Physical mobility and virtual communication in Italy: Trends, analytical relationships and policies for the post COVID-19

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Abstract

People have always moved guided by the need to carry out various activities in different places, including that of meeting and communicating with other people. Over the past two decades, the concept of "communication" has significantly evolved given the introduction of multimedia digital technologies, which have enabled people to communicate without necessarily their physical presence. During the COVID-19 pandemic, "virtual mobility" (or "virtual communication") has been playing a crucial role in ensuring communications between people in different contexts of social life, growing in few months to previously unforeseeable levels and demonstrating that it can substitute physical movements in many occasions. A smart management of mobility that combines the ability to virtually communicate and the use of Intelligent Transportation Systems (ITS) to support physical mobility, can therefore strongly influence people's choice to move or not, and how. Starting from the analysis of physical mobility and virtual communications trends before and during the health emergency in Italy, this paper analyses the relationships between these two forms of communication, evaluating how virtual communication affected the different segments of Italian mobility during the pandemic and how it will affect the way people move in the post COVID-19 period. A SWOT analysis of virtual mobility is performed for each communication segment, with the aim of highlighting its pros and cons, but also future opportunities and possible threats, not exclusively for transport systems. Some policy indications are also provided in relation to different mobility segments, governance levels (urban, regional and national) and congestion/pollution scenarios, highlighting how virtual mobility can help regulate physical movements, with the ultimate goal of pursuing a safe, sustainable, effective, efficient and connected mobility.

Keywords: virtual and physical mobility relationships, motionless communication, SWOT analysis, COVID-19, scenarios evaluation, Intelligent Transportation Systems, mobility segments.

1. Introduction

Mobility is essential to allow people's private, social and economic life. It is so important that it became a guaranteed right with the Universal Declaration of Human Rights of 1948. Over the last two decades, the concept of "communication" has significantly evolved thanks to the introduction of multimedia technologies - above all the Internet - which have allowed people to communicate without necessarily their physical presence [1].

Until the last century, mobility could be classified into two types: motorized mobility, which involves the use of vehicles supplied by an internal combustion engine and/or an electric motor (cars, buses, trams, flights, subways, etc.) and non-motorized mobility, in which the motion is generated by the human body (bicycles, walking, etc.). In recent decades, thanks to the widespread diffusion of Information and Communication Technologies (ICT), the so-called "communication without movement" (here also called "virtual communication", "virtual mobility" or "motionless communication", opposite to "physical communication" or "physical mobility", i.e., the communication between people that requires the physical movement, motorized or not) has increasingly taken hold. Thanks to information technologies, physical transport infrastructures (networks and nodes) are nowadays flanked by a new infrastructure consisting of a fiberglass network connected worldwide [2]. Virtual mobility allows people to communicate remotely quickly, cheaply and easily accessible, connecting them from one end of the world to the other. The two types of communication today coexist, influencing each other and, possibly, cooperate through ITS [3]-[6].

During the COVID-19 pandemic, motionless communication played a crucial role [7]: it almost completely replaced physical mobility, ensuring communications between people in different contexts of social life, and growing in few months to previously unforeseeable levels [8]. In fact, one of the most important responses from countries around the world to slow down the spread of the virus was to limit the movements of people (as well as goods), which obviously had an imposing effect on the demand and supply of transport systems [9], [10]. The challenges of urbanization, automation and digitalization, which had already been topical in

recent years [11], have been recently integrated with aspects relating to social distancing and the need to provide a secure mobility from the health viewpoint.
Based on current trends [12]-[19], the pandemic is likely to change - not only in Italy - people's behaviours and mobility preferences, with a structural increase in virtual communications compared with the pre-COVID period.
Virtual communication has been rapidly affecting an increasing number of segments/areas of people's lives, such as work [20]-[21], education, some indoor sports, food delivery, shopping by e-commerce, at different levels of development and use. With the inability to move, many companies have favoured the work from home (also called “smart working”) [22]-[24] and students have been encouraged to follow lessons using “distance teaching” [7]. Moreover, more and more services (banks, public administration, etc.) have been also provided in virtual mode [25].
Already in the pre-COVID-19 era, the practice of working from home was spreading in developed countries and the number of regular remote workers was steadily increasing [26], also thanks to the growth in coverage of high-speed Internet access and the simultaneous increase in transport costs. The shock of the COVID-19 pandemic has reshaped perceptions of individuals and organizations at work, providing a boost to an already initiated process: the great "home experiment", as mentioned by [27], can profoundly change the working models of the future. The benefits of working from home are not only related to health aspects and travel costs: by reducing the number of business trips, the time saved on commuting can be used for additional non-working trips during off-peak hours [28]-[29]. By analysing US data related to COVID-19 period [30], it emerges that many workers, commuting on a regular base, could be converted to remote workers and that younger people were more likely to switch to remote work.
The lockdown due to COVID-19 has not only had devastating effects on society from a social and economic point of view, but has also some positive effects by reducing negative externalities related to transport. In fact, the reduction of physical mobility allowed to significantly reduce local air pollution and partially CO_2 emissions, with obvious benefits for the environment [31], [32] and congestion [33] on transport networks. The impact of the COVID-19 lockdown on the mobility of Indian community is analysed in [34], whereas in [35] the current and long-term impact of COVID-19 on transportation in Lagos State (Nigeria) is addressed, analysing the effect on transportation in emerging economies, where lockdowns and restrictions on movement may be ineffective due to high population density and poor transportation infrastructures. A study conducted in China, the country of origin of the infection and the first to implement lockdown policies, shows the roles of the different modes of transport in the spread of COVID-19 pandemic in Chinese cities [36].

1.1 The impact of past epidemics on travel behaviour

Controlling and restricting people's movements has gained much attention - both by researchers and practitioners - also during past pandemics, in the attempt of containing or slowing down the virus spread. These controls, together with self-imposed travel restrictions, have contributed to a significant reduction of mobility, such as international air traffic, but in many cases have proved ineffective in containing the spread of the virus, which has managed to reach pandemic proportions in a short time [37], [38], [39].
The potential for infectious diseases to spread rapidly through an increasingly well-connected, steadily growing world population was brought into sharp focus during the 2003 epidemic of severe acute respiratory syndrome (SARS). Hollingsworth et al. [40] elaborated a mathematical model of an epidemic in a source country, highlighting that travel restrictions, even with a degree of effectiveness >99%, only slow down the exportation of cases (i.e. the infection) rather than halting spread: if the source epidemic is controlled before there are thousands of cases, travel restrictions during the containment phase may have a large impact on the probability that an infected individual travels out of the source area and potentially seeds a new outbreak. Germann et al. [41] investigated the spread of the H5N1 avian virus through the U.S. population of 281 million individuals, demonstrating that, in a highly mobile population, restricting travel when a pandemic flue is detected, is able to delay slightly the time course of the outbreak without impacting the eventual number of illes.

Also in small territories or areas with limited access possibilities, such as islands, intensive travel volume restrictions alone seem to be not sufficient to avoid the arrival of pandemics: multiple additional interventions, such as screening campaigns, quarantines and physical distancing are needed to raise the probability for islands of remaining pandemic free or achieving substantial delay in pandemic arrival [42].
Troko et al. [43] pointed out that the relationship between public transport use and acquisition of acute respiratory infection (ARI) is not well understood but potentially important during epidemics and pandemics. Hisi et al. [44] pointed out that the mobility rate plays an unexpected role in the epidemic spread; in their study, the authors highlight a peak in the persistence of such spread in relation with the observed mobility rate and susceptible individuals' density.
More in general, epidemiological and economic modelling studies have shown that travel restrictions are not as cost-effective and efficient in containing pandemics as the national application of intervention measures to interrupt transmission [45]- [46].
In order to substantially limit the viral spread, the policies of restrictions must be accompanied by social policies that intrinsically modify people daily life, reducing close contacts between them, so interrupting the spread of the infection.
What differentiates the COVID-19 pandemic from the previous pandemics is precisely the possibility of using the internet and virtual communication, or being able to carry out a number of activities remotely (work, school, shopping, etc.). This made it possible to adopt severe restrictive measures such as lockdowns, which allowed to slow down the spread of the infection and to alleviate the burden on national health systems.

The contribution of the present paper is to analyse the effect of the COVID-19 pandemic on the mobility of people in Italy, on the base of the previous trends of physical mobility and motionless communication, and to investigate how virtual mobility have contributed to facilitate or compensate the need of people to communicate and carry out daily activities.

Given the growing need of communication among people, on one side, and the increasing sensitivity towards environmental and social issues on the other, virtual mobility represents a useful tool for policy makers to regulate mobility levels - or even to substitute it - and, consequently, moderating transport negative externalities (pollution, congestion, accidents, noise, etc.). In their review paper, Van der Waerden et al. [1] analyse some endogenous relationships between physical and digital mobility with the aim of finding out if there is an exchange between these two types of mobility, looking for planning tools to reduce the number of undesired physical movements. Also Dalla Chiara et al. [47] deal with the relationships between communication with and without movement, with the aim of outlining common elements between the two and pointing out the role of being connected in future transport systems.
In other words, virtual mobility may be used to properly regulate and maintain nearly constant levels of physical mobility; this can help to minimize the construction of new physical infrastructures and make existing transport systems "smarter", i.e. more compliant with the environment, of higher quality, efficiency and safer. In this context, an important role is played by ITS [11], [50] that rely on information technology, telecommunications and multimedia [48] in order to face with problems of public and private mobility in an innovative way, developing safe, efficient, effective, economical and sustainable solutions [49]. Besides, ITS can help to meet the needs expressed both by operators (optimization, fleet management, economic balance, etc.) and users of public and private transport (reducing congestion and saturation of vehicles, increasing the frequency of transport means, provision of customized services, etc.). In fact, in addition to the variation of mobility demand patterns, the COVID-19 pandemic will inevitably also lead to a redefinition of the transport offer, defining new relationships between physical and virtual mobility [1]. A smart management of mobility by using ITS combined with the ability to virtually communicate without moving can strongly influence people's choice to move or not, and how.

Starting from the analysis of physical and virtual communications trends in Italy before and during the health emergency, this paper analyses the relationships and mutual impacts between these two forms of communication - in relation to different segments/purposes of mobility, i.e., work, education, food delivery, etc.) - during and after the COVID-19 pandemic. A SWOT analysis is specifically elaborated to highlight pros,

cons, future opportunities and possible threats of virtual mobility. The ultimate objective of the paper is to provide policy indications in relation to different segments of mobility, considering various governance levels (urban, regional and national) and three different scenarios (regarding the levels of congestion and pollution: high/unacceptable, medium/critical and low/acceptable) with the final goal of allowing communication between people in a more sustainable, safe, effective, efficient and connected way.

The remainder of the paper is structured as follows. In Section 2, the evolution of physical and virtual communication in Italy in the last 30 years is analysed, including the trends related to mobility demand and technological innovations. Section 3 provides an analysis of the impact of COVID-19 health emergency on the two types of mobility, physical and virtual. In Section 4, a SWOT analysis relating to the different segments of physical and virtual mobility is presented, whereas, in Section 5, policy indications in relation to different mobility segments and scenarios are provided, for both mobility typologies. Finally, in Section 6 some final concluding remarks are illustrated.

2.The evolution of physical mobility in Italy in the last 30 years

2.1 Physical mobility in Italy in the pre COVID-19 period

As already pointed out, physical mobility of people can be distinguished into two types: motorized and not-motorized. As shown in Figure 1, the trend of road motorized mobility in Italy during the last 30 years shows a slight increase from 90s to 2000 and, then, a stagnation up to 2010, when a second weak increase is registered. Regarding rail transport, which is much less used than road transport, passenger mobility has not changed significantly since 1990 [52], with the exception of a rapid increase of high-speed trains after 2010. Before the 1990s, the trend in the use of motorized mobility had been steadily growing since the end of the 20th century, then taking on an S-shape with the 21st century, similarly to the life cycle of many products; this seems to be confirmed by the number of vehicles on the market in the Countries analysed.

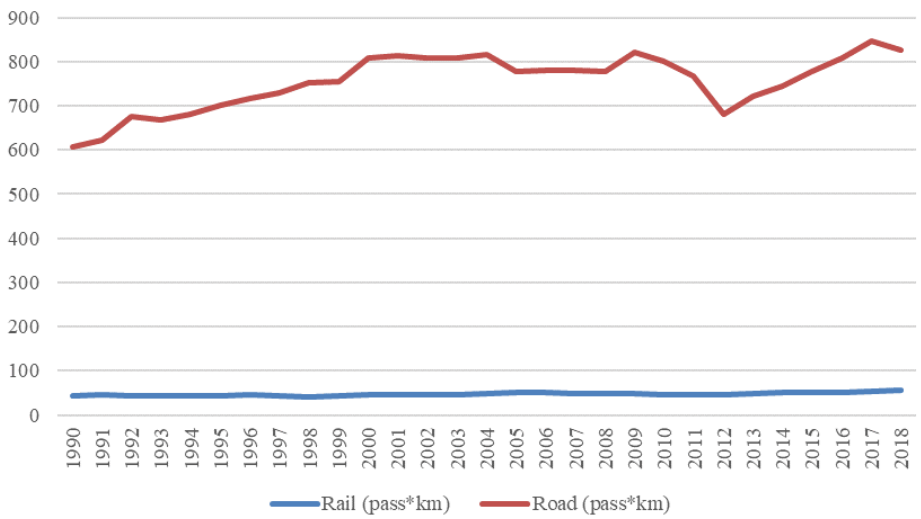


Figure 1 - Trend of physical mobility (car and rail) in Italy (1990-2018)
Data Source: [52]

By analysing more in detail the segments of motorized and non-motorized mobility (Figure 2) it can be noted that non-motorized mobility represented 27.1% of travel in 2018, almost 7 percentage points more than in 2016, demonstrating that, even in the pre-COVID-19 period, this kind of mobility was already growing and attracting more and more users taking them away from private motorization and public transport. Passengers*km by bike increased from 3.1% in 2016 to 5.2% in 2018, recording a growing trend for medium and long distances [53].

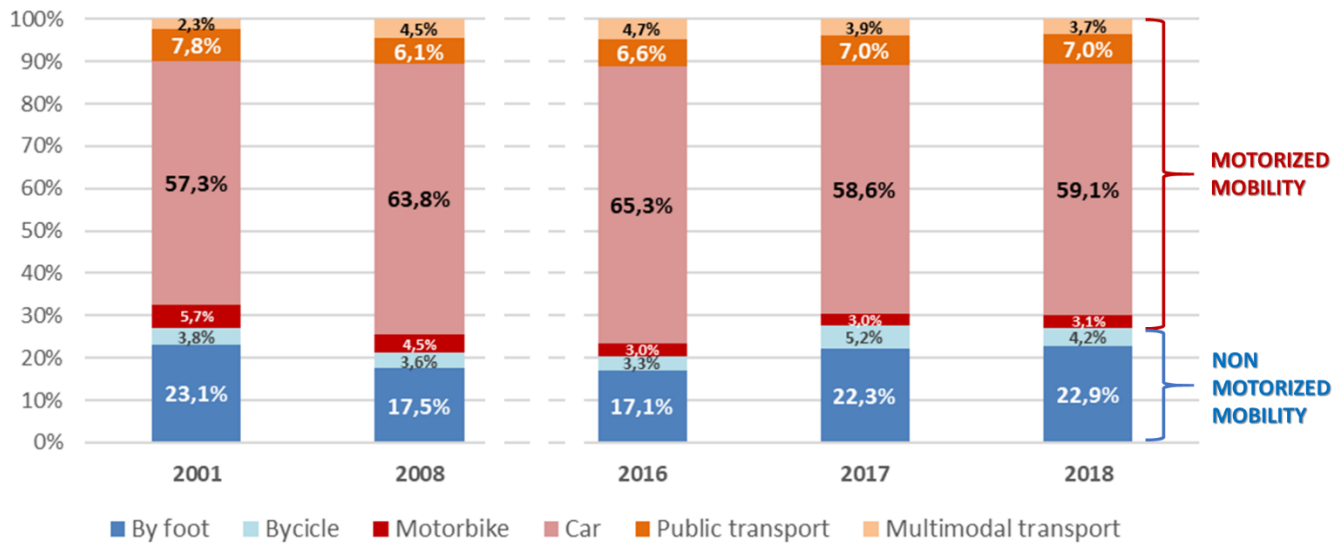


Figure 2 - Motorized mobility in Italy (years 2001, 2008, 2016-2018)

Data Source: [53]

The stagnation of motorized mobility registered in the last years is mainly due to the following limiting factors and negative externalities [54]:

a) saturation, in terms of number of vehicles on current infrastructures and land available to build new infrastructures (scarcity of land);

b) growing concerns about the scarcity of fossil fuels (mainly oil, on which transport depends for at least 94% in European countries);

c) pollution, mainly deriving from the combustion of engines, and consequent related health problems;

d) need to maintain and technologically update the existing infrastructures;

e) effort to reduce road accidents.

Some of these aspects, such as the accident rate and pollution emitted, are not present or less significant for the railway mode. In fact, the passenger-km data by rail (Figure 1) [52] are more stable.

This slowdown in the growth of motorized mobility cannot be attributed to adverse economic conditions alone, but also to a behavioural change of users, enabled by the introduction and continuous development of ICT technologies. On one side, the increasing and pervasive use of the internet and IT services allows people to easily, quickly and cheaply communicate without the need of moving; on the other side, negative externalities of motorized mobility, such as congestion, push people towards more sustainable transport means [55]. Moreover, the possibility of using ITS systems favours the use of vehicles that can allow people to move and communicate at the same time, such as trains, planes, metros, etc., i.e., all those vehicles that do not require driving the vehicle, including autonomous vehicles.

According to the Audimob-ISFORT Italian observatory, the number of trips - performed in an average day by Italian citizens between 14 and 80 years old - has experienced a sharp drop in the past decade, representing around a fifth of total journeys (left graph of Figure 3) and 30% less passengers*km (left graph of Figure 3) [53].

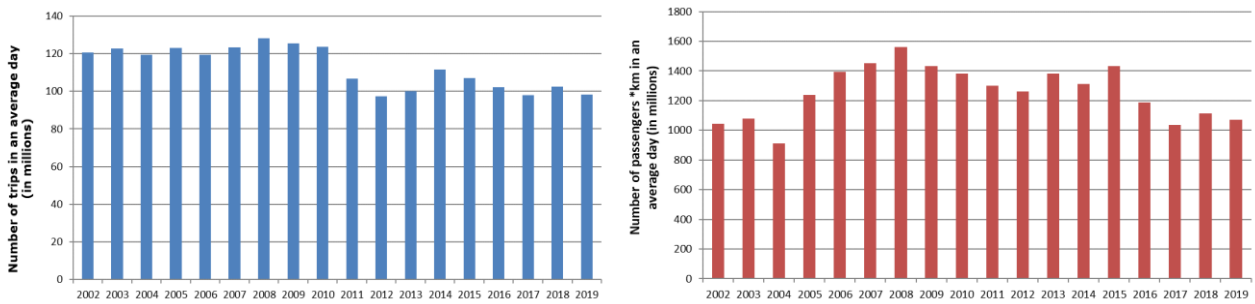


Figure 3 – Trend of total number of trips (left graph) and passenger*km (right graph) in an average Italian weekday (in millions)
Data Source: [53]

Italian citizens spend just under an hour a day traveling, covering just under 30 km a day. Compared to 2008, year of the economic-financial crisis, the decrease recorded is -29% for average distances and -18% for average mobility times (Figure 4).

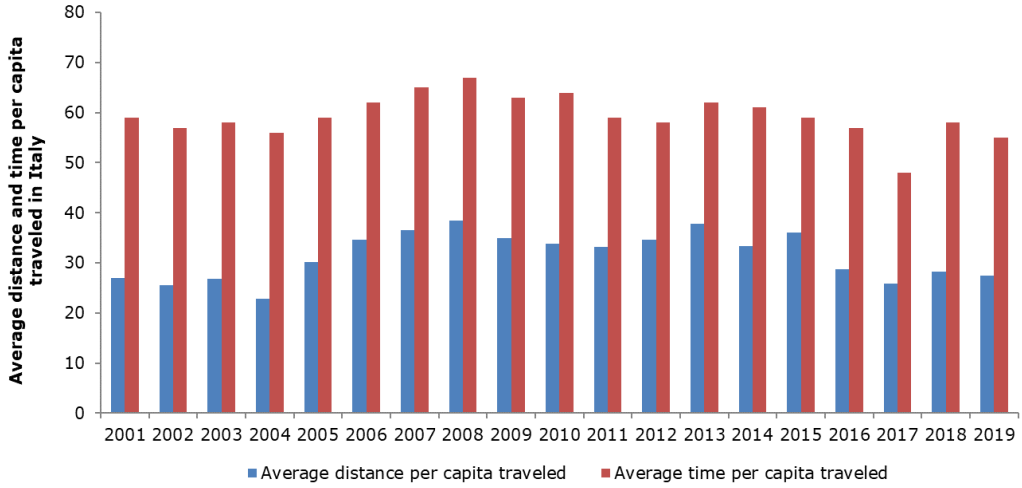


Figure 4 – Total average distance and time per capita travelled in Italy (2001 - 2019)
Data Source: [51]

Short-range mobility, that refers to trips less than 10 km long and which absorbs almost all trips on foot and by bicycle, has a dominant position in the Italian demand model: more than 3 out of 4 trips refer to this type of mobility. Also in terms of passengers*km, local mobility (distance in the 0 - 50 km range) accounts for 65,9% of the demand. In 2018, 32,9% of the movements were performed for work and study reasons. Since 2001, the weight of the movements due to leisure and family management reasons has increased respectively of 3 and 4.3 percentage points to the detriment of school and work [53].
The number of occasional trips (i.e., those repeated less than 3 times a week) represents 39% of total trips in 2018, against the remaining 61% related to commuting. Since 2001, the demand for systematic mobility - that is, that related to commuters - began to decrease significantly and then stabilized after 2008. At the same time, the concentration of trips during rush hours decreased by about 10 percentage points from 2008 to 2018 (Figure 5).

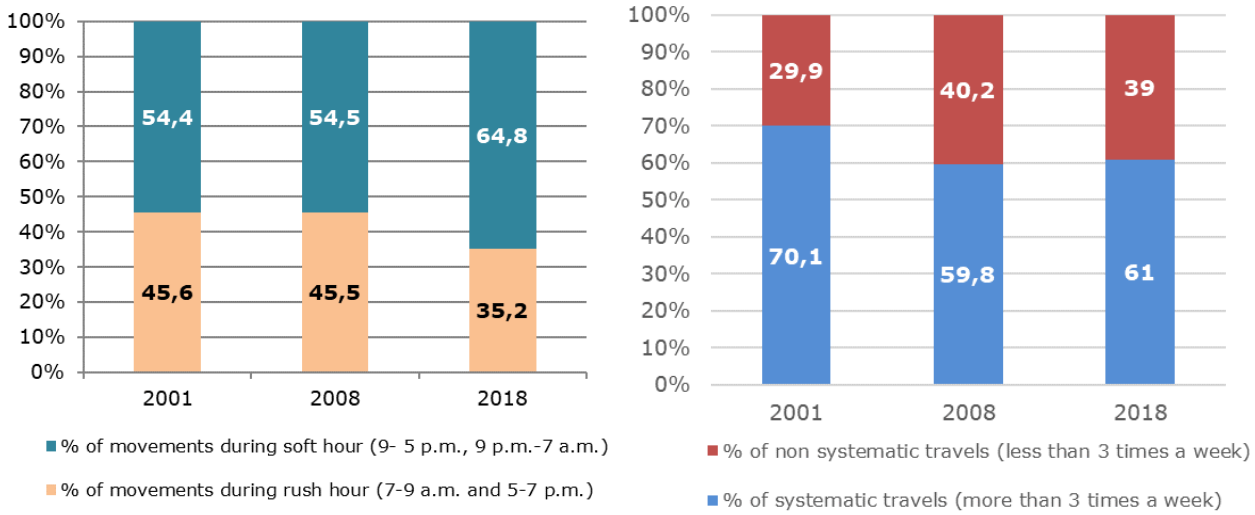


Figure 5 - Systematic versus non-systematic trips (left graph) and hourly distribution of trips (right graph) in Italy
Data Source: [53]

2.2 Physical mobility in Italy during COVID-19 period

In Italy, the mobility of people during the lockdown (the so-called "phase 1") of the COVID-19 health emergency has undergone rapid changes. The Italian maps depicted in Figure 6 shows the variation in the number of trips in Italy in 16 significant days, highlighting the abrupt reduction in mobility and its recovery in correspondence to openings and restrictions imposed by the Italian Government according to the pandemic evolution (three waves occurred since the beginning of the health emergency in February 2020 up to May 2021). The time difference in the implementation of the measures issued in the different Italian Regions has generated a different evolution of the corresponding people movements. The levels of mobility in the provinces of Brescia, Milan, Lodi and Bergamo, as of 30 April, had decreased by about 80-85% compared to January; indicatively, 15-20% of the demand corresponded to unavoidable travel. The data collected on May 3, 2020, the last day of phase 1, show mobility levels reduced to the bare minimum, with connections between and within the cities reduced respectively to less than 10% and 25% with respect to the number of movements recorded in January, while the first day of the partial reopening of the country (beginning of phase 2) shows an increase in movements similar to the mobility situation at the beginning of phase 1 [56]. In June 2020, the contingent improvement of the pandemic has allowed a relaxation of restrictions with a consequent increase in the movement of people; this increase in mobility raised and reached its peak during the summer months. In October 2020 a second pandemic wave pushed the Italian Government to introduce severe mobility restrictions, also according to the pandemic evolution in the various Regions (introduction of yellow, orange and red zones). In correspondence with the Christmas holidays, a total lockdown was imposed to limit the movement of people as much as possible. In January 2021, the establishment of the so called "white zones" allowed some Regions to have the opportunity to increase their mobility, but a third wave - which took place in March 2021 - led to a tightening of containment measures. In May 2021, also thanks to the vaccination campaign, mobility throughout Italy has significantly increased.

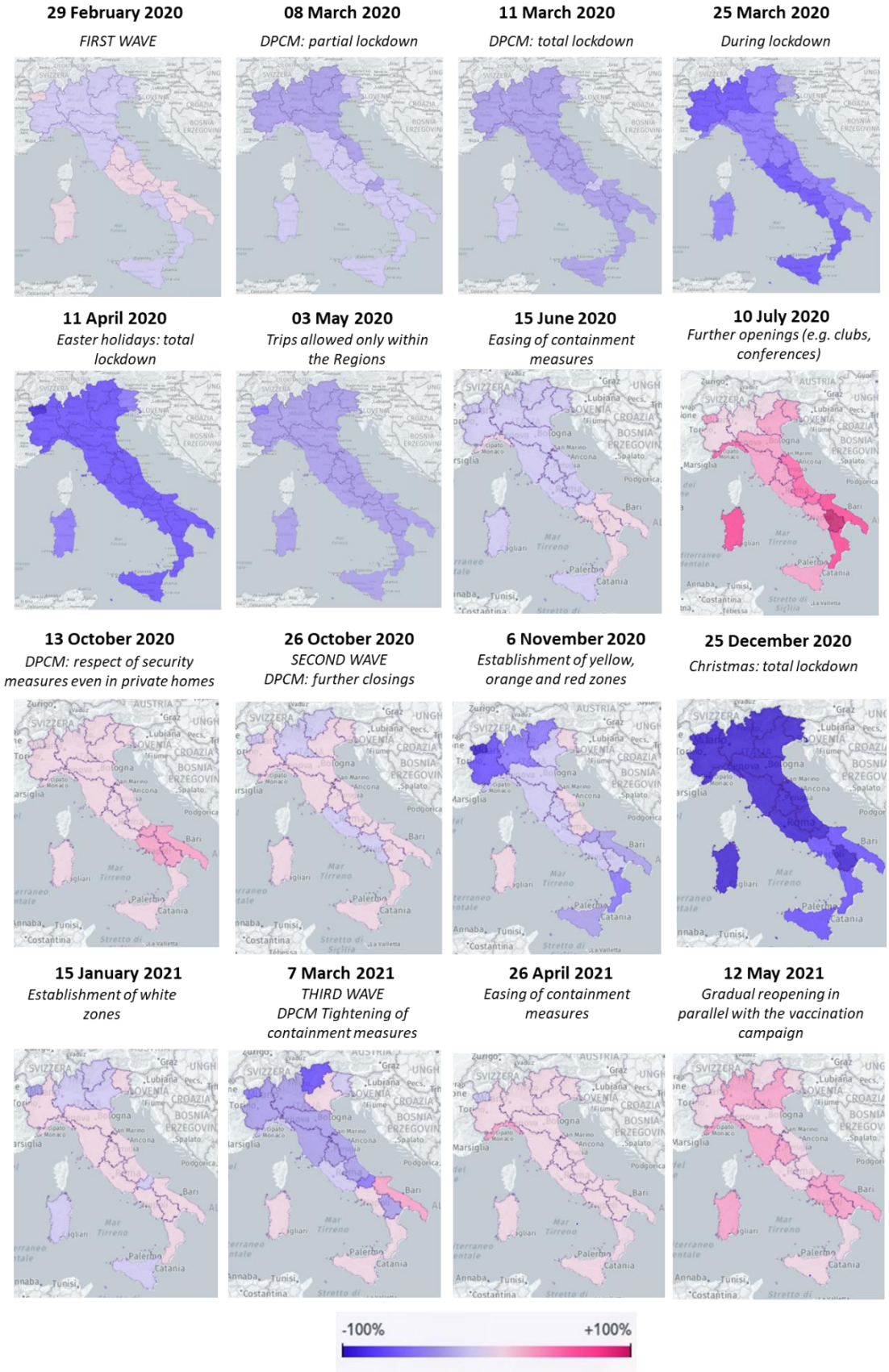


Figure 6 - Changes (in %) in the movement of people in Italy in significant moments of COVID-19 pandemic
Source: [15]

Figure 7 shows the % variation compared to an average pre-COVID day of daily traffic by place of destination, in the period February-December 2020), highlighting three significant moments, i.e., the start and end of the lockdown, and introduction of red zones by the Italian Government. It can be noted that, during the lockdown

period, the most significant reductions in mobility have concerned sectors in which travel is not necessary or urgent, such as in the case of recreational activities or access to parks. The movements for the purchase of pharmaceutical or food products, being primary goods, underwent a decidedly more limited reduction. The reduction in commuting for work, due to the interruption of many work activities, was partially offset by a massive use of agile work from home (i.e., “smart working”). The only type of movement that has shown a positive change compared to the phase before the lockdown concerns movements to the places of residence, motivated by the need to return home by people who work or study in areas other than those of residence. From the end of the lockdown till the “red zones” DPCM, the segment that regained greater mobility is the one related to playgrounds, gardens and beaches (blue line), whereas the one that maintained the most reduced mobility was the one concerning workplaces.

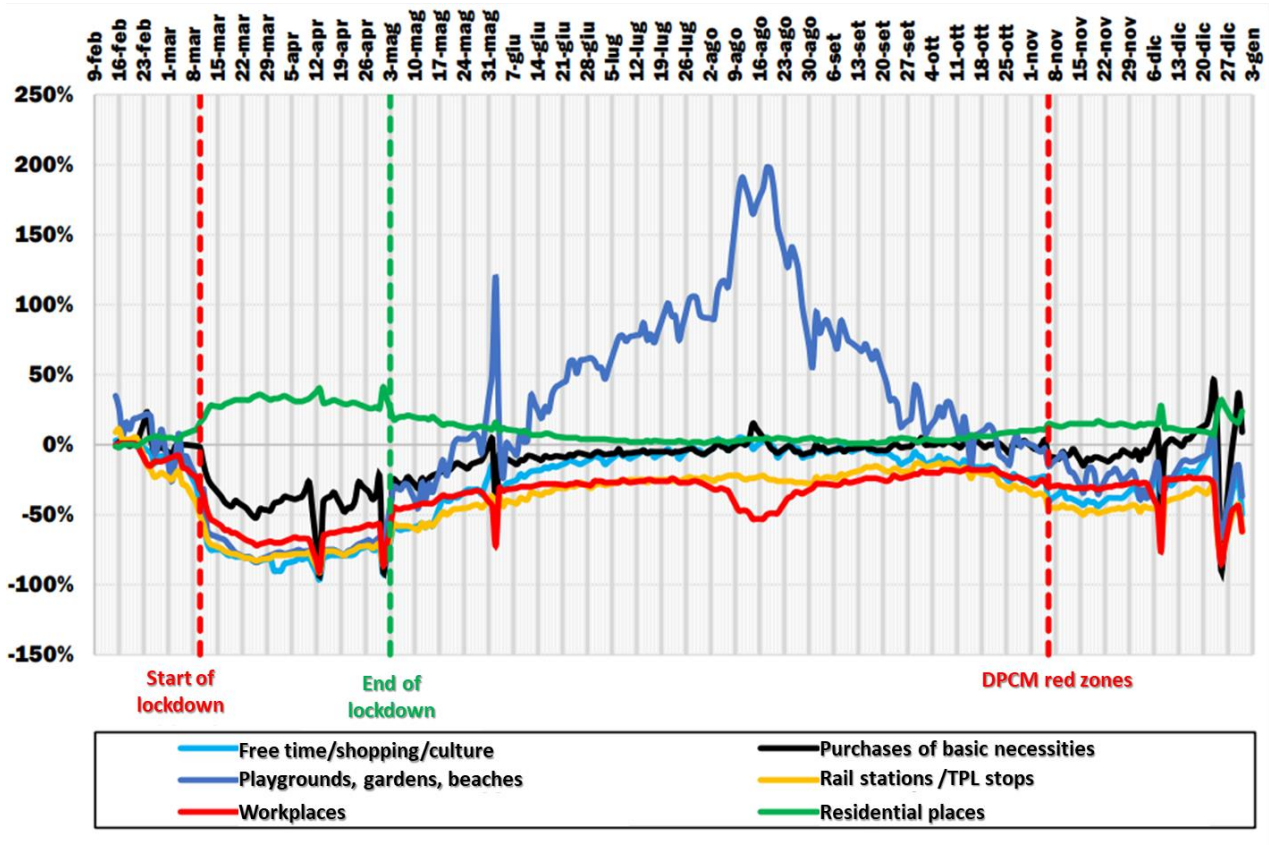


Figure 7 - % variation compared to an average pre-COVID day of daily traffic by place of destination (February-December 2020)
Data Source: [14]

Figure 8 describes the trend of private traffic in some large Italian metropolitan cities (Turin, Genoa, Milan, Rome and Palermo). It can be noted a slight increase in trips in the period from mid-January to approximately 20 February, when there was an average reduction of 35% (-20% in Rome and -40% in Milan) until 8 March; this is not dictated by formal restrictions imposed by the Italian Ministerial Decree and may be attributable to the information provided to citizens in relation to the development of the epidemic on the national territory; this information may have led to a concern such as to push people to limit their movements. Only after the Ministerial Decree of 10 March 2020, which extended the lockdown to the whole Country, a decrease of mobility up to -90% was registered in urban areas. This decrease, however, was more sudden for cities like Milan - in the so-called "red zone" - and milder in cities like Rome, where the health emergency was decidedly less critical. Two other phases of mobility reduction can be recorded; the first in August 2021 due to the physiological reduction of trips due to summer holidays; the second in correspondence with the third pandemic wave in October 2021.

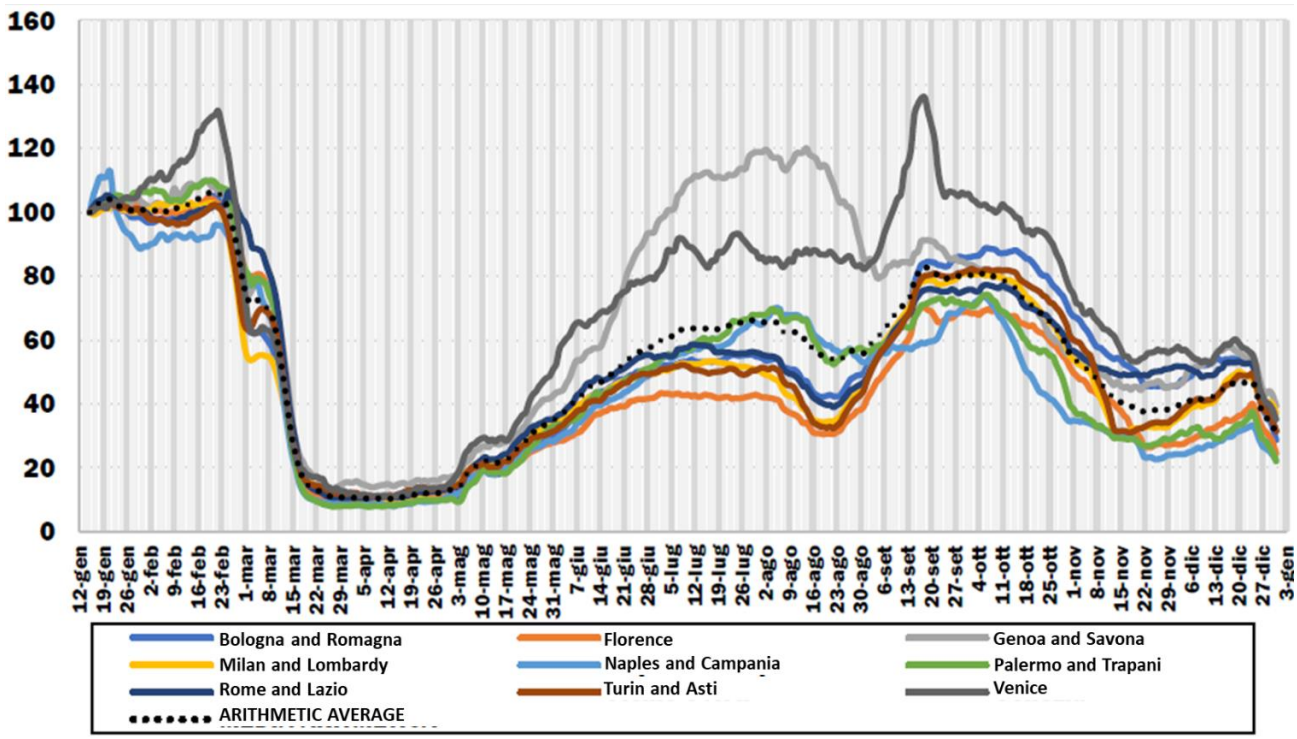


Figure 8 - Movements in some Italian metropolitan cities by private vehicle (car) from 15th Jan. until 3rd January 2021
Data Source: [57]

This trend is also confirmed by the analysis of the movements strictly related to urban centres, excluding movements to and from urban belts: compared to January 2020 a decrease of -75% and -85%, respectively on weekdays and holidays was registered (Figure 9).

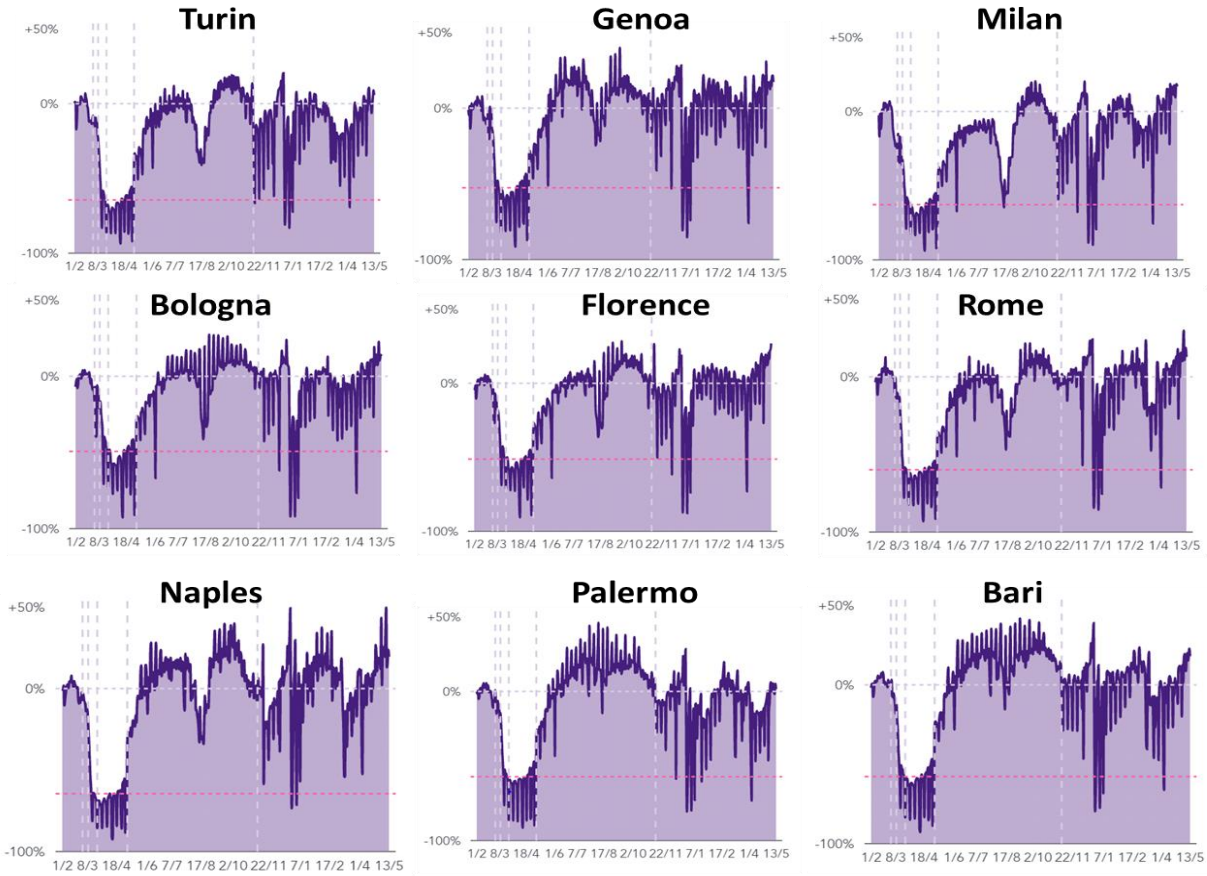


Figure 9 - Variation in the number of journeys in the main Italian cities (1st Feb 2020 - 13th May 2021)
Data Source: [15]

In addition to the reduction in the number of trips, the pandemic also led to a change in the choice of the mode of transport by users who, since the start of the lockdown and throughout its duration, preferred private transport (cars) over the public transport, mainly for reasons of social distancing to reduce the risk of contagion. These behaviours were also favoured by the ministerial provisions aimed at limiting the movement of people.
With the health emergency, public transport has dropped from 70 to 90% in major cities around the world, with the obligation for operators to implement and control strict hygiene protocols and interpersonal distancing. Many public transport operators have suspended most of their services, leaving only the minimum ones deemed sufficient. Furthermore, many operators of time-sharing services (micro-mobility and car sharing) have suspended their services [57].
In Italy, the use of public transport passed from 12,2% in 2019 to only 5% during the first 30 days of lockdown. A reduction, although more contained, was recorded with regard to private motorized mobility, in favour of non-motorized mobility which gained almost 13 percentage points compared to the average of 2019 (Figure 10).

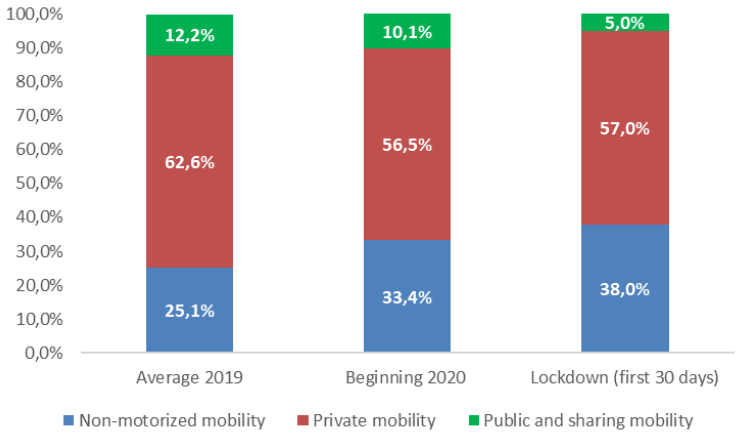


Figure 10 - Modal split in Italy pre and during COVID-19 health emergency period
Data Source: [52]

As pointed out by Figure 11, the qualitative trend of Italian mobility is the same for the different modes, but with quantitative differences between one mode of transport and the other, in favour of private transport over public one. In Rome, during the lockdown (phase 1) public local transport undergone a decrease of up to -90% against -78% of private transport. The city of Milan also presented similar trends. Due to the restrictive measures, a marked reduction in walking movements (-75% at national level) was also registered. In general, Figure 11 points out that as of May 2021, the mobility quota for the period prior to COVID-19 has been pretty much recovered for all the analysed cities, apart from Florence. In particular, for Rome and Florence, the reduction in mobility on foot was more marked than that relating to the use of private cars.

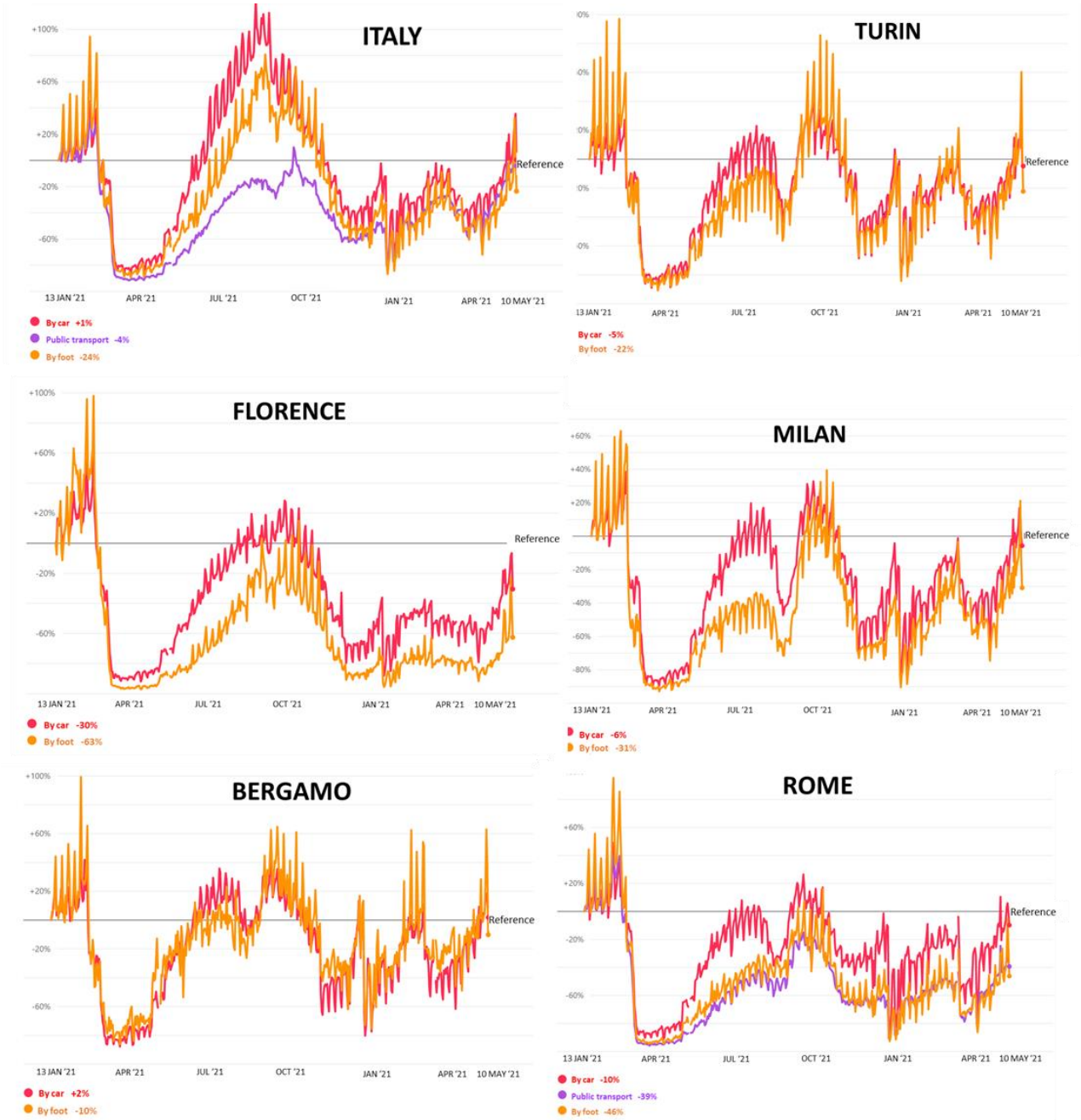


Figure 11 - Movements in Italy and in the cities of Turin, Florence, Milan, Bergamo and Rome, 13th Jan. – 10th May 2021. Percentage of mobility variation respect to the period May 10, 2021 and January 13, 2020

Source: [13]

Considering specifically phase 2 of the Italian lockdown, as shown in Table 1, there are still significant decreases in traffic compared to the period of February 2020; however, there has been a partial recovery in travel related to personal commissions and work in companies [58].

Table 1 - Movements in Italy in phase 2 of the lockdown (gradual reopening)
Data Source: [58]

Reason	***Total demand variation***	***Interregional movements***	***Use of Local Public Transport***
Study	-100%	=	=
Work (Industry)	-30%	Allowed	-20%
Work (tertiary)	-60%	Allowed	-50%
Business	-80%	Prohibited	-40%
Personal commissions	-40%	Prohibited	-80%
Free time	-80%	Prohibited	-80%
Freight transport	-50%	-	-

Table 2 provides the estimates drawn up by the Audimob-ISFORT Italian observatory [53] on the dynamics of the modal split, divided into three macro-groups: non-motorized mobility, individual motorized mobility and collective mobility associated with intermodal movements (in which the public transport normally has a predominant function). It can be observed that the first phase of the lockdown led to a significant increase in the share of non-motorized mobility (from 33.3% to 38%) and a marginal increase in the private one (+0.6%), to the detriment of public and intermodal mobility, which has more than halved its weight (from 10.3% to 5%). The concomitance of multiple factors has favoured the drastic reduction of systematic movements (work and school commuting) which are generally more satisfied by public transport and the average shortening of travel.

Table 2 - Italian modal split pre and during COVID-19
Data Source: [59]

	Average 2019	**PRE-COVID**	**DURING COVID**	**DURING COVID**	**Variation on 2019**
		Beginning 2020	Lockdown (first 30 days)	Lockdown (whole period)	
Active/non-motorized mobility (on foot, by bicycle, other non-motorized vehicles)	25.1%	33.4 %	38%	34.9%	+ 9.8%
Private mobility (cars, motorcycles and other individual motorized vehicles)	62.6	56.5%	57%	61%	- 1.6%
Public and exchange mobility (public transport, combinations of vehicles)	12.3%	10.1%	5%	4.1%	- 8.1%

Table 3 summarizes the difference, in terms of mobility features, before and during the COVID-19 health emergency in Italy. In the first 30 days of Italian lockdown a drastic reduction in the demand for mobility was registered: around 60% of journeys and 90% of passengers*km (km travelled) less than the daily average.

The reduction of the mobility rate was more contained, i.e., 32%, if all trips - even very short ones - are considered. This means that more than half of the population has made one-day trips, in some cases of short duration.

Table 3 - Variations of mobility demand volumes pre and during COVID-19 in Italy
Data Source: [53]

	Average 2019 (a)	Beginning 2020 (b)	Lockdown (c)	Variation 2019 (c) - (a)
Mobility rate	85%	80%	32%	-53%
"Extended" mobility rate (includes trips of less than 1 km and on foot)	91%	90%	49%	-42%
Average number of daily trips	2,14	2,03	0,7	-67%
Average length of trips (km)	11,2	9,6	5,8	-48%
Trips (million), excluding the ones on foot	103	98	34	-67%
Passengers*km (millions)	1210	941	197	-84%

More in general, during the COVID-19 period, longer, structured and systematic trips have been often replaced with very short ones, on foot, in the neighbourhood (the so-called "proximity mobility"). As regards the division of the population into age groups, the elderly population recorded a reduced mobility rate of 30% and an overall contraction of movements of 80% compared to the total; the drop in the demand for mobility of young people, due to the total closure of the schools, it was somewhat higher than the middle-aged population groups. The segmentation between professional conditions is rather marked: retirees remained largely at home; students, housewives and unemployed they drastically reduced their movements, while those who have a job carried out at least one daily shift in two out of three cases, registering a reduction in demand of about 50% (10% less than the general average).
The average length of journeys has decreased by over a third. Furthermore, there was a modal repositioning, in the order of 5 percentage points, in favour of non-motorized mobility (in particular on foot), to the detriment of collective and intermodal mobility, whose weight more than halved during the lockdown.
The weight of cars in the modal split is growing more in the North-West and in the Centre of Italy, where the presence of large metropolitan cities is stronger, while it decreases in the South and in the islands (Sicily and Sardinia).
Table 4 expresses the variation of the use of different transport modes during and after the lockdown in Italy. It can be noted that, after three months from the end of the lockdown, the negative effects of the pandemic on local public transport and long-distance travel are still very relevant.

Table 4 - Variation of transport mode use during and after Italian lockdown
Data Source: [60]

	During lockdown	**After lockdown** (in the first 3 months)
Local Public Transport	-85/-90%	-60/-80%
Shared Mobility	-70/-90%	bike/scooter -20% car -50%
Long-distance travel (rail and car)	-95%	-70/-80%
Travel by car	-70/-80%	-10/+10%

Specifically regarding local public transport, from May to September 2020 the reduction was around 60%, whereas from September to December 2020, it further reduced to -40% (*Source: Agens, Anav, Asstra*).

3. The evolution of virtual communication in Italy

3.1 The evolution of virtual communication in Italy before COVID-19

In recent decades, technological progress and digital technologies have played a fundamental role in the transformation of our society. The innovations that have taken place in the technological sector (ITS and ICT) since the 70s (Figure 12) have increasingly allowed people to communicate easily and economically, also in a virtual way, with obvious benefits in terms of time and cost savings as well as environmental protection and positive social impacts. Territorial boundaries and spatial distances have been tremendously reduced, with a consequent impact on mobility patterns.
Figure 12 shows the devices, transmission systems, service and ITS tools from 1970 to 2018. Virtual communication, especially through the use of short messaging, is becoming the predominant mode of communication: more than 6 out of 10 people regularly communicate via SMS, e-mail, Skype, instant messaging and social networks. A percentage of 4.5% of the population (2 million 560 thousand people) declares that they regularly use all five of the communication methods considered. Among young people aged between 18 and 24 the percentage of "multi-user" reaches 13.8% [17]. If the geographical distribution in Italian Regions is approximately uniform, there is a greater use of virtual communication in metropolitan areas than in less populated ones.

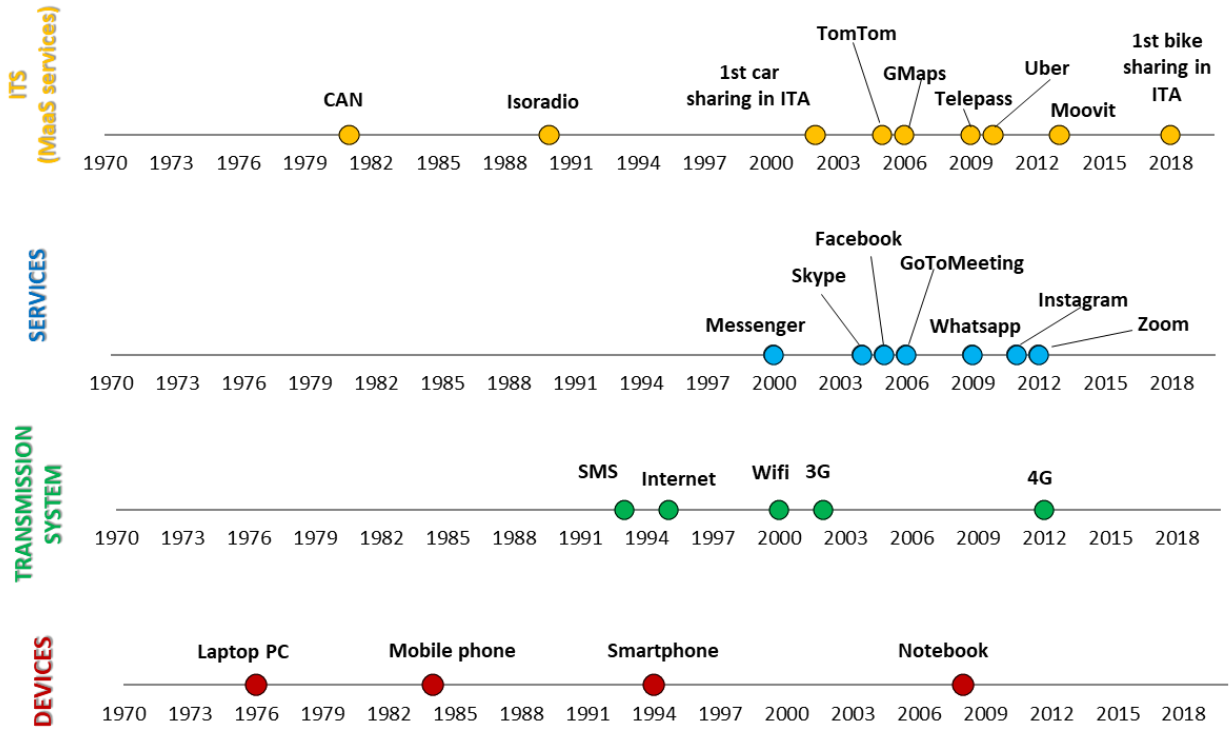


Figure 12 - Introduction of ITS and ICT technologies in the market, 1970 -2018

Italy was among the first European countries to access the Internet in 1986. In the last fifteen years in Italy the share of regular and strong Internet users has continued to increase at the expense of non-Internet users (Figure 13).

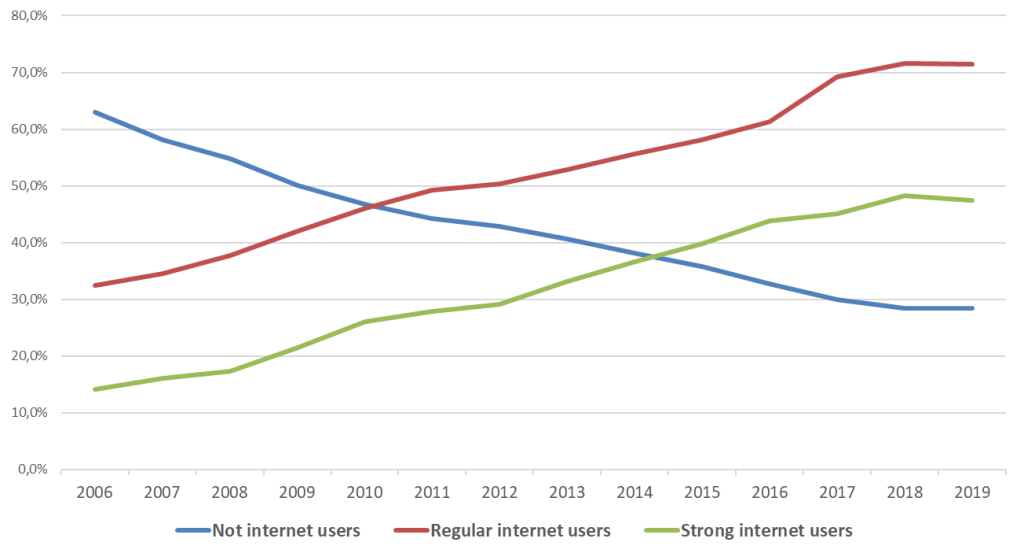


Figure 13 - Use of internet in Italy, 2006-2019
Data Source: [17]

Figure 14 shows the trends related to motorized mobility and to the use of ICT technologies in Italy from 2005 to 2018. It can be noted that after a strong initial increase, the use of ICT has undergone a slight decrease between the years 2014 and 2016 and, afterwards, it continued to grow. On the contrary, as already pointed out in Section 2.1, in the same years the trend of motorized mobility remained nearly constant.

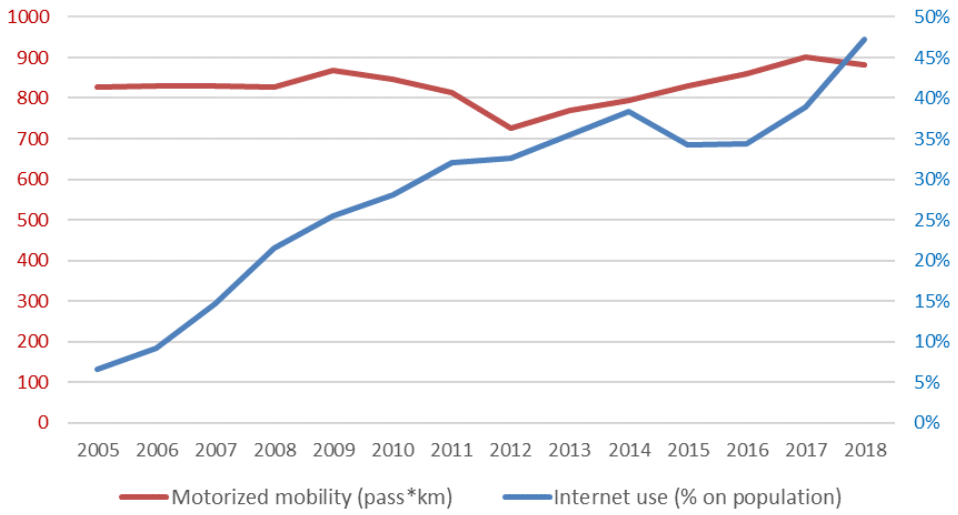


Figure 14 - Motorized mobility and use of ICT technologies in Italy from 2005 to 2018
Data Source: [52]

3.2 Virtual mobility in Italy during Covid-19 health emergency

The pandemic has highlighted the huge role that the Internet plays in our lives, in keeping our society functioning and cohesive [61]. The obligation to stay at home and to go out only in cases of extreme necessity, imposed by the Italian decree "*I'm staying at home*" (8th March), had great implications on users' digital consumption habits.
During the lockdown period, the digital world has allowed millions of people to keep communicating and be connected in many life segments, such as work or school, as demonstrated by the increase of gigabytes per second used by the Italian population (Figure 15). Since the release of the decree, in fact, there has been an increase in internet traffic of around 25%.

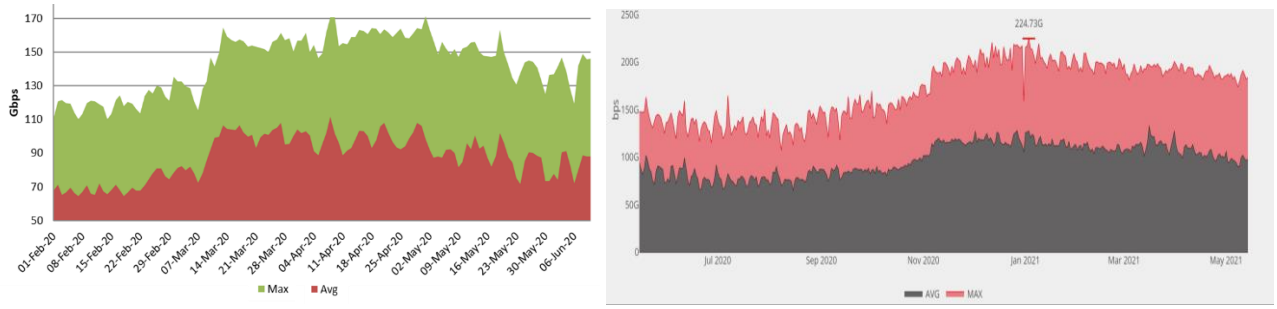


Figure 15 - Amount of gigabytes per second (upload and download) in Italy, max and average values, February 2020-May 2021
Source: [62]

In Italy, the first European country hit by the pandemic, internet traffic has increased significantly starting from the week of 17-23 February 2020.
In the impossibility of going out, the Italians made the most of social media and messaging services to "meet", share experiences and information.
Regarding e-commerce, with the lockdown, the use of internet sites for purchases increased. The first peak occurred in May and June 2020, while the second in October 2020 in which there was an increase of 30% and 40% respectively compared to the same periods of previous years.
Having to limit outings to buy food, visits to supermarket sites to buy on the web have increased, especially during the first lockdown period of March 2020.
Web visits to consumer electronics chains (such as Mediaworld, Unieuro and Euronics) were characterized by only a slight increase in April and May 2020; the “Back to school” and the “black Friday” period were more positive.
Staying at home during the pandemic lockdown, there was no need to buy clothes. Therefore, clothing sales collapsed in March- April 2020, followed by a recovery in the next months.
The health crisis has generated a natural desire to be updated, to deepen the health and news aspects related to the moment out of the ordinary. A phenomenon highlighted by the increase in visits to online news sites, which more than doubled in March.
In the impossibility of going out, the Italians made the most of social media and messaging services to "meet", share experiences and information. Both the number of users and the time spent on various social media have grown.

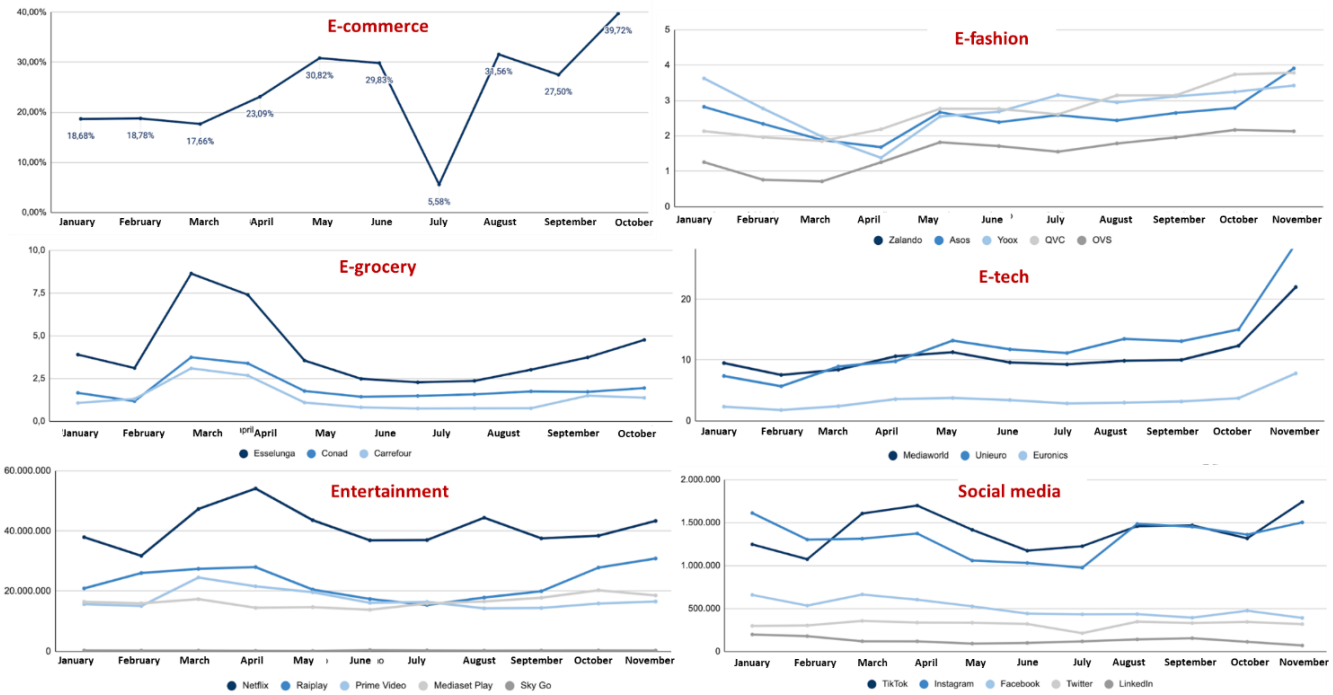


Figure 16 - On line behaviours during COVID-19 in Italy, January-November 2020

Source: [63]

As regards videoconferences tools, the graphs in Figure 17 show the use of the main platforms in Italy in the period January-November 2020: as expected, the number of accesses grew significantly from February 2020 and reached a peak in May 2020. This number then decreased in the summer, but has resumed at a rapid pace since September 2020.

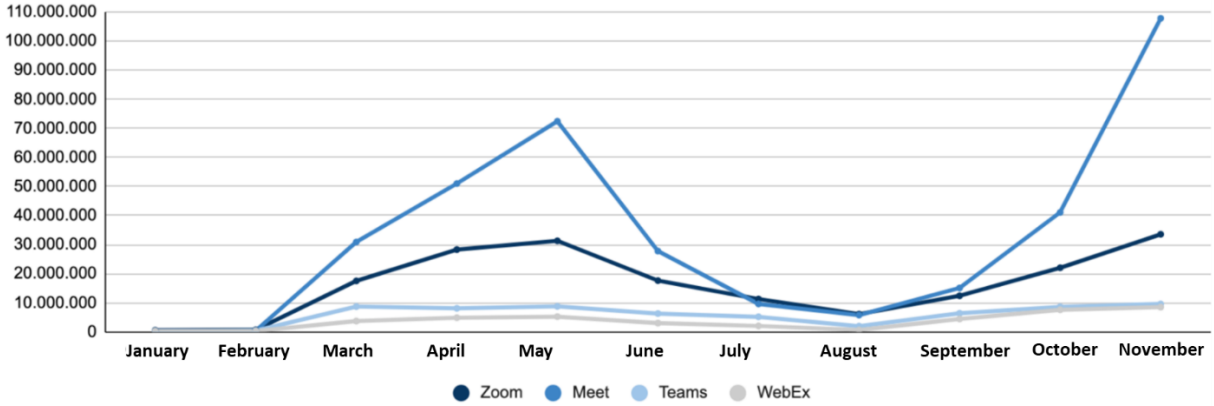


Figure 17 - Use of videoconference tools in Italy (accesses), January-November 2020

Source: [63]

4. The relation between physical and virtual communication in Italy

Based on the effects of COVID-19 pandemic on the Italian society, in this section it will be analysed the relationship between physical and virtual mobility during and after the COVID-19 health emergency and, also through the use of a SWOT analysis, it will be evaluated how virtual communication may impact the demand for physical mobility in the post COVID-19 period.

It is increasingly evident that virtual mobility can represent a fundamental tool for regulating the level of physical mobility, so as to reduce the negative externalities associated with the physical movement of people (environmental pollution, congestion, etc.). In particular, the influence of virtual mobility on the demand of physical mobility may be of three types:

- "reducing": virtual mobility contributes to reducing the demand for physical mobility;
- "neutral": virtual mobility has no influence on the demand of physical one;
- "reinforcing": virtual mobility helps to increase the demand for physical mobility.

Table 5 points out the relations between physical and virtual mobility in Italy during and post COVID-19, differentiating between the main mobility segments (i.e., the main reasons behind people's movements). More specifically, Table 5 reports the percentage of total trips in Italy in 2008 and 2018 [53], the type of impact of virtual mobility over physical one both during the Italian lockdown period and after COVID-19 health emergency, the technologies involved and the main area of influence (urban, sub-urban and long distance). All types of communication without movement have an effect on physical mobility, albeit in a different way:

a. *Work*: people movements for work reason represent nearly one third of the whole mobility in Italy before the lockdown. According to a research conducted by the smart working Observatory of the School of Management of the Milan Polytechnic [19], before COVID-19 pandemic in Italy there were 570000 smart workers (at least one day a week), an increase of 20% compared to 2018. Respect to colleagues who work in the traditional way, "smart" workers are on average more satisfied in relation to the organization of their work (31% of smart workers against 19% of other workers), the relationships between colleagues (31% against 23%) and the relationship with their superiors (25% against 19%). According to the Italian Ministry of Labour, in Italy, at the end of April 2020 there were a total of 1827792 smart workers, of which 1606617 due to the health emergency, representing a 320% increase respect

to 2018. It is conceivable that the numbers of smart workers after COVID-19 will inevitably decrease but will still remain higher than in the period preceding the pandemic. In any case, this phenomenon will surely have repercussions in the future, also on physical mobility. A substantial use of smart working may modify work characteristics: the possibility to work in other places than in the office, allows to reduce the load on transport infrastructures, mainly in peak times. Furthermore, by managing time more autonomously and saving time to get to the workplace, it is possible to devote more time to movements dedicated to carrying out unsystematic activities (free time, fun, etc.). Smart working allows to adapt work hours to people habits and peculiarities (some people prefer to work at late hours or at night, others prefer in the morning) and this flexibility can help a better distribution of mobility throughout the day, also with the help of ITS. With the increase in coverage of high-speed Internet access and the increase in transport costs, working from home is becoming increasingly attractive and the projections say that it will be equally likely that this number will be well beyond the original 500,000 pre-COVID-19.

If on the one hand, IT videoconferencing services allow remote meetings without the need to physically bring people together, on the other, these tools allow to easily put in contact distant working environments, so potentially generating new demand for physical mobility, but with a lower intensity compared to the replacement of physical demand mobility.

Although in many companies, employees are gradually returning to work in the office (when permitted by local state laws and the current health situation), more flexible work structures are expected to increase, as many workers say they would like to work from home more often. This means that the demand for digitalization and enabling technologies - such as video calling software - will strongly increase [64].

b. *Education*: during the lockdown period, a phenomenon similar to that of intelligent work hit the world of education (school and university), which day by day found itself struggling with distance learning methods. Like the work segment, the main effect of virtual communication in the educational world is to subtract physical mobility quotas; however, in some cases, the use of ICT technologies can generate a new demand for mobility, putting people in contact with each other (even if this is more valid for the university than for the school sector).

c-d. Shopping and food delivery: the COVID-19 lockdown has literally boosted e-commerce (i.e., the purchase of products through online services) to the detriment of physical stores which have started facing a significant drop in sales.

In order to facilitate the online purchase of products, some companies in the consumer goods sector have started offering interactive online shopping, with purchases in streaming mode and shop assistants in chat to support customer questions. An Italian clothing brand, which has numerous points of sale throughout Italy, has launched a sort of interactive shopping, a kind of personal shopper able to give advice in real time to customers, as the buyer were shopping in a physical store accompanied by a shop assistant. Another Italian company organized 'live stream shopping', consisting of direct streaming in which the sellers present the new collections and the customers, connected live, can participate and chat also by purchasing the garments directly by clicking on the images that scroll. In this way, customers can easily shop and avoid the queues outside the store [65].

The main effect of e-commerce (i.e., the purchase of products through online services) is to reduce the number of trips of customers towards shops and shopping centres. Moreover, the ability to shop directly from home has an impact on the types of travel: to a reduction in the number of customer trips corresponds an increase in the traffic of couriers and vans for home delivery.

e. *Travel:* during the COVID-19 period, people stopped travelling, both because of government restrictions and dangers of infection on transportation means. After the emergency phase, people are gradually resuming travel. In this segment of mobility, the internet and digital technologies can generate new demand for physical mobility, connecting people with other parts of the world and providing useful information for travelling.

f. *Meetings with known people*: if the use of virtual communication during the lockdown was fundamental to guarantee communication among family members and friends, it is likely that this type of communication will play a marginal role in the post-COVID period and that it will return to approximately pre-pandemic levels. In fact, the opportunity to meet people live is definitely more satisfying from the point of view of interaction than communicating with them virtually, with some distinctions; in fact, already before the pandemic, some studies [69] pointed out that younger people sometimes prefer communicate remotely through electronic devices rather than physically move. Therefore, the possibility of having access to instant messaging software (i.e., WhatsApp, Telegram, etc.), social networks (i.e., Facebook, Instagram, Twitter, etc.) and video chat platforms (i.e., Skype, Zoom) only partially replace the need to physically move.

The possibility of generating new physical mobility thanks to virtual communication between known people is marginal.

g. *Meetings with unknown people*: during the lockdown, virtual tools (such as social networks and online dating sites) did not replace physical mobility linked to movements to meet unknown people, since it is precisely virtual communication that allows unknown people to be put in contact. In the post-COVID 19 period, virtual devices may generate a new demand for mobility, albeit at a marginal level.

h. *Sport and entertainment:* during the lockout period, people started using virtual tools for things they most likely would not have used digital channels for before, or at least not so much, such as virtual gym, virtual pub or live chat [66]. Once the health emergency is over, it is likely that virtual communication, which potentially subtracts physical mobility quotas, will increase a bit respect to the pre-COVID period but still play a marginal role in this segment.

i. *Healthcare, banking, insurances and public administration services*: the new Coronavirus pandemic has constituted a (forced) accelerator of the digitization process also for public administrations and public service providers, both as regards the increase in the range of services offered "remotely" and the greater propensity to use by consumers. For several years, States have been oriented to push citizens to create a certified digital identity (in Italy SPID), the experience of the lockdown shows how these policies are to be pursued more effectively.

Fewer and fewer people will move to deliver/ withdraw documents, recipes, reports, which will be conveniently delivered in digital format. This will encourage an increase in free time, thus probably generating a new demand for mobility in the post COVID-19 period [67].

Table 5 - Relationship between physical and virtual mobility in Italy during and post COVID-19
Source: [53]

Reason to move Motivation			Percentage of total trips in Italy (2008- 2018)		Impact of technologies during COVID-19 (lockdown)	Impact (and related degree) of technologies post COVID-19 (respect to pre-COVID-19)	Technologies involved	Main influenced area
a	Work and education	Work (including business trips)	30,8%	29,0%	**REDUCING** high level	**REDUCING** medium level	Videoconferencing services and internet	Urban, Suburban, Long distance
b		Education (school, university)	5,1%	3,9%	**REDUCING** high level	**REDUCING** medium level	Videoconferencing services	Urban, Suburban
c	Purchase	Shopping	11,9%	11,0%	**REDUCING** high level	**REDUCING** medium level	E-commerce websites (platforms and individual shops)	Urban, Long distance
d		Food delivery			**REDUCING** high level	**REDUCING** medium level	E-commerce websites (platforms and individual shops)	Urban
e	Free time	Travel	32,7%	34,1%	**NEUTRAL**	**REINFORCING** low level	-	-
f		Meetings with known people			**REDUCING** high level	**NEUTRAL**	Social network, messaging/video chat services	Urban
g		Meetings with unknown people			**NEUTRAL**	**REINFORCING** low level	Social networks and dating sites	Urban
h		Sport and entertainment			**REDUCING** low level	**REDUCING** low level	Videoconferencing services	-
i	Services	Healthcare, banking, insurances and public administration	19,5%	22,0%	**REDUCING** medium level	**REDUCING** high level	E-mail and telematic services	Urban, Suburban

Besides, it can be seen that most of the movements are carried out in urban or suburban areas (last column of

Table 5); in fact, long distance movements influenced by the use of technology mainly concern business travel and the distribution of consumer goods. Therefore, the means of transport most influenced by virtual communication are short-range private cars, local public transport (buses, trams, subways), shared mobility (cars, bicycles, etc.), medium-distance trains and air transport business segment.

Also the worldwide consulting company McKinsey, through a survey carried out in February 2021[1], has put into evidence that Italian picked up new digital activities since the start of COVID-19 and that post-COVID online purchasing is expected to grow across almost categories, as shown in Figure 18.

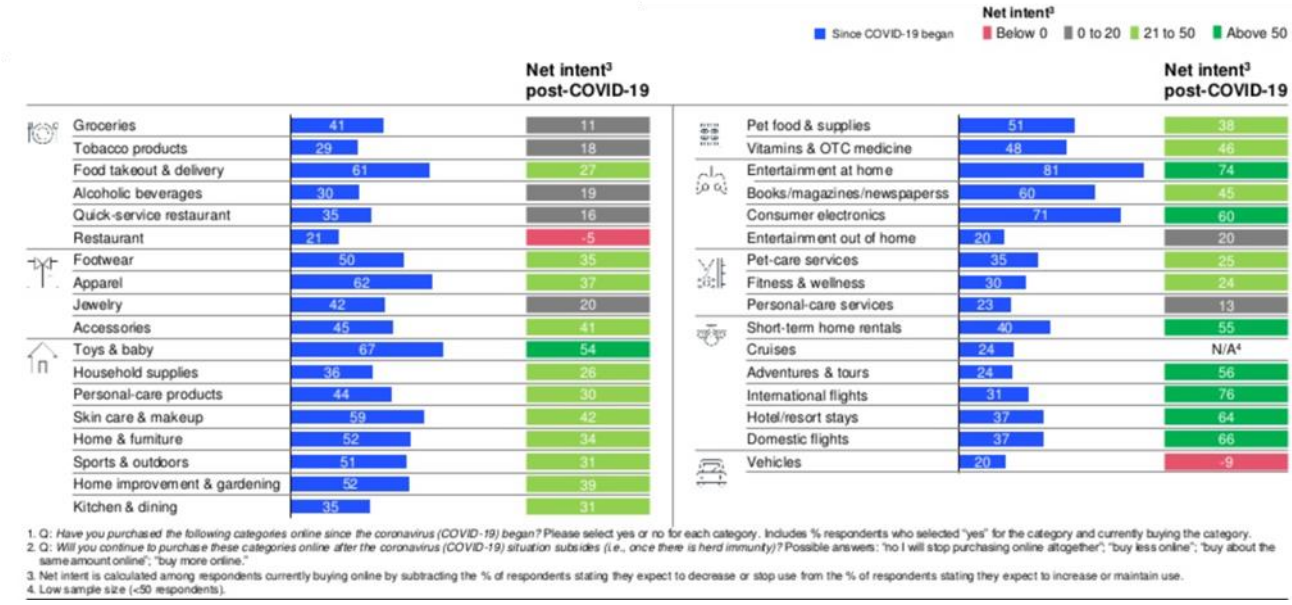


Figure 18 - Consumers' use of online channel during[1] and after[2] COVID-19 (% of respondent buying this category)

Source: Mckinsey and Company consulting company

The reduction of physical mobility enabled by digital technologies has two main positive impacts: on the environment and on the society. Regarding the former, several studies pointed out the enormous benefits in terms of pollution reduction reached during the lockdown period. A problem known in Italy for several years concerns the pollution of the Northern part of the Country where limits have been imposed on vehicular traffic; these limits have been increasingly stringent over the years but never sufficient. Figure 19 highlights the comparison between the average nitrogen dioxide concentrations in the period 14-25 March 2020 and the monthly average of March 2019 in Italy: the level of pollutants is much lower during the lockdown period, especially in regions with high pollution as the Po Valley ("Pianura Padana").

[1] McKinsey & Company CODID-19 Italy consumer Pulse Survey 2/23-2/27/2021, n=1, 091, sampled to match Italy general population 18+ years.

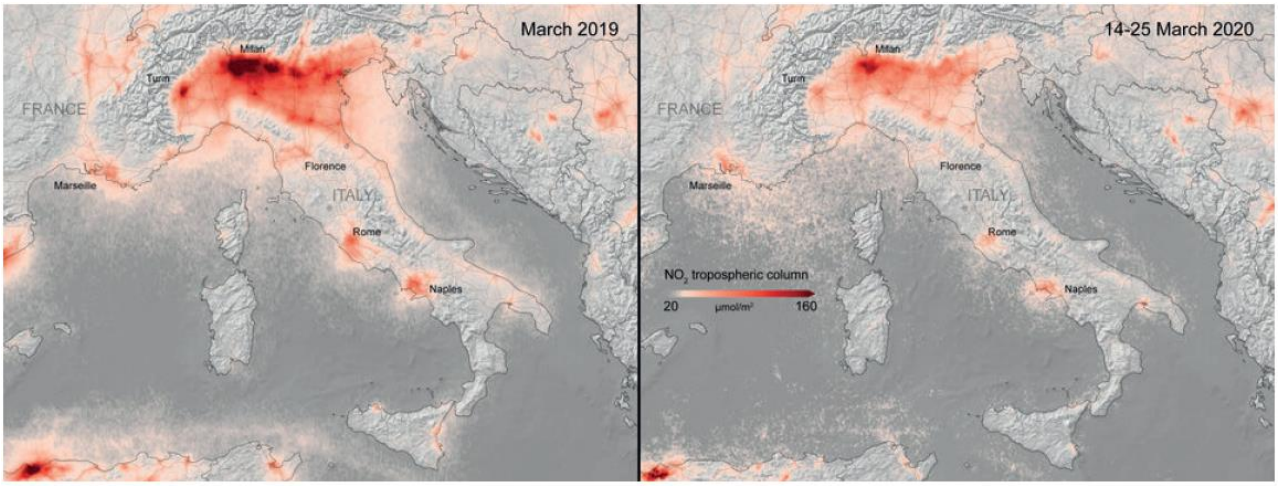
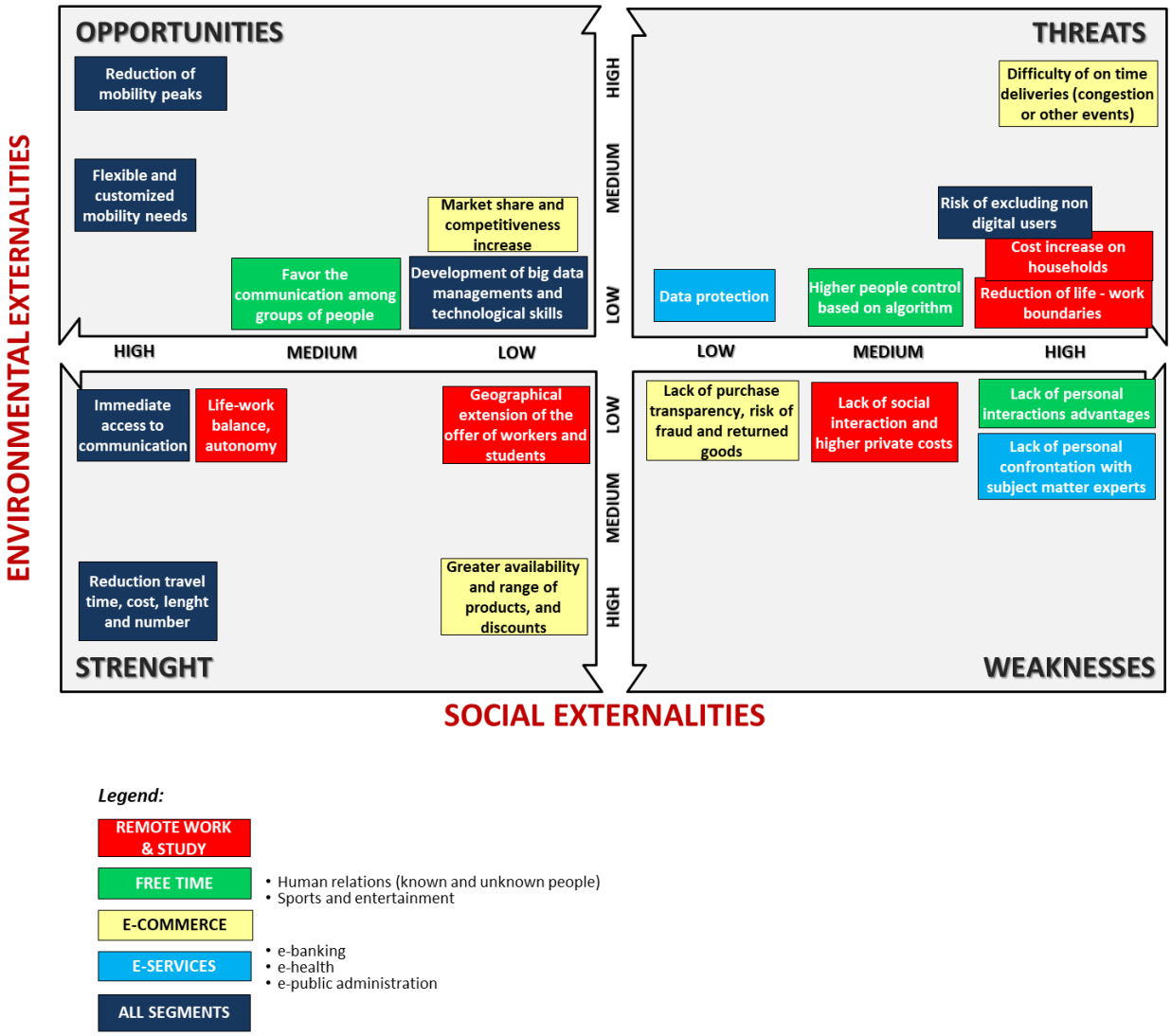


Figure 19 - Average of nitrogen dioxide concentrations from 14 to 25 March 2020 compared with the monthly average of the concentrations of March 2019 in Italy

Data Source: Copernicus Sentinel satellite - 5P

4.1 A SWOT analysis on Virtual communication

In Figure 20, a SWOT analysis is presented to highlight Strengths, Weaknesses, Opportunities and Threats of virtual communication. As explained in the figure legend, the boxes are coloured according to the different segment of mobility and their position provides indication in relation to their impacts (high, medium or low) respect to social (security, privacy, extension of the offer, attention to weaker groups of population, containment of road congestion, noise, etc.) and environmental (reduction of level of pollution, greenhouse gases, etc.) externalities.



Legend:

- REMOTE WORK & STUDY
- FREE TIME
  - Human relations (known and unknown people)
  - Sports and entertainment
- E-COMMERCE
- E-SERVICES
  - e-banking
  - e-health
  - e-public administration
- ALL SEGMENTS

Figure 20 - Virtual mobility SWOT analysis

In the following, the SWOT analysis for each segment of mobility is analysed more in detail (Figure 2020).

4.1.1 Remote work and study

The main point of strength related to remote work and distance learning is represented by the chance to carry out work and education activities in whatever places, also very distant from the main locations, with related benefits in terms of travel time and cost saved. Another advantage is represented by the possibility to access to a greater basin in terms of workers and students. Moreover, remote working - through an appropriate regulation - allows to find a more efficient balance between private and working life, making the worker more responsible. Remote working and learning will also have potential positive repercussions on road congestion and the environment, thanks to the reduction in the number of trips.

However, the risks concern an increase in costs for the family unit (for example relating to electricity or internet connection, rather than the necessary IT devices) as well as the threat of a reduction in the boundaries between life and work, with a consequent erosion of free time. To meet this last critical issue, the concept of "right to disconnect" is increasingly being introduced into companies; it will therefore be essential to set appropriate regulations capable of protecting all the parties involved and properly regulating hours and methods of work and study.

4.1.2 Free time

Digital technologies allow people to communicate also for activities related to their free time (social relations, sports, etc.) with the main advantage - common to all other segments - of reducing costs and travel times,

with relative reduction negative externalities. However, the main threat is represented by the potential exclusion of those who are unable to use digital technologies, as well as the risk of controlling people's preferences through specific algorithms.
Furthermore, it should be emphasized that such virtual interactions cannot be totally substituted for physical interactions, under penalty of the threat of alienation for both young people and adults.

4.1.3 E-commerce
The possibility of exploiting online commerce not only represents a strength for users who can access a greater number of products - that may not be found locally - and potential discounts, but also for dealers who can enhance their market share and competitiveness, by reaching a bigger and also more distant clientele simply by sponsoring their products through the web. The convenience and benefit of buying remotely, however, is subject to the threat of online scams, little transparency or falsification of information. A policy aimed at mitigating these phenomena and greater awareness in the use of e-commerce would reduce the threats and weaknesses of this virtual mode.
Furthermore, the increase in online sales must certainly be accompanied by a rethink in transport models and processes, in order not to congest road infrastructures and, at the same time, satisfy users in terms of time deliveries.

4.1.4 E-services
The use of online services (such as banking, insurance, health care) for the citizen represents a convenient advantage both in terms of saving time and managing privacy. Among the main threats is the adequate protection of personal data and the possible lack of trust that is instead often guaranteed by human interactions. This latter aspect is more important for some services, such as e-health, than for others.

4.1.5 All segments
For all segments of mobility, virtual communication enables wider and immediate accesses to services, so significantly reducing the time and costs needed for the movements, which ultimately translate into significant environmental and social benefits: congestion reduction, mobility peaks and pollutants, together with a more balanced and sustainable social life. An important opportunity refers to the possibility of better distributing physical mobility during day hours, so reducing congestion on the roads and pollution levels. Moreover, as shown in Figure 5, this is already an ongoing process, which supports the needs of the demand for mobility that is changing over time. Flexible and customized mobility needs, made possible through the use of IoT (Internet of Things), Big Data and ITS, represents another element of opportunity introduced by virtual communication, together with the chance of strengthening technological skills and competences that may be also applied in other fields.
It must be also pointed out that policies to enhance the development of digital culture and competences are necessary to support the "weak" users of digitalization, who have no chance or familiarity with information technology.

5. Policy indications in relation to physical and virtual mobility in Italy

One of the main goal of the present paper is to provide some policy indications in relation to different segments of mobility (work and study, purchase, free time and services), based on different governance levels (urban and regional/national). The ultimate goal is to pursue secure, sustainable, effective and connected communication between people, using virtual mobility to regulate physical one, thus reducing negative externalities associated with the transport of people.

As already previously pointed out, the reduction of physical mobility during COVID-19 pandemic period has also highlighted how a decrease in transport is able to significantly reduce local air pollution and partially CO_2 emissions, with obvious benefits for the environment. Considering the growing need of communication among people on one side, and the increasing sensitivity towards environmental and social issues on the other, virtual mobility may represent a useful tool for policy makers to regulate mobility levels and, consequently, reducing transport negative externalities (pollution, congestion, accidents, noise, etc.).

In other words, virtual mobility may represent a fundamental instrument to maintain constant levels of physical mobility; this may help to minimize the construction of new physical infrastructures and make existing transport systems "smarter". In this context a crucial role is played by Intelligent Transport Systems, that rely on information technology, telecommunications and multimedia, in order to face with problems of public and private mobility in an innovative way, developing safe, efficient, effective, economical and sustainable solutions. The constant evolution in the technological development sector, in fact, allows to manage the people transport system in an intelligent way and to meet the various needs expressed both by operators (optimization, fleet management, economic balance, etc.) and by public transport users and private (congestion, vehicle saturation, frequency of passages, etc.). The smart management of mobility through ITS, combined with the ability to communicate without moving, can substantially influence the choice of people to move or not and in what way.

For all mobility segments, the hours of entry at work, schools, public and commercial services, commercial, leisure and entertainment places (culture, parks, gardens, etc.) should be expanded and differentiated, to reduce peak hours and make better use of spaces and available services, in particular by using sharing mobility and collective transport.

In companies, smart working should be increasingly adopted by companies, not only during emergencies, with the aim of working more effectively, efficiently and with greater flexibility; if unforeseen events occur (e.g. a strike of the means of transport or the postponement of the delivery time of a certain job), the worker must be ready to work away from the workplace and at a different time than usual.

The role of Mobility Managers in companies, schools and territorial area is important in order to match supply and demand and imagine flexible management and dedicated services.

The sharing of mobility and MaaS (Mobility as a Service) services should be broadened and strengthened. Bike sharing, scooter sharing and micro electric mobility are essential services to move independently and maintain safety distances between people. The combination of these services, together with mobility offers integrated with local public transport, dedicated and flexible services, mobility bonus, info-mobility and real-time demand/offer, form the backbone for the MaaS Services, i.e., the mobility as a service that several cities are planning [59].

Regarding urban logistics services, it is desirable to favor sustainable and efficient low-impact services, adopting less pollutant vehicles (such as electric ones), in agreement with the operators. Moreover, other important actions would be the reorganization of distribution systems, transit points, multi-product delivery services, bookable parking areas, proximity distribution centers.

The aftermath of the COVID-19 pandemic has accelerated digitalization. The use of digital tools allows to strongly customize the transport offer. Moreover, they allow to better manage people flows. In this context, artificial intelligence systems and optimization algorithms may be used to: (i) predict future mobility demand by using, in an integrated way, data coming from external apps, IoT (that allow to monitor people on transport means and in stations) and ticket purchase systems (websites, self-service machines, local operators), (ii) provide increasingly dedicated and personalized services to users, also in real time. By knowing load factors on transport means and in different time slots, it is possible to better manage means capacity and better allocate vehicles on time slots and routes. When there is no possibility of increasing capacity, digital tools allow to better distribute the flows.

Ultimately, digital tools can be used to influence the demand for mobility, informing users in real time of the conditions of the network and vehicles, thus providing travel alternatives in both spatial and temporal terms, with the aim of reducing crowding on vehicles and vehicular congestion on the roads.

Tables 6, 7 and 8 provide some policy indications according to three different scenarios with increasing impact regarding the levels of congestion and pollution generated by physical mobility: low/acceptable, medium/critical and high/unacceptable.

Regarding physical mobility, the areas of administrative competence have been divided according to the competence areas defined by the current Italian legislation, whereas for virtual mobility, a division of competences between the administrative bodies is not yet provided; this aspect represents a criticality: since, the measures related to digitalization are entrusted to individual projects and territorial bodies, without often having an overview. Only in recent years, the Italian Government set up a Ministry specifically dedicated to digital innovation, collecting various projects deriving mostly from local policies.

The proposed policies must be read in an increasing sense with the scenarios: to implement the policies of the most critical scenario, those of the previous scenarios must be adopted first.

In the following the three scenarios are analysed, leaving more details to Tables 6, 7 and 8:

- **Scenario A** represents a future scenario with low and acceptable levels of congestion and pollution. Policy actions focus, on one side, on discouraging the use of the private motorized vehicles in favour to sharing public and non-motorized mobility and, on the other side, on providing them the chance of carrying out some activities remotely, albeit gradually and in limited quantities. he proposed policy actions take longer to persuade and accustom users to use new ways of managing their activities and mobility. The use of the ITS system is encouraged.
- **Scenario B** refers to a critical level of congestion and pollution. The policies presented are focused, on the one hand, to more substantial incentives/bonus for shared and "green" mobility and, on the other hand, to more significant limitations. Virtual communication policies regard offers of services managed or financed by the Public Administration towards local businesses. The use of ITS system is strongly encouraged.
- **Scenario C** represents that characterized by high and unacceptable levels of congestion and pollution (generated by physical mobility). The proposed policies represent obligations and restrictions on normal daily activities in order to promote ever greater sustainability. Having created a network of mobility services through the policies suggested in the previous scenarios, in this scenario we try to orient citizens' habits towards a predominant use of virtual communication. Furthermore, the use of motorized private mobility is strongly discouraged in favour of smarter (use of ITS, MaaS, etc.) and shared mobility.

Table 6 - Policy indications: scenario A

Mobility segment	SCENARIO A: LOW/ACCEPTABLE levels of congestion and pollution due to physical mobility		
	Physical mobility		Virtual mobility
	Urban level	Regional/national level	
Work (including business trips)	Sharing services activation. Pursuit of objectives related to Urban Plan of Sustainable mobility (UPSM).	Investments in Local Public Transportation. Incentives to sustainable mobility. Revision of the Highway Code regarding travel by bike and micro mobility.	Incentives/bonus for technological purchases to workers/companies adopting the remote mode with significant frequency. Support public administrations and private companies that decide to reorganize work in a smart working perspective, also by studying tax advantages. Investment in high speed technological infrastructures.
Education (school, university)	Incentives to students for the use of sustainable mobility. Creation of infrastructures for sustainable mobility and local school-bus services. Construction of a network of urban cycle routes to main school and university centers. Differentiation of entry and exit times to/from educational buildings.	Creation of school-bus services in agreement with regional transport companies, rethinking timetables of metropolitan railway lines and favoring multimodality.	Incentives/bonus for technological purchases to schools/universities (both hardware and software). Investment in high speed technological infrastructures.
Shopping	Creation of lockers for non-presence delivery/collection of parcels/goods.	Creation/improvement of distribution and logistics centers, so to. Favor policies on fair competition and social impact on workers, policies in favor of the use of credit card payments.	Favor online service for the purchase of remote shopping.
Food delivery	Incentives to create/sustain local neighborhood markets. Favor extended opening hours supermarkets in barycentric city areas.	Promote the development of distribution centers in optimal location from the point of view of environment and congestion.	Favor online service for the purchase of remote food shopping. Reduction/incentives related to delivery costs for products of primary importance.
Healthcare, banking, public administration services	Creation of lockers for non-presence delivery to collect/deliver documents.	Decentralization of services. Open branches supported by already existing service networks (e.g. post offices, tobacconists, outpatient centers).	Promote the digitalization and dematerialization of Public Administrations. Favor the use of online ICT services, also by educating people on using them.

Table 7 - Policy indications: scenario B

Mobility segment	SCENARIO B: MEDIUM/CRITICAL levels of congestion and pollution due to physical mobility		
	Physical mobility		Virtual mobility
	Urban level	Regional/ National level	
Work (including business trips)	Creation of Limited Traffic Zones, interchange parking, design and implementation of modern transport systems (subways, people movers, etc.). Investment in Local Public Transport. Differentiated pricing policies for parking areas and road accesses in different times. Favor the use of MaaS. Promote the establishment of collective transport services dedicated to employees.	Incentives for purchasing hybrid and electric cars. Promotion of high-speed rail transport for business trips.	Higher incentives/bonus/ tax advantages for public administrations and private companies adopting smartworking mode with high frequency. Favor staggered entrances to workplaces at different times slots.
Education (school, university)	Create pedestrian/protected areas around education centers. Discounts/incentives for the use of public transport, bicycles and micro mobility. Favor the use of MaaS. Promote the establishment of collective transport services dedicated to students.	Promote intermodality services to connect schools and universities with urban areas.	Stronger e-learning incentives and investment in IT services for schools /universities. Development of dedicated platforms and software (ministerial license system for use by schools). Public training courses on IT tools for teachers and students.
Shopping	Incentives for people to make shopping not in rush hours. Discounts/incentives for the use of public transport, bicycles and micro mobility. Pricing policies/reward systems for parking and accessing roads in different times. Definiton of delivery times for goods so to distribute traffic in less busy hours. Home delivery bonus for weaker/low-income families. Favor sustainable urban logistics services for efficient low-impact goods with electric vehicles. Favor the installation of lockers to innovate the delivery and collection of products purchased online.	Create intermodal centers for medium - long haul transport. Incentives to sustainable (hybrid, electric vehicles,..) deliveries. Incentive to local productions.	Bonus to companies for the purchase of internet subscriptions and video conferencing platforms. Bonus for purchasing sustainable delivery vehicles.
Food delivery			
Healthcare, banking, public administration services	Improve the accessibility to public services buildings.	Incentives for the construction of APM for high concentration and influx places.	Favor the digitalization of services, also through different pricing policies with respect to non-remote services. Make certain digital services mandatory for the Public Administration. Promote the digital identity (SPID).

Table 8 - Policy indications: scenario C

Mobility segment	SCENARIO C: HIGH/UNACCEPTABLE levels of congestion and pollution due to physical mobility		
	Physical mobility		Virtual mobility
	Urban level	Regional/ National level	
Work (including business trips)	Strong limitation to private motorized mobility based on time slots and traffic conditions. Dynamic pricing policies for parking areas and road accesses according to traffic levels and pollution. Organize dedicated shuttles for emplyees with dynamic planning.	Taxation for the purchase of private vehicles. Company car limitation (tax system), incentives for scrapping old cars, polluting car restrictions, investment in high-speed lines and regional trains.	Smartworking mode in higher frequency than the physical presence in companies. Incentives for companies adopting smartworking. Obligation of doing smartworking in particular conditions (high traffic, particular events, critical weather conditions, etc.).
Education (school, university)	Strong limitation to private motorized. Mobility based on time slots and traffic conditions. Differentiated accesses of students to education buildings based on time slots and traffic conditions. Organize dedicated shuttles for students with dynamic planning.	Reimbursement and possibility of deduction of public transport expenses, creation of large provincial interchange centers with rail and metro services designed for schools /universities accesses. Disincentive to use private vehicles.	Compulsory distance learning mode in some periods and in particular conditions (high traffic, particular events, critical weather conditions, etc.). Prevalence of distance learning mode.
Shopping	Hourly regulation for the delivery of goods to large centers and shops. Limitation of private cars. Obligation of differentiated pricing parking policies according to particular conditions (high traffic, particular events, critical weather conditions, etc.).	Prohibition of heavy vehicles on the road if the goal is only to cross the region (Swiss model), creating adequate railway services. Heavy vehicle limitation on roads. Reduced taxation/deduction for intermodality.	Obligation for companies to activate remote purchase mode alongside the traditional on-site purchase method. Prohibition to physically purchase in shops (e-commerce only) in particular conditions (high traffic, particular events, critical weather conditions, etc.).
Food delivery	Creation of exclusive distribution centers for km-0 with reduced tariffs. Hourly regulation and limitation for the delivery of food to shops.	Prohibition of heavy vehicles on the road if the goal is only to cross a territory (Swiss model), creating adequate railway services. Customs tariffs on non-EU food products, obligation to use rail transport for macro-areas based on distance.	Obligation for companies to activate remote purchase mode alongside the traditional on-site purchase method. Prohibition to physically purchase in shops (e-commerce only) in particular conditions (high traffic, particular events, critical weather conditions, etc.).
Healthcare, banking, public administration services	Favor the provision of multi-services in single places so to minimize transport distances with "Single Window" approaches.	Booking obligation with the aim of distributing access to the structures uniformly throughout the day, assigning appointments to users also on the basis of territorial proximity. Increased accessibility from peripheral areas through dedicated bus or subway services.	Obligation to use telematic/online services in particular conditions (high traffic, particular events, critical weather conditions, etc.).

The access to an ever-growing number of different types of data allows to know the phenomena related to mobility - or the behaviour of people - in real time, and therefore to be able to use them to make decisions, develop strategies and provide services to regulate and govern mobility. The management and use of big data, their ownership, traceability and availability to public decision-makers, users' security and privacy, will be crucial issues in the near future.

Furthermore, decision-makers will have to try to contain the risk introduced by digital technologies in terms of disparity and opportunity between those who can access telematic mobility services and those who are unable to do so.

Finally, new public and private skills will be needed to process the huge amount of mobility data made available by technologies, to analyse them and read their underlying patterns of behaviours with the final goal of responding to mobility needs though smart solutions.

6. Conclusions

The new needs relating to the COVID-19 health emergency represent a challenge for transport systems that must necessarily be grasped, exploiting the technological potential and solving the problems inherited from the past. The pandemic COVID-19 imposes to rethink the way people communicate and move, leveraging this catastrophic event to make mobility more sustainable (both from the environmental and social point of view), "green", effective, reliable, secure and connected. Even if physical mobility can never be completely replaced by the virtual one, communication without movement may be of great help in regulating physical mobility minimizing its negative externalities and, therefore, it is very likely that motionless communication will acquire more and more space than it had in the pre-COVID19 period. Of course with some distinctions between different segments of mobility: work and business trips, for instance, may make more use of virtual mobility than other segments, such as sport, entertainment or social relationships. In any case, given the obvious benefits for companies, workers, the environment and the community, virtual communication should be strengthened.

Certainly in the future, communication with and without movement (i.e., physical and virtual mobility) will have to integrate and dialogue more closely and effectively than they did in the past. ICT technologies will have not only to help reducing the movement whenever possible and proper, but also to improve physical mobility, providing useful information to users and enabling the possibility of doing different activities than driving while travelling on transport means (e.g. rail and air transport, autonomous vehicles).

Virtual communication is fundamental to reduce transport negative externalities by regulating physical mobility, reducing peaks of physical mobility during "rush hours" and better distributing mobility demand throughout day hours. In this perspective, the timing of services and human activities (work, education, etc.) should be rethought, in a logic of de-synchronization of timetables and, consequently, of greater distribution of mobility flows.

The variation in demand inevitably leads to variation in supply. It is therefore necessary to invest not only in transport infrastructures, in order to make them safer and smarter, but also in virtual infrastructures that simultaneously allow dual communication, with and without movement.

It is difficult to predict the modal mix once the pandemic will be finally over: the physical distancing induced by the emergency situation could have a significant impact on people behaviour and mobility preferences, leading to structural changes in the future. According to some recent literature, the structural changes will largely depend on the habits of people pre-COVID-19: those who tended to use a private vehicle (car or motorbike) are likely to use it more, while those who previously relied on public transport could switch to cycling, micro-mobility or walking. Most probably, this will be a transitory behaviour; however, surely public and multimodal mobility will face greater difficulties than private motorized vehicles, due to the rigorous access regulation systems adopted on public transport to prevent infection and whose time application cannot be predicted exactly. In the short term, a strengthening of private mobility will most likely occur, which will have to be contrasted with policies aimed at promoting integrated mobility solutions that favour the use of pedestrians and bicycles over short distances and in urban areas, and the adoption of solutions for co-modality and flexible transport services over long distances [68]. The use of MaaS through ITS must also be encouraged and strengthened, together with an increasingly pervasive process of digitalization in all transport areas, process that has been accelerated by COVID-19.

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