional approach. Responses are analyzed to highlight correlations between different factors affecting mobility changes: some interest is reserved to the modes used according to the journey scope (work, errand, shopping). Overall, results reveal more people walking for their daily journeys, while a significant decrease in the use of public transport is observed. Although these changes affect women more, the main reason behind this is the need for more safety in terms of low risk of contagion, irrespective of gender. A specific focus on using modes commonly associated with a Smart Mobility offer (such as shared modes, public transport, walking, and biking) reveals differences originating when comparing men and women responses and various age ranges.

Keywords: Gender balance, Smart Mobility, COVID-19, mobility survey.

1 Introduction

The impact of the COVID-19 pandemic on the world of transport and mobility has been significant, following the measures that have required many businesses' closure, forcing people to stay at home to reduce the risk of contagion. These measures have been

demonstrated to be necessary for limiting contacts and have influenced travel behaviors, mainly in public transport use, due to the lower level of health security perceived associated with specific means of transport and crowded places [1].

Transport systems in most cities were able to cope with the pandemic's immediate challenges, but some adverse effects have been observed. Unequal access to transit, which is commonly affecting users such as people with disabilities, has been exacerbated in the emergency period [2]. Many cities are widely characterized by limited spaces for pedestrians and cyclists in their urban planning. However, cycling and walking can be seen as a great way to stay healthy facing, for example, the closure of gyms in many cities. These two modes are also an effective way to support physical distancing and relieve public transport burden during a pandemic [3].

Also, it is worth investigating how this crisis affected shared modes (as car sharing or bikesharing) that have started to populate the cities in the last decades and how these services are linked with characteristics such as gender and age. The use of these means, which, for the same definition of being shared, would imply treating specific cleaning and sterilizing approaches to avoid infection risk, seems to be perceived as a safer alternative for traveling.

The current work fits into the European TInnGO (Transport Innovation Gender Observatory) project framework, which deals with gender inequalities in smart mobility opportunities and transport employment. The project's primary goal is to create a mechanism for a sustainable game change in European transport through the transformative strategy of gender and diversity-sensitive Smart Mobility (SM) [4]. TInnGO also acts by creating a network of 10 national Hubs in 13 different European countries: each Hub addresses issues of local importance in gender and diversity sensitive Smart Mobility. This latter has become a buzzword of the 21st century; it involves four main contents, such as "vehicle technology, Intelligent Transport Systems, data, and new mobility services" [5].

Smart Mobility, although just one component of a smart city, is seen as a means of delivering key benefits such as reducing air and noise pollution, traffic congestion, transfer costs, increasing transport safety and improving transfer speed [6]. Moreover, it is commonly associated with the offer of various mobility options and services such as on-demand ride services, real-time ridesharing services, car- and bike-sharing programs, multimodal trip-planning apps, smart traffic control, up to the self-driving vehicles concept [7]. Many of these themes have been catapulted to the discussion about urban mobility during (and in the future after) the pandemic. Transport systems have been asked to become "smart", as citizens are changing their commuting preferences to adapt to a new way of life where main changes include people distancing and crowds reduction.

The present paper aims to shed light on how the COVID-19 emergency influences mobility choices (also the "smart" ones) of women and men in Europe, highlighting inequalities. This is done by intersecting users' profiles (gender, age, work status before and after COVID-19) with their mobility patterns and mode choice in the pre- and post-COVID scenario. Additionally, this study will analyze the stated reasons behind these changes and the connection between mode choice, gender, and caregiving roles. Understanding how mobility habits changed during the pandemic and the reasons behind,

and analyzing the differences in men and women's behavior is crucial for planning the reboot of cities' transport services consistent with future needs.

The paper is structured as follows: the next section will try to correlate known women's mobility habits with the restrictions due to the COVID-19 emergency, with particular attention to the Smart Mobility concepts. The methodology and the data collection procedure will be described in section 3. Then, the results obtained through analyses correlating various respondents' characteristics are presented in section 4. Finally, conclusions will discuss and elaborate on the impact and implications of this work.

2 Women's mobility habits and COVID-19 emergency

Previous studies have shown that different user characteristics, including social roles rooted in society, lead to different activity patterns and a gender mobility gap. Women are known to use Public Transport (PT) more than men, who in a traditional society make commuting trips by car and get the first right to car usage in a household [8]. However, during the pandemic, governments and local authorities implemented restriction measures to reduce the use of PT, as their overcrowding represents a high-level risk of contagion [9]. Thus, women's mobility might be more affected by COVID-19 because they are more frequent public transport users than men [10].

While many employers can rely on smart working, reducing their journeys only to necessary food shopping, other essential service personnel, such as healthcare (hospitals and pharmacies), have continued their trips to the workplaces. In such a context, it is relevant to highlight the differences between genders in the presence in the labor market's different sectors to characterize, for example, the PT users. As stated in [11], women make up almost 70% of the healthcare workforce, so they have to reach hospitals and other care facilities during the emergency. Thus, they are asked to arrive at their workplace, possibly trying to reduce contagion risk. In this context, it is interesting to see if they are willing to rely on the same means they were used to as in the pre-COVID situation.

In general, it is observed that, in need of moving during the emergency, people favored to travel with modes that guaranteed adequate physical distancing, such as cycling, walking, or private cars. At the same time, there was a drop in transit and shared transport use [9]. However, these changes in the mode choices need to be investigated more in detail. Research conducted before the COVID pandemic revealed that gender seems to affect the interest towards various transport means differently. For example, women are commonly not seen as frequent cyclists, mainly due to significant safety concerns and family burden issues [8]. These elements seem to influence bike-sharing services, too; a considerable number of male users commonly characterizes them due to the design of the bikes themselves and the absence of baby saddles that would prevent women from relying on this service [12–14]. However, the changes observed in the city affected by restrictions, as the creation of pop-up bike lanes, with the potential to become permanent cycling infrastructure [3], and a reduced number of cars traveling around, could draw more women to this means of transport. Moreover, the need to

travel just for 'mandatory' trips (to reach workplaces or for caring issues), namely without dependents as in the pre-COVID situation, could influence these mobility choices.

As mentioned in the previous section, the ultimate goal of introducing the Smart Mobility concept in the cities is reducing traffic and pollution. So, introducing proper infrastructures, such as new bike lanes, could be seen as a relevant measure to reach a low level of congestion and make citizens flow more fluid. The sharing of vehicles and modes, on-demand services, and micro-mobility are other potential answers of Smart Mobility to environmental and personal sustainability problems. Car sharing systems, a real presence in the SM framework, are commonly characterized by a lower frequency of female users than males. The main features of people joining this service are somewhat similar, despite the gender [15].

Moreover, the costs of car sharing compared to car ownership could play a more significant role for women than for men [16], mainly because the former commonly drive a household's second car and the use of this service could be less expensive than buying a second car [17]. The shared modes seem to have been able to face the change in mobility choices associated with the pandemic better than other means. For example, a report shows that after the first lockdown in Italy in March – April 2020, car sharing had a relatively low recovery in May with only 30% points more compared to the previous months. However, shared bikes and e-scooters showed a more consistent increase, respectively, 60 and 70% more, reaching almost the pre-Covid-19 levels of use [18].

While the female interest in bike-sharing systems has already been cited, the spread of e-scooters and their shared offer is a relatively new trend in urban mobility. This micro-mobility mode has seen a significant increase in association with the pandemic travel restriction, as they are sustainable individual means of transport. A reduced number of studies have investigated the differences in users' gender so far, but some preliminary results are available. For example, research conducted in a big German city showed that three-quarters of the e-scooter sharing customers are male [19]. Moreover, the distribution of ride lengths proves that gender hardly has any influence on usage patterns.

Ride-hailing and on-demand services are other modes in the SM domain that have gained a lot of success in pre-COVID cities worldwide. Despite the fear of traveling with unknown people, women seemed interested in the service. A reduced number of studies has focused on the impacts of ride-sourcing. Still, there have been reports of some considerable safety setbacks as cases of drivers sexually assaulting female passengers have emerged from across the globe [7]. The bad experiences reported have led to increasing demand for safe transport services. Many women-only ride-hailing services (exclusively for females drivers and passengers) have been launched in various countries [7]. Besides, SM could provide a useful contribution, as technology can increase accountability for crimes committed. GPS tracking, trip arrangement through apps, driver and rider feedback, and law enforcement outreach are examples of actions that could be of interest for potential female customers [20]. Compared to other modes in the SM offer, ride-hailing seems to be the service that could be more affected by the fear of contagion: this puts a strain on the sense of trust towards peers commonly required by this type of platform.

The provided overview on mobility habits gendered differences is mainly based on the pre-COVID scenario. A low number of studies are currently focusing on this topic in the post-COVID scenario, whereas some investigations on the general trends on the influence of the emergency on travel behavior are already available. A fundamental point that must be taken into account while conducting these investigations is considering the employment dynamics changes due to the COVID-19 pandemic. As already cited, people have switched to smart working as much as possible following the measures to reduce contacts. However, differences between the genders are found in this context, which would inevitably reflect their mobility. As highlighted in [10], women "will likely experience a significant burden on their time given their multiple care responsibilities as school closures and confinement measures are adopted, possibly leading to reductions in working time and permanent exit from the labor market".

A study conducted in Nederland has already highlighted these differences [21], looking at the distribution between men and women across different professions and estimating the effects of restriction measures. The authors estimated that more than 50% of the men were probably still traveling for their commuting, while this percentage reduced 10 points in women's cases. They also tried to evaluate the distribution of people who stayed at home or were temporarily out of work due to the COVID-19 crisis, saying that it can assess to 21% in the female population, reducing to only 10% among men. The disproportionate impact due to lockdown measures on women, which reduced their mobility more than men, has been verified in this study [22], based on the analysis of mobility indicators derived from anonymized and aggregated data provided by a mobile phone operator. In this case, the authors recognized that the travel patterns' differences are mainly because of the uneven burden in caring for children when schools are closed. They raised the attention to the need for targeted policy intervention to support women during the pandemic, for example, by offering parental leave to both men and women to encourage equal dependents' care, joining with more campaigning and supportive activities connected to the workplaces.

Despite these latter aspects being far from the focus and the current paper's scope, we think it is necessary to consider when analyzing mobility changes due to an exceptional situation like a pandemic affecting peoples worldwide. Thus, in the following, we will present an analysis of a dataset collected at the European level to relate how this pandemic affected women's mobility patterns also in connection with job changes.

3 Methodology

The spread of mobility surveys has gained more importance in a period with cities affected by a worldwide pandemic that it is expected to produce considerable changes in daily life and travel patterns. One of the TInnGO project aims is to investigate possible barriers and potential improvements that could help operators create a better and more gender-equal transport system. This knowledge was planned to be gained through a data collection procedure based on a survey investigating which aspects can be modeled to explain and predict mobility choices. Focus group analyses and a detailed literature review were conducted as preliminary activities to the questionnaire design [8]. These

allowed to collect information on particular users' mobility needs, gain new knowledge of possible barriers and potential improvements to help transport operators improve their services.

According to the project-planned activities, the data collection campaign was planned to be started in the TInnGO Hubs cities in spring 2020. However, the COVID emergency forced a delay in the data collection and pushed us to reconsider the original plans. Indeed, expecting that the pandemic would produce changes in people's mobility habits, the typical journey characteristics have been investigated in a pre-COVID scenario and in a post-COVID one. This could provide insights into how the emergency changed the mobility scenario, how it could affect different kinds of users, and highlight potential improvements to help transport operators manage city mobility in the future. It is relevant to observe that the reference to what we call 'a post-COVID scenario' does not aim at investigating future intentions but is associated with the condition of life after the worldwide spread of the virus. Thus, the objective is to understand how the respondents have changed their mobility habits due to the cohabiting with the COVID-19.

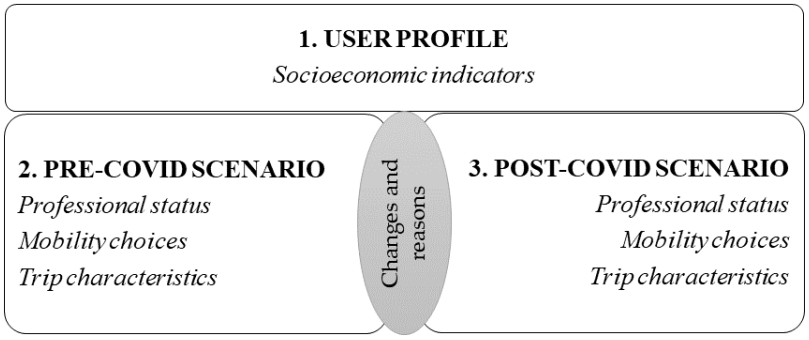


Fig. 1. The survey structure.

Before the data collection procedure, the survey structure has been reviewed by the TInnGO Project coordinator (namely Coventry University) to check its compliance with the University's ethical framework. It has been approved through a formal Research Ethics procedure confirming that it is GDPR-compliant too. The respondents are informed about all these points before participating in the survey. They are told that their answers are anonymous and treated confidentially and the information they provide is kept anonymous in any research outputs and publications.

The survey structure can be depicted in Fig. 1. As it can be observed, the first part of the questionnaire aims to outline the respondent profile, investigating her/his socio-economics characteristics, such as gender, age, social level, education, ethnic origin, family composition, sexual orientation, accessibility to car use. The focus on specific questions, such as "*Do you have children living in your household?*", "*In your family*

unit, do you live with any dependent person?" and "*Which, if any, of the following disabilities do you have?*", have the objective of better understanding specific user groups' mobility characteristics, according to the literature review and the focus group activities operated in [8].

The focus then goes on to the analysis of typical travel patterns and how they have been affected by the COVID emergency. The respondents have to state which mode they used the most (e.g., motorized and non-motorized, owned, and shared) for different activities (e.g., job, commuting, shopping) in a pre- and post-COVID scenario. Obviously, the possibility of not conducting certain kinds of journeys is proposed as a possible answer. For these cases, a specific question tries to understand the motivation behind this choice: "*Which are the reasons behind your changes in the modes used?*", including safety, sustainability, and planning issues.

Regarding the trip characteristics, the questionnaire aims to collect a better characterization of the transport chain (activity patterns) to assess possible differences between women and men as reported in the literature. This is done through asking explicitly: "*Do you use to travel with a dependent person on this trip? (children, elderly, caring for disabled people)*", "*Do you use to stop regularly along this journey?", "What are the reasons for these stops?*". On the whole, some details about the accessibility to all the possible means of transport are required.

As highlighted in the previous sections, it is necessary to relate how this pandemic affected women's jobs in their mobility patterns. As seen in Fig. 1, changes in the professional status and the organization of respondents' work are investigated. For example, have they chosen some lay-off or part-time? Was the taking care of children and household chores equally distributed in the household?

The data collection activity has been opened from July to September 2020, intending to collect the first wave of a limited number of results in the 10 TInnGO Hubs' working-age population. This allows having insights into the effects of the pandemic on mobility patterns in cities with different restrictions during a so-called *1st lockdown* in Europe. The investigation of the responses collected in 13 EU countries, each of them facing the COVID-19 emergency at various moments and, sometimes, in not uniform ways, can provide a broader view of the pandemic's impact on users' mobility patterns. At the same time, it is well known that the situation influenced employment, producing, for example, an increase in the commonly known inequality.

4 Results and discussions

4.1 Sample characterization

The data collected refer to 208 European respondents, 57% of which were women. The results analysed in this paper are related to the preliminary phases of a more extensive study that will broaden the survey to a much larger sample (around 4000 answers expected). Table 1 provides an overview of the sample's socioeconomic characteristics (section 1 in Fig.1). The respondents are from different European countries: Portugal, Spain, France, Italy, United Kingdom, Germany, Sweden, Denmark, Romania, Greece,

Lithuania, Latvia, Estonia. The TInnGO partners conducted the survey campaign through their personal contacts, professional contacts and social media, thus resulting in a good majority of respondents in the age ranges 25-34 (37%) and 35-44 (26%), mainly with a high-level education (Degree, Master or Doctorate). The investigation on the residential area type revealed a great majority of respondents living in an urban environment (74% of answers), with only 6% of them declaring a rural one. Table 2 shows the sample's breakdown according to age and gender; the respondents in the age ranges 25-34 are mainly women, while the balance is greater for the other age ranges.

Table 1. Descriptive statistics on socioeconomics characteristics of the respondents.

Feature	Choices	%
Age bracket	18-24 years	14
	25-34 years	37
	35-44 years	26
	45-54 years	11
	55-64 years	7
	65-74 years	3
	>75 years	2
Children in the HH	No	64
	1	17
	2	16
	3	3
Dependent person	No	71
	Preschool age children (under 5 years)	13
	School age children (5-10 years)	10
	School age children (10-16 years)	12
	Elderly relative	1
Residence area type	Urban	74
	Suburban	20
	Rural	6
Level of education	Secondary	13
	Degree	15
	Master	46
	Doctorate	23
	Other	3

Table 2. Age and gender characteristics of the respondents

Age/Gender	Female	Male	Prefer not to answer	
18-24 years	13	17		30
25-34 years	47	29	1	77
35-44 years	27	28		55
45-54 years	17	6		23
55-64 years	9	6		15
65-74 years	3	4		7
>75 years	1			1
	117	90	1	208

4.2 Pre-COVID scenario

As could also be expected based on the respondents' age, most of them stated that they worked in an office in the pre-COVID scenario, around 70% of answers (Table 3). It also emerges that the proportion of women working remotely, self-employed or unemployed, is higher than that of men, although this difference is relatively marginal. The overview of professional status distribution is essential since, as pointed out above, employment status can influence mobility choices, especially in the pandemic scenario.

Table 3. Professional status in pre-COVID scenario

Professional status pre-COVID	Female	Male
Paid employment - Working in an office/plant	70%	72%
Paid employment - Working remotely	5%	4%
Paid employment - Parental leave	1%	1%
Paid employment - Lay-off	0%	0%
Self-employed	7%	4%
Non-paid work	2%	0%
Student	11%	14%
Homemaker	1%	0%
Retired	2%	1%
Unemployed (health reason)	0%	0%
Unemployed (other reason)	2%	1%
Prefer not to answer	0%	1%
DK/NA	0%	0%
Other	0%	0%

The focus goes on users' mobility habits, distinguishing the answers according to gender to highlight peculiarities and possible differences. In the pre-COVID scenario, the most used mode of transport for each activity is investigated and the results are reported in Table 4 separately for women and men. The only respondent that preferred not to declare her/his gender was excluded from this analysis.

Table 4. Mobility habits according to gender and scope (pre-COVID scenario)

Mobility habits pre-COVID [%]		Private car/moto	Shared bikes	Owned bikes	PT	Shared modes	Walking	Other
Job/university/school	F	41	1	15	30	2	7	5
	M	40	3	15	25	0	17	0
Visiting people another town	F	55	0	3	33	3	4	2
	M	55	0	6	32	0	4	4
Running an errand	F	39	1	14	10	3	32	1
	M	41	1	14	17	0	26	1
Out dinner	F	32	2	10	21	3	29	3
	M	32	0	11	19	3	33	1
Tourism	F	21	3	17	24	2	32	1
	M	23	2	13	21	0	39	1
Tourism other city	F	38	2	0	32	3	23	2
	M	49	0	0	28	0	20	3
Groceries	F	41	3	11	3	2	39	1
	M	34	2	8	7	0	48	1
Shopping center	F	56	0	10	21	1	11	2
	M	59	2	6	20	0	13	0
Weekend activities	F	47	2	15	20	2	14	2
	M	50	1	16	21	1	10	1

In general, the private vehicle is the most frequently chosen means of transport, especially for visiting a shopping center, while the second choice is walking. This being said, it emerges, however, in line with what is found in the literature, that men are more likely both to use a private vehicle and to walk. On the other hand, women seem more inclined to use local public transport except to run an errand or go shopping. Sharing solutions seem to be of little attraction to both women and men at less than 3%. More than 70% of the respondents stated that they work in an office (Table 3), so it is interesting to focus on the mobility habits to get to the workplace, which is most probably the main journey. Preferences are quite similar between men and women: the first

choice is the private car with, respectively, 40 and 41% of answers, followed by public transport with 25 and 30%. The following options are different, with 17% of men saying they walk and 15% using their bicycles; women, on the other hand, prefer to cycle with 15% and walk with 7%.

4.3 Post-COVID scenario

Excluding the 28% of respondents who do not know or cannot answer, 38% of them work remotely, whereas 35% declare going to the office in the post-COVID scenario. As might be expected, these two percentages are very different from the pre-pandemic scenario in which 71% of respondents went to the office, and only 5% worked smart. Interestingly, in the pre-pandemic, no respondents had selected the DK/NA option; probably this is linked to the still uncertain situation in Europe in the survey period (July-September 2020). Table 5 reports the detailed percentage distribution of replies according to gender and the variation from the declared answers for the pre-COVID scenario.

Table 5. Professional status in post-COVID scenario and variation from pre-COVID one.

Professional status post-COVID [%]	Female	Variation	Male	Variation
Paid employment - Working in an office/plant	28	-42	21	-51
Paid employment - Working remotely	26	21	29	24
Paid employment - Parental leave	0	-1	1	0
Paid employment - Lay-off	0	0	0	0
Self-employed	5	-2	0	-4
Non-paid work	2	0	0	0
Student	4	-7	11	-3
Homemaker	0	-1	0	0
Retired	1	-1	1	0
Unemployed (health reason)	0	0	0	0
Unemployed (other reason)	2	0	2	1
Prefer not to answer	0	0	0	-1
DK/NA	30	30	24	24
Other	0	0	0	0

The mobility habits in post-COVID are expected to change according to different governmental choices to limit non-essential travel. Countries across Europe have significantly limited public life in order to stop the spread of the COVID-19 outbreak. In Italy, France, Belgium, and Spain, for example, people are only permitted to leave the house for health reasons or for going grocery shopping. Instead, Germany and Portugal have opted for less restrictive measures, advising to limit unnecessary travel. Sweden,

on the other hand, has not imposed severe lockdowns, for example, but adviced people to work from home and avoid crowded public transport.

A possible additional answer, "*I stopped making this trip*", has been introduced to consider that a specific type of journey is no longer carried out. As shown in Table 6, women and men stopped moving mainly for tourism to other cities (24% and 26%), to go to the shopping center (21% and 19%), and to go out to dinner (16% and 20%).

Table 6. Mobility habits according to gender and scope (post-COVID scenario)

Mobility habits post-COVID [%]		Private veh.	Shared bikes	Owned bikes	PT	Shared modes	Walking	Other	I stopped making this trip
Job/university/school	F	38	3	15	12	1	9	9	14
	M	41	1	10	12	0	18	4	13
Visiting people another town	F	55	1	11	11	2	8	3	9
	M	59	2	4	12	1	7	3	11
Running an errand	F	37	1	15	6	0	37	3	3
	M	44	1	18	6	1	27	1	2
Out dinner	F	28	1	9	12	1	28	4	16
	M	32	0	9	9	1	27	2	20
Tourism	F	17	3	13	11	0	37	3	16
	M	21	4	14	6	0	38	3	13
Tourism other city	F	39	2	4	13	0	14	4	24
	M	38	1	1	10	1	19	4	26
Groceries	F	36	0	11	1	1	44	3	4
	M	40	0	10	4	1	43	1	0
Shopping centre	F	44	0	7	11	0	12	4	21
	M	50	0	8	12	1	8	2	19
Weekend activities	F	45	1	16	10	0	18	3	6
	M	49	1	18	7	0	18	3	4

4.4 COVID impacts on mobility patterns

Having analyzed the main elements in the pre- and post-COVID scenario about mobility habits disaggregated by gender, in this section the particular aspects of the declared changes are reported and discussed. As shown in Table 7, 62% of the women inter-

viewed stated that they had not changed their professional status but their mobility habits. A similar situation occurs among male respondents, of whom 63% have not changed their job, but 64% have changed their travel choices.

In particular, filtering out the positive responses to the job change, it emerges that the COVID-19 emergency brought changes in the professional situation mainly due to the necessity of starting to work remotely (71% of respondents), but this affected women and men differently, with this percentage coming to 68 and 75, respectively.

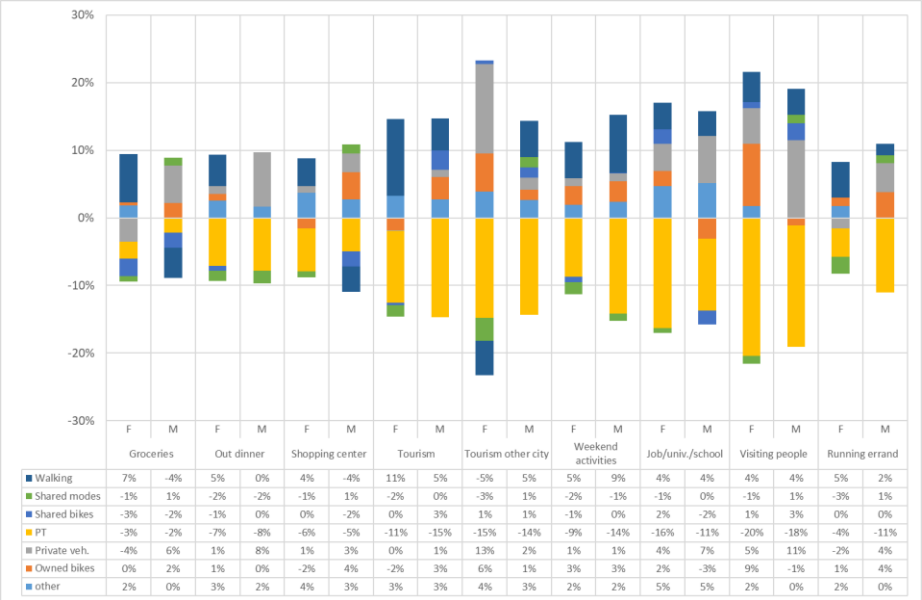
Table 7. Change in professional status and mobility habits based on gender and age

	Change Professional Status		Change Mobility Habits	
	Female	Male	Female	Male
No	62%	63%	38%	36%
Of which				
18-24 years	15%	23%	2%	26%
25-34 years	36%	26%	43%	23%
35-44 years	22%	28%	27%	32%
45-54 years	16%	9%	18%	10%
55-64 years	8%	9%	7%	6%
65-74 years	1%	5%	2%	3%
>75 years	1%	0%	0%	0%
Yes	38%	37%	62%	64%
Of which				
18-24 years	5%	9%	15%	16%
25-34 years	48%	32%	38%	36%
35-44 years	25%	27%	21%	30%
45-54 years	11%	2%	13%	5%
55-64 years	7%	2%	8%	7%
65-74 years	5%	2%	3%	5%
>75 years	0%	0%	1%	0%

Most people, as expected, changed their travel choices, and the graph in Fig. 2 shows the percentage changes between the pre- and post-COVID scenarios net of those who said they would no longer make that journey.

It clearly emerges that public transport (yellow bar in Fig. 2) is the mode that has been most affected by the changes in mobility due to the spread of the pandemic, probably because it is considered unsafe in terms of infection. Women were found to be the primary users of this transport solution (Table 4), and indeed they are the ones who report the main changes, especially for work-related trips. Sharing modes of transport, which are already little used, decreased further regardless of the gender. On the other

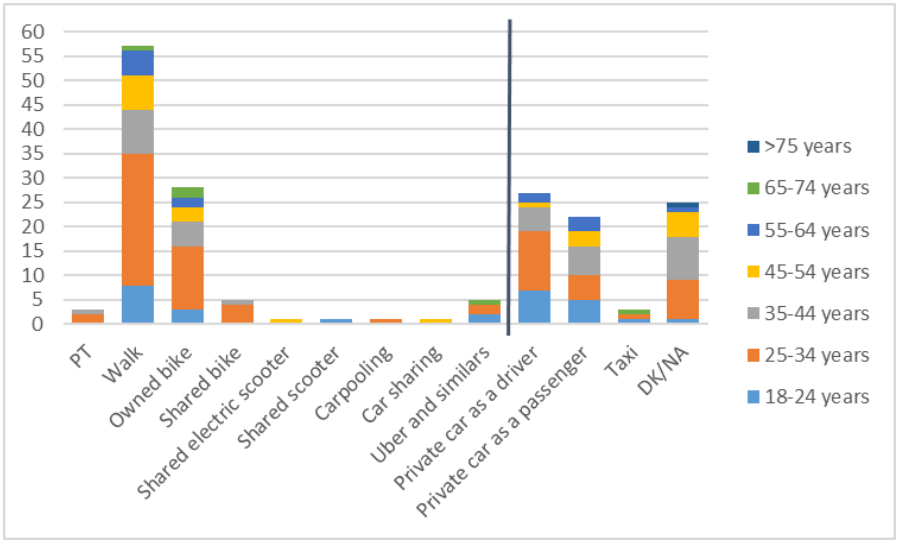
hand, private transport (cars and bicycles) or walking have increased, but not homogeneously by gender or purpose. For example, women started to walk for many of their activities, more than men, with an increase of 7% for shopping for groceries or 11% for tourism in their city. The opposite behavior is observed for the male component, which has stopped going to groceries and shopping centers on foot but seems to have opted for the own bicycle (orange bar in Fig. 2). This alternative is now used more by women to travel mainly to other cities, for tourism or to visit other people.



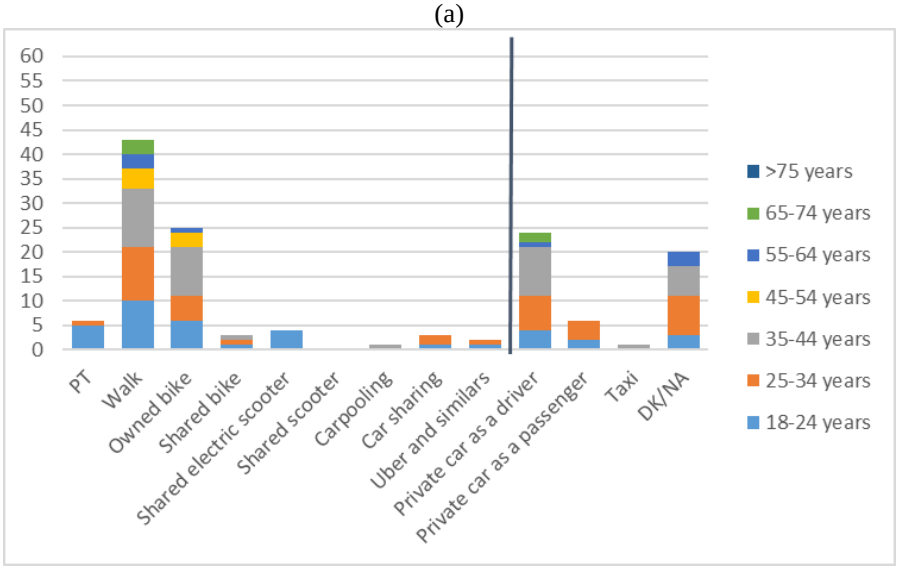
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
	Groceries		Out dinner		Shopping center		Tourism		Tourism other city		Weekend activities		Job/univ./school		Visiting people		Running errand	
Walking	7%	-4%	5%	0%	4%	-4%	11%	5%	-5%	5%	5%	9%	4%	4%	4%	4%	5%	2%
Shared modes	-1%	1%	-2%	-2%	-1%	1%	-2%	0%	-3%	1%	-2%	-1%	-1%	0%	-1%	1%	-3%	1%
Shared bikes	-3%	-2%	-1%	0%	0%	-2%	0%	3%	1%	1%	-1%	0%	2%	-2%	1%	3%	0%	0%
PT	-3%	-2%	-7%	-8%	-6%	-5%	-11%	-15%	-15%	-14%	-9%	-14%	-16%	-11%	-20%	-18%	-4%	-11%
Private veh.	-4%	6%	1%	8%	1%	3%	0%	1%	13%	2%	1%	1%	4%	7%	5%	11%	-2%	4%
Owned bikes	0%	2%	1%	0%	-2%	4%	-2%	3%	6%	1%	3%	3%	2%	-3%	9%	-1%	1%	4%
other	2%	0%	3%	2%	4%	3%	3%	3%	4%	3%	2%	2%	5%	5%	2%	0%	2%	0%

Fig. 2. Mobility habits variation based on gender and scope

In general, walking, owned bikes, and private cars have been declared as transport modes used more than in the pre-COVID scenario, as shown in Fig. 3. These plots collect the responses to the question "*Which of the following travel mode have you started using more than previously?*", where multiple choices are allowed for the female and male samples. The option "PT" combines various means, namely bus, private bus, train, trolleybus, tram, and metro. The group of users who stated that they use new means of transport more than previously are 25-34 years' women (with 42% of the answers), whereas, for male respondents, the change is more homogeneous in the three minor age groups (18-24 years; 25-34 years; 35-44 years). Moreover, it could be observed that in the female sample, a higher number of respondents have started being passengers, both on private cars and taxis. In the former case, significant differences among age ranges could be observed while comparing the genders. Indeed, a considerable number of people older than 35 years are found in the "*Private car as a passenger*" column in Fig. 3(a), while they are absent in the corresponding column of Fig.3(b).



(a)



(b)

Fig. 3. Number of users for means of transport used more than previously based on age for (a) female and (b) male; SM before the blue line

A specific focus is proposed on the investigation of modes associated with Smart Mobility, according to the definition provided in [4], namely shared modes, public transport, walking, and biking. Results are proposed in Fig. 3, where SM's means are found before the blue line. The plot clearly shows that female respondents' sample seems less prone to approach some SM modes than men, mostly the shared ones. Among these modes, those gaining more interest among the women are the shared bikes

and services such as Uber and similar. Other means that have started spreading in the cities and are expected to reach a good success after the COVID-19 emergency are shared e-scooters. However, these means seem to attract men more than women, confirming what is assessed in Section 2.

After it has become clear that the COVID-19 pandemic has changed mobility habits, it is interesting to understand the motivations behind these changes, and this can be done by assessing the answers to the question: *"Which are the reasons behind your changes in the modes used?"*, with a multiple-choice option. In general, the most selected answer was the motivation related to health issues to prevent infection. However, Fig. 4 shows how all the possible choices separate between gender. For example, most women are found among those respondents declaring a change in the modes due to a longer travel duration while using the previous mode. A similar partition between gender is found for the option "*Increase of conditions in the use of previous modes (more bike lanes, more bus lanes, …)*". Women seem to be more affected by the reduction of reliability in PT services, obviously connected to the fact that they are known to be more frequent users of this means. In contrast, economic savings move more the choices done by men.

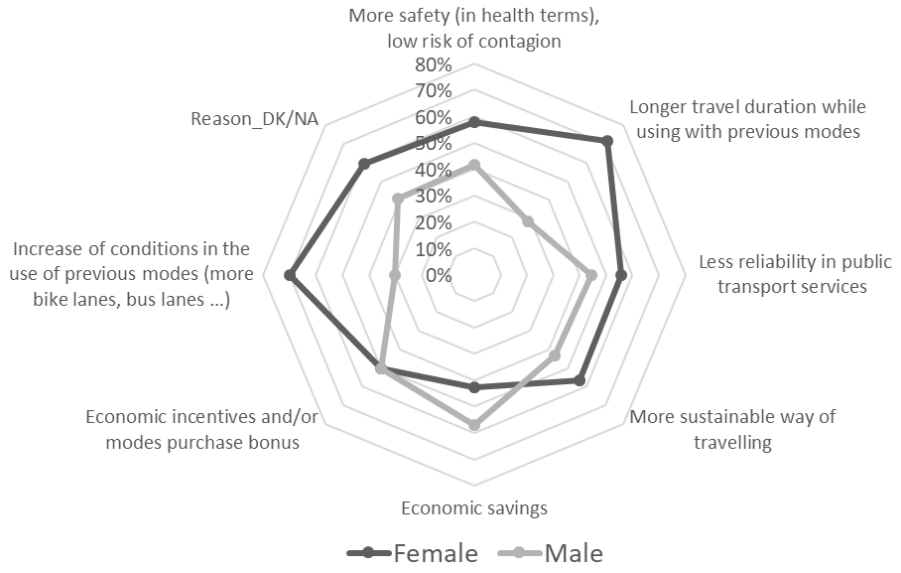


Fig.4. Reasons behind the changes in mobility habits separated according to gender.

5 Conclusion and discussion

The COVID-19 pandemic has affected in many ways people's lives. The required changes in the working conditions and the imposed restrictions in social activities have inevitably affected mobility behavior. As expected, these changes are not homogeneous across the population. Previously observed differences in travel behavior and mode

choices among genders and age groups have amplified due to the current conditions. This paper has analyzed changes in people's mobility trends in 13 European countries, focusing on how these changes vary between men and women and various age groups.

A survey that addressed mobility choices before and after the pandemic was performed, and 208 replies were collected. The data analysis demonstrated that there are actually differences in the new mobility patterns of men and women. The reasons that led to these shifts in behavior are also explored. Monetary incentives drove men's choices while women were affected by the reliability and safety of public transport services. The trip purpose also differentiated the mode choice between men and women, with the latter showing a stronger shift towards walking while men towards biking for groceries. For shopping and tourism, men revealed a preference for biking.

In general, walking increased while a significant decrease in the use of PT is observed. These results have been expected due to the limitation of the trips performed per day due to the mobility restrictions imposed in many cities and the increase of remote work. These changes seem somehow correlated with gender, considering, for example, that women are commonly more likely to use PT than men [8]. However, the main reason behind the changes in mobility habits is the need for more safety in terms of low risk of contagion, irrespective of gender. A shift towards private car use is evident in the age groups of people older than 35. Given the preventive measures of social distancing and frequency of cleaning commonly used facilities, shared modes use has dropped during the pandemic. However, shared bikes, specifically, have seen an increased interest from male users.

The current exploratory analysis has shown that mobility behavior has been affected by the pandemic's advent and its impact on daily activities and working conditions. Different groups of people, clustered by gender and age, have been experiencing these changes in various ways as far as their mobility is concerned. In general terms, it is seen that walking activities have in general increased, followed by biking while in motorized transport, the private car usage is dominant followed by ride-hailing options. It is still unknown how these changes will evolve in the future and how mobility behavior is expected to be formed under the conditions of the pandemic and the post-pandemic era. Future research aims to analyze the post-COVID19 mobility behavior of people and analyze if the shifts towards active modes will remain or will be absorbed, again, by the use of motorized transport and if the current preference towards private cars could change towards public transport modes.

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References

1. Abdullah, M., Dias, C., Muley, D., Shahin, M.: Exploring the impacts of COVID-19 on travel behavior and mode preferences. Transp. Res. Interdiscip. Perspect. 8, 100255 (2020). https://doi.org/10.1016/j.trip.2020.100255.
2. Cochran, A.L.: Impacts of COVID-19 on access to transportation for people with disabilities. Transp. Res. Interdiscip. Perspect. 8, 100263 (2020). https://doi.org/10.1016/j.trip.2020.100263.
3. Transformative Urban Mobility Initiative (TUMI): COVID-19 and Sustainable mobility. (2020).
4. Woodcock, A., Romer Christensen, H., Levin, L.: TInnGO: Challenging Gender Inequality in Smart Mobility. Put i saobraćaj. (2020). https://doi.org/10.31075/pis.66.02.01.
5. Pirra, M., Carboni, A., Diana, M.: Assessing gender gaps in educational provision, research and employment opportunities in the transport sector at the European level. Educ. Sci. 10, (2020). https://doi.org/10.3390/educsci10050123.
6. Bencardino, M., Greco, I.: Smart communities. Social innovation at the service of the smart cities. TeMA – J. L. Use, Mobil. Environ. (2014). https://doi.org/10.6092/1970-9870/2533.
7. Singh, Y.J.: Is smart mobility also gender-smart? J. Gend. Stud. 1–15 (2019). https://doi.org/10.1080/09589236.2019.1650728.
8. Pirra, M., Kalakou, S., Carboni, A., Costa, M., Diana, M., Lynce, A.R.: A preliminary analysis on gender aspects in transport systems and mobility services: Presentation of a survey design. Sustain. 13, 1–20 (2021). https://doi.org/10.3390/su13052676.
9. Lozzi, G., Marcucci, E., Gatta, V., Pacelli, A., Rodrigues, M., Teoh, T.: Research for TRAN Committee – COVID-19 and urban mobility: impacts and perspectives. , Brussels (2020).
10. de Paz, C., Muller, M., Munoz Boudet, A.M., Gaddis, I.: Gender Dimensions of the COVID-19 pandemic. (2020).
11. OECD: Forthcoming OECD policy brief: Women at the core of the fight against COVID-19. (2020).
12. Wang, K., Akar, G.: Gender gap generators for bike share ridership: Evidence from Citi Bike system in New York City. J. Transp. Geogr. 79, 1–6 (2019). https://doi.org/10.1016/j.jtrangeo.2019.02.003.
13. Ma, X., Yuan, Y., Van Oort, N., Hoogendoorn, S.: Bike-sharing systems' impact on modal shift: A case study in Delft, the Netherlands. J. Clean. Prod. 259, (2020). https://doi.org/10.1016/j.jclepro.2020.120846.
14. Zhang, L., Zhang, J., Duan, Z.Y., Bryde, D.: Sustainable bike-sharing systems: Characteristics and commonalities across cases in urban China. J. Clean. Prod. 97, (2015). https://doi.org/10.1016/j.jclepro.2014.04.006.
15. Chicco, A., Pirra, M., Carboni, A.: Preliminary Investigation of Women Car Sharing Perceptions Through a Machine Learning Approach. In: Stephanidis C., A.M. (ed.) HCI International 2020 - Posters. HCII 2020. Communications in Computer and Information Science, vol 1224. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-50726-8_81.

16. Kawgan-Kagan, I., Popp, M.: Sustainability and Gender: A mixed-method analysis of urban women's mode choice with particular consideration of e-carsharing. Transp. Res. Procedia. 31, 146–159 (2018). https://doi.org/10.1016/j.trpro.2018.09.052.
17. Alonso-Almeida, M. del M.: Carsharing: Another gender issue? Drivers of carsharing usage among women and relationship to perceived value. Travel Behav. Soc. (2019). https://doi.org/10.1016/j.tbs.2019.06.003.
18. Osservatorio Nazionale Sharing Mobility: Quarto Rapporto Nazionale sulla sharing mobility. (2020).
19. Degele, J., Gorr, A., Haas, K., Kormann, D., Krauss, S., Lipinski, P., Tenbih, M., Koppenhoefer, C., Fauser, J., Hertweck, D.: Identifying E-Scooter Sharing Customer Segments Using Clustering. In: 2018 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2018 - Proceedings (2018). https://doi.org/10.1109/ICE.2018.8436288.
20. International Transport Forum: Women's Safety and Security: A Public Transport Priority, https://www.itf-oecd.org/womens-safety-security, last accessed 2021/01/05.
21. Kloof Van Der, A., Kensmil, J.: Effects of COVID-19 measures on mobility of men and women, https://www.google.
22. Caselli, F., Grigoli, F., Sandri, Damiano; Spilimbergo, A.: Mobility under the COVID-19 Pandemic: Asymmetric Effects across Genderand Age. , Essen (2021).