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URBAN MOBILITY SCENARIO EVALUATION IN A POST-COVID-19 ERA

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Abstract. This paper brings an evaluation of different mobility scenarios in the context of COVID-19 pandemic. The mobility is a fundamental human need, a manifestation of an integrated society and an individual and rational act. Building scenarios offer a means of dealing with critical issues of innovation, reflexivity and framing in analysing change in socio-economic systems. Forecasting, exploratory or backcasting scenarios, they are all analysed from the point of view of collective behavioral choice, public policy or technology. The pandemic brought first a serious decrease in traffic and mobility imposing a lockdown, but after it generated an amplified transition to private motorised transport, as public transport is a potent force in disease spread. And this is translated by congestion and pollution. Luckily, based on the same priciples, walking and cycling gained particular importance. A key element in the concept of sustainable development is the reduction of greenhouse gas emissions.

Keywords: urban mobility, scenarios, post COVID-19 mobility, active mobility, transport policy

1. Introduction

A city without mobility would represent just a territory without networks as a field of blurred and blind spots. A society that restricts the mobility of its members compromises its own development and its very existence as a political society. References to the right to mobility converge on rules of individual and institutional practice that can be summarized in three pillars. The first pillar is the one through which mobility is recognized as a fundamental human need, the second pillar is that of mobility recognized as a manifestation of an integrated society, defined by a set of productive activities, and the third pillar is that of mobility as an individual and

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rational act. These three pillars support, at the level of general public opinion, the pertinence of the right to mobility. [1]

Mobility has significantly evolved in the past, under the influence of industrial evolutions. Following the first industrial revolution enabled by the invention of steam powered technology, the railway industry emerged. The second industrial revolution with mass production enabled the emergence of the automobile industry and, closer to us, the third industrial revolution with digitalization enabled the emergence of computer-aided travelling (e.g. GPS in a car). Today we are entering what could be called a fourth industrial revolution, represented by industry and technology convergence, leading to the emergence of, for example, clean energy vehicles or connected mobility solutions. [2]

Cities occupy less than 2% of the world's surface, but they incorporate about 53% of the total population and concentrate about 80% of the planet's economic production, a growing percentage. [1,2]. It is becoming increasingly important to think about longer term possibilities and directions that are trend breaking and can help anticipate the unexpected. The future is perhaps becoming less certain, or at least uncertainty is a central feature of future trajectories. Current trends indicate that more people will choose to use private motorized transport, leading to a staggering 6.2 billion private motorized trips every day in cities of the world. If the world fails to change its mobility habits, the future of our planet looks decidedly bleak. By 2025, worldwide transport-related greenhouse gas emissions will be 30% higher than 2005 levels. Traffic congestion will bring cities worldwide to a standstill. [3]

Transport seems to be completely coupled to economic growth. Therefore, as a direct consequence of economic development, transport sits today as one of the major final energy consumers and one of the most important sources of carbon dioxide emissions. Furthermore, in the absence of major technological change, this unsustainable situation will most undoubtedly get worse in the future. In order to have a reasonable chance of keeping concentrations well below 550ppm CO_2-equivalent, analyses for the EU Environment Council show that global emissions should be limited to an increase of 35 % above the 1990 level by 2020 and then decrease to 15 % below the 1990 level by 2050. [4]

In cities around the world, congestion is undermining mobility, imposing huge costs, not just on commuters or people out to run a simple errand, but on society as a whole. According to the Texas Transportation Institute, the average American commuter spent 14 hours in 1982, 34 hours delayed in traffic in 2010 and more than 40 hours annually in 2020. All told, the annual cost of congestion in America alone now exceeds $100 billion. [8]

Evidence-based policy recommendations are urgently needed to ensure that transport systems have resilience to future pandemic outbreaks, particularly within Global South megacities where demand for public transport is high and reduced access can exacerbate socio-economic inequalities. [11]

2. Scenarios for the evolution of medium and long term mobility

Concerns about the positive dynamics of average temperatures with direct consequences for rising sea and ocean levels and the future of life on Earth have led the world's leaders to establish increasingly stringent regulations on anthropogenic activities that affect the quality of life of the current generation and especially future. [1]

The traditional means by which we have forecast the future is to use the knowledge that we have about the past and then to 'run the trend' or extrapolate forward into the future. This type of approach is effective in the short term, but increasingly there is a necessity to look further ahead so that longer term, more strategic horizons can be addressed. Such thinking is evident when considering issues related to climate change, mobility and the costs of transport. The idea of scenarios was first used by the American futurologist Herman Kahn in the 1950s to contrast with forecasting the most likely future. One of his most well-known scenario-based studies was developed for the US federal government looking at how nuclear wars might start and evolve (Kahn,1962; Van der Heijden,1996). He became known for 'thinking the unthinkable', including creative but dire scenarios of the 'winnable' nuclear war and life after fallout. ''Scenarios offer a means of dealing with critical issues of innovation, reflexivity and framing in analysing change in socio-economic systems [...] the future cannot be extrapolated through data relationships because drivers of change in social systems are not only multiple, but unstable.'' (Berkhout and Hertin, 2002, p.38 and p.39). [3]

A key element in the concept of sustainable development is the reduction of greenhouse gas emissions, and to achieve this goal, the guidelines, analyzes, coordinated actions, decisions, implementations, mobility assessments are materialized in scenarios. Three basic types of scenarios can be identified, but in many applications different approaches are used that combine elements of each type so that the process is customised for the particular situation under investigation. This flexibility in approach is characteristic of scenario building. [1,3]

- forecasting scenarios, with starting points in the present situations and the extrapolation of the current trends in the proposed future; They are most useful for situations where substantial external change is not expected and where there is some expectation that current trends will continue into the future, having been associated with the 'American Tradition'. [1,3]
- exploratory scenarios, the most widely used form of scenarios and they typically take two dimensions of change within which four scenarios are constructed, usually within a two by two matrix. The main aim is to be challenging and to trigger new thinking. They are also known as prospective scenarios and have been associated with the 'French Tradition' [3]
- prospecting or backcasting scenarios, with starting points in the desired future to be reached and the identification of the upstream stages, in the opposite direction of the passage of time (from the future to the present) [1]. These approaches have been used to look at preferred futures over the longer term and are again designed to be

trend breaking in their thinking. This could be described as the ‘Swedish Tradition’ as this is where most development and use of the approach has taken place. [3]
All scenarios for prospecting the future of medium and long-term urban mobility have identical objectives - sustainable mobility and quality of life in urban agglomerations. So we are dealing with two issues: traffic infrastructure and the environment. Two demarcation lines in the evolution of urban mobility must be taken into account. One is about collective behavioral choices, and the other is about public policy. The combination of the two disjointed alternatives of the two demarcation lines results in four synthetic scenarios of urban mobility policies:

- Scenario 1: "Technological Voluntarism" (Homo Technicus) - gives priority to technological evolution as a source of dynamism and an essential way of resolving conflicts. And as technology requires, in addition to the innovative capacity of engineers, also a regulatory intervention of the State, it is necessary to understand the voluntary component of this scenario.
- Scenario 2: "Cost Awareness" (Homo Oeconomicus) - inspired by an economical and compatible vision, it reveals the importance that prices have in the good behavior of users. Here, too, the not inconsiderable intervention of the State in the financial field through regulations in determining the costs and pricing modalities influences the users' behavior.
- Scenario 3: "Mobility Control through individual transactions" (Homo Contractor) - like the previous one, economically oriented, it admits that the property right as well as the pricing can orient the collective and individual behaviors in a performance sense. The scenario considers that the limited energy resources require a reduction of mobility, by establishing a market of traffic rights.
- Scenario 4: "Mobility control through a collective urban transaction" (Homo Politicus) - considers the political dimension of the options to be decisive. Accepting, as in scenario 3, the need to reduce mobility, it is based on collective actions to regulate mobility. What is forbidden for one cannot be possible to another. [1]

There is also a certain number of possible solutions through scenario building in a backcasting manner using the TILT (Transport Issues in the Long Term) model. In particular, three different scenarios are evaluated that address how technology and different public policies can contribute towards a sharp reduction in CO_2 emissions. Furthermore, we can estimate the infrastructure investment needed as well as insight on how transport budgets (time and monetary) could evolve in each of the three scenarios presented.

- Pegasus - promoting strict technology standards
- Chronos - promoting green multimodality
- Hestia - promoting transport-GDP growth decoupling. [4]

Pegasus is a scenario where the speed/GDP elasticity of 0.33 for passengers and 0.6 for freight are maintained for the 2000-2050 period and where transport times are stable (1 hour per person per day). In Chronos scenario, market oriented policies constrain the use of fast high carbon footprint modes leading to an increase in slower and cleaner transport modes. The 75% reduction objective is nearly attained through an action favoring greener modes by increasing transport costs accordingly to speed and emissions. The main issue in Hestia scenario is a trade-off between an elevated transport cost and transport distances. Indeed, transport costs are higher than in Chronos and this translates into economic agents choosing to modify their locations and concentrate on proximity strategies. [4]
Thus, the sensitivity assessment of the three scenarios is calculated on the basis of effective CO_2 reductions (i.e. those that are not due to new motor technologies, which account for 48% of the reductions). The results obtained are as follows in figure 1:

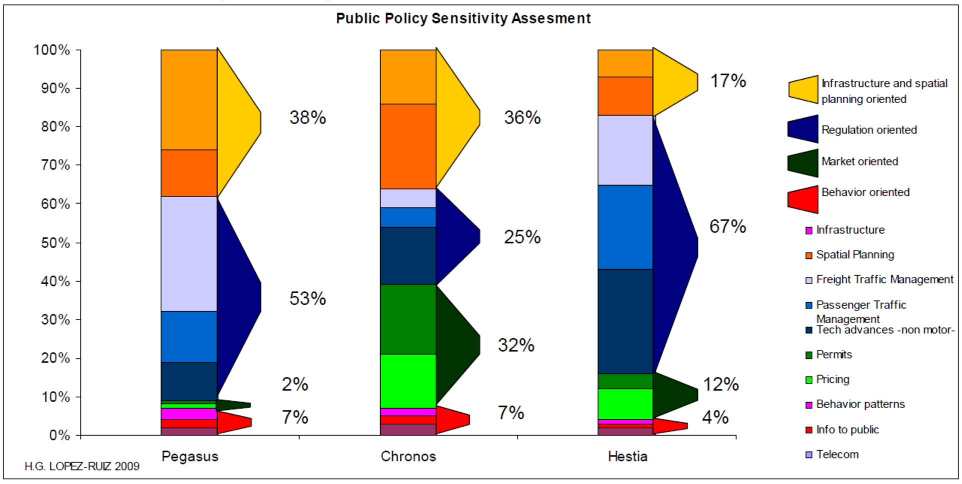

Fig. 1 Public Policy Sensitivity Assessment.

The three scenarios are analyzed in order to come up with an assessment pertaining to the impact of four basic policy packages inspired by the work done in the VIBAT project:

- behavior oriented policies
- market oriented policies
- regulation oriented policies
- spatial and infrastructure planning policies. [4]

The basis of the TILT approach lies on the fact that it is based on a twofold structure composed of a macro- and a microeconomic part (see figure 2).

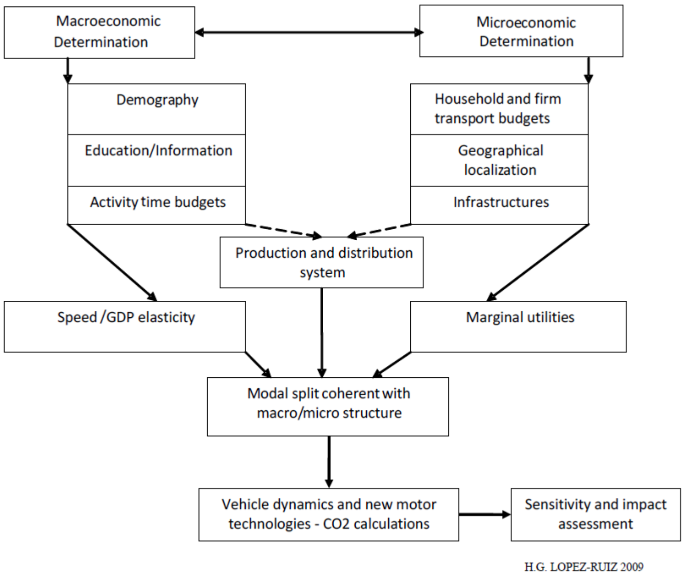

Fig. 2. TILT Model structure [4].

This structure serves as the core transport model that will provide input to three additional modules. These modules are designed to give insight concerning: total energy use, CO_2 emissions, public policy sensitivity and economic impact for any specified scenario. From the determination of time used in transport activities, the macroeconomic mobility determination is established through the use of average modal speeds that evolve based on a speed/GDP elasticity. The microeconomic component of the TILT model is based on a representative agent's optimization of decisions based on the opportunities inherent to household/firm locations, transport costs and infrastructure availability (based on a lateness index – eq. (3)). [4]
The microeconomic component is largely inspired by developments done on ant algorithms and relies on the idea of a representative agent that optimizes his/her transport choices by taking into account opportunity and cost in respect to a certain level of service on infrastructure. Thus, the results stemming from the macroeconomic determination will influence the representative agent's choices. In turn, these choices must be coherent with the overall transport structure in order to be validated and represented in the decision table where the value assigned to each choice ($a_{ij}(t)$) is calculated using the following equation:

$$a_{ij}(t) = \frac{[\tau_{ij}(t)]^{\propto}[\sigma_{ij}]^{\beta}}{\sum_{l \in N_i}[\tau_{il}(t)]^{\propto}[\sigma_{il}]^{\beta}}, \forall\, j \in N_i \qquad (1)$$

where

$$\sigma_{ij} = \frac{opportunity}{cost} \qquad (2)$$

and

$$\tau_{ij}(t) = Lateness\ index\ (t) \qquad (3)$$

On an economic level, all scenarios have roughly the same hypothesis. The differences between each scenario are linked to the transport structure where: speed/GDP elasticities, modal speeds and transport times differ.

The hypothesis made for the emissions calculations for each of the scenarios take into account the current state-of-affairs. The most important points are that:

- emission calculations are “well-to-wheel”
- plug-in hybrid vehicles hit the market by 2010 and electric vehicles by 2020 (first at the urban and regional scale, and then at the interregional scale)
- second generation bio-fuels represent 35% of fuel sales by 2050 and are consistent with cropland use for food
- all trains are supposed electric by 2050 and electricity production is supposed to be 100% from nuclear origin (compared to 80% in 2007)
- airplanes emit, in average, 35% less by 2050. [4]

As part of the 4th European Framework research programme, the POSSUM (Policy Scenarios for Sustainable Mobility) consortium had the task of constructing scenarios for achieving sustainable mobility within the context of the Common Transport Policy and the development of the TransEuropean Networks. The broad objectives of the CTP are to maintain competitiveness (efficiency), promote cohesion (regional development), while at the same time improving the quality of the environment. The POSSUM project is primarily concerned with identifying interesting policy options that might be required for the future, rather than proposing precise policy packages for different external conditions. The POSSUM project is also concerned with identifying policies that might be useful under a range of external conditions. Major changes in transports in urban areas seem to be crucial to achieve sustainable mobility. [5,6]

A modified backcasting approach is used, which means that it identifies external developments, which constitute different contexts for transport policy making. The ”solutions” differ depending on the external conditions in the specific cases. In a planning context where the actors involved may greatly affect the development, a reasonable strategy would be to attempt to shape the future according to what is preferred, instead of just adapting to what may emerge. This is the question of external vs. internal factors, which is highly relevant in the context of transport policy analysis. Because of the existence of salient external factors, it was chosen to modify the pure backcasting model, adding an element of explorative scenario methodology. [5,6]

Main policy measures of the POSSUM project are:

- Possibilities for telecommuting, tele-services and tele-shopping/doorstep delivery are much improved.
- Appropriate land-use planning supporting IT-accessibility and public transport, by, for example, promoting decentralised concentration.
- Conditions for walking, cycling and public transport improved, by, for example, dedicated lanes.
- Space for cars is progressively reduced.

- Low speed zones (30-40 km/h) are introduced in residential areas.
- Environmental zones to stimulate very clean niche vehicles.
- Coordinated distribution with very clean vehicles is promoted.

Technology has a key role to play in moving policy in the direction of sustainable mobility, particularly in the longer term. In the shorter term, firm action and direction is required at the EU level to promote best practice and to help push particular technological paths. For example, should research be directed at new technology (based on hydrogen as the fuel) or at an intermediate technology (methanol). [5,6]

Urban mobility can also be supported by the software and devices known as 'smartness tools', which make the mobility supply more and more tailored. The analysis of bigdata coming from transport users and operators makes it possible to identify in real time events such as accidents, traffic jams, service interruptions, and to devise different transport options. Mobile devices and social networking applications acquire information flows from several sources, the contents of which are generated by the users by means of crowd-sourcing systems so as to enable a conscious, tailored choice. [7]

Integrated transport models are becoming more and more widespread, as they can rapidly adapt themselves to the changing conditions and needs as well as monitor data with the aim of suggesting new transport solutions in real time. In Italy, projects such as TAM-TAM and TraffiCO2, have been developed, which, thanks to the support of mobile devices and software, analyse the contents generated by the community and offer solutions to the citizens' demands of mobility. The TAM-TAM project is an integrated platform for the management of the mobility supply, which develops solutions related to traffic de-congestion by proposing the optimisation of individual and collective choices. The aim is to provide an efficient service, optimise mobility flows as well as increase awareness concerning ethical and sustainable behaviours, with reward-based systems linked to the volumes of CO_2 accumulated by individual choices in terms of mobility and games. [7]

Change is coming to transportation, whether we're ready for it or not. You can see it in automakers' focus on next-generation vehicles, in the arrival of services that help urbanites get around without owning a car, in the widening recognition that the "information everywhere" world will utterly disrupt the transportation status quo. Sharing rides, bikes, and cars and other entrepreneurial business models are spreading, built on the recognition that empty car seats and idle vehicles form an immense "wasted asset". At least, that was the idea before COVID-19 pandemic. [8]

Three scenarios for digital-age transportation

It may be a fool's game to make confident and detailed predictions about the future of urban mobility, but it's not so hard to extrapolate from current trends. What follows are less alternative scenarios than parallel ways of grouping developing trends. Indeed, the future is likely to contain elements of all three: widely connected vehicles or "the Internet of cars", pricing that aligns supply with demand and the spread of social networking into transportation decision-making.

Scenario 1: The Internet of cars

The notion of ubiquitous connectivity will change the perception that cars are just standalone vehicles of choice and start being cosidered one piece of the larger transportation system. In other words, transportation will evolve beyond selling cars to integrating cars into a vehicle-to-grid system. Vehicle connectivity "facilitates communication with the public transport system so that drivers could be made aware of rapidly changing schedules, for example, or make seamless plans for intermodal transport while traveling. The connected vehicles topic comes with some issues to address, for instance, the security. A hacked connected-car network would create chaos. As one German academic said, "Most people would rather have malicious software running on their laptop than inside their car braking system". [8]

Scenario 2: Dynamic pricing

The world is moving inexorably toward the notion that goods and especially services doesn't need to be priced statically. Airlines and hotels have been pricing seats and rooms dynamically for years, electric utilities have been installing smart meters that will, among other things, allow them to respond to changing demand by changing prices. Transportation is moving in the same direction, made possible by the spread of mobile technology, location-based services and "contactless" payment systems. These will ultimately allow for two key values to be embedded in transportation pricing:

- Users pay a more direct portion of the actual costs of the services and modes they use.
- Prices respond to demand to increase the overall efficiency of the transportation system. [8]

Economists and transport planners have suggested to charge for the externalities imposed: dynamic congestion pricing by street, dynamic pricing of emissions by street, CO_2 taxation, dynamic pricing of parking by location, crowding pricing in trains. The pricing would need a clear formulation of the social goal to be achieved for each of the taxes. [12] Disposing of traffic conditions and predictive forecasting should make it possible for drivers to choose between the lowest cost and the quickest routes to their destination, with full knowledge both of their cost and travel time, while the transportation managers and providers would be able to set prices according to availability, cost, congestion and demand. If a subway system is straining under the load of rush-hour passengers right now, you want to make sure that potential passengers know that the amount they pay will be lower if they just wait a half hour or take the bus instead. The way to get there is to promote wireless payments. [8]

Scenario 3: Social transport

There main drawback of the current transportation system is that its parts don't talk to one another directly. The transportation system of the future will be built on collaboration among neighbors, communities, governments, and traffic managers on everything from traffic planning to signal timing to commute planning, thanks to the technological advance of networked cars and infrastructure, location awareness, and social networks. Here is the ideal: When it's time to get somewhere, you plug in your commute or your itinerary, and the network gives you every option, whether you're going to work or just to do some shopping across town. It lets you know about traffic conditions, whether a rideshare possibility is passing your way, what time the next bus or train gets to a nearby station, and how long it would take you to walk. [8]

3. The impact of COVID-19 on the urban mobility

The 21st century saw the emergence of a newly found coronavirus, also known as the SARS (Severe Acute Respiratory Syndrome) COV–2 in the Wuhan city of China. [9] The COVID-19 crisis has meant a significant change in the lifestyle of millions of people worldwide. It is mandatory to explore the effect of the pandemic on changes in travel behaviour in post-COVID-19 times. [10] The stay-at-home orders, as a measure to limit the spread of the deadly virus, had a drastic effect on the life of every common man. It caused a direct impact on the usage of the transport system. As the stay-at-home order took effect, ridership data show steep decline in both transit ridership and vehicular traffic for all the year of 2020. [9]

The most affected mode was public transport rather than private cars. It can be expected that people will travel less and try to avoid public transport. Meanwhile, walking and private cycling might gain particular importance. [10] It raises the question about people's preference in moving in the shared taxis to their workplaces or their reluctance and denial of the idea of moving in the shared vehicle because of the fear of getting infected. The sensitivity of the situation will compel the people to move in a single occupied vehicle (SOV). The rise in the number of vehicles on the roads will result in traffic jams and different kinds of pollution where people battling with the pandemic will inevitably get exposed to other health-related issues. [9]

In Spain, the willingness to use and to pay for using public transport and shared mobility services given a set of COVID-19 safety measures to be implemented after the lockdown was explored. The methodology included a survey structured into three main sections: socio-demographic information, mobility behaviour in pre-COVID-19 pandemic times and the possible user adoption of post-COVID-19 adaptations of public transport and transport sharing services. A choice modelling framework based on Heckman specification was adopted to explore individuals' willingness to use and willingness to pay regarding specific transport modes in post-COVID-19 time. Five different transport options were included in the questionnaire: public transport, car-sharing, taxi/ride-hailing, bikesharing/kick scooter-sharing, and moped scootersharing. They all imply transport options in which cleanliness and sanitising would be managed by the operators, either public or private. Regarding modality for those who expected to continue working after COVID-19 lockdown, 38% reported that they would telework, 38% that they would work in person and 24% do not know which modality they would do so. These responses reflect the general drop in travel frequency for commuting reasons. Interestingly, around 64.3% of total respondents declared that they would pay more (compared to pre-COVID-19 times) for using public transport services if operators implemented sanitising measures. [10]

Certainly, a "new normal" is to be expected for the transport sector. On the one hand, it is widely known that transport is a potent force in disease emergence and spread as human-incubated pathogens or disease vectors can be moved large distances in short time. Unsurprisingly, public transport, where it remained in operation, experienced a significant drop in ridership. Individual motorized traffic has increased in many cases to avoid social contacts while traveling. Nevertheless, it is only available to those with access to vehicles and linked to other negative externalities such as noise and air pollution. Active mobility is also experiencing a renaissance, especially as an alternative to mass transit. However, many cities, mainly in the Global South, do not provide adequate infrastructure to enable safe and efficient walking and cycling. [11] Those who rely most on public transport and without access to private cars are disproportionately affected by the lockdown, which has intensified the unequal access to transport systems. It became evident that during the pandemic, public transport was not able to fulfil its service function to the public and that a paradigm shift is observed, as people increasingly relied on active mobility. [11,16]

A case study results from Istanbul, another developing megacity, point to the risk of an unsustainable development, in which private cars become the dominant mode of transport. A large part of additional car journeys could thereby result from users that previously relied on more sustainable travel options such as mass transit, active mobility, and shared mobility solutions. Accordingly, Pawar, Yadav, Akolekar, and Velaga (2020) found that during the COVID-19 pandemic, 5.3 % of commuters in India shifted from public to private modes. To regain trust in public and shared modes, therefore, social attitudes and human factors need to be addressed more explicitly, while street space should be allocated to cyclists and pedestrians. [11] As expected, in all countries/regions, a large share of modal shift from public transport to other modes was observed based on experts' subjective observations: the largest shift to car (64.8%), followed by walking (42.3%), cycling (35.6%), and motorcycle (19.7%). [13]

As for changes in lifestyles, the experts are agreed that "online working (working at home, neighboring satellite offices, cafes, etc.) will become popular", followed by agreement on "the car dependence will become more obvious due to adverse reactions to crowded public transport during the COVID-19 pandemic" and "online shopping will become the most popular shopping activity". Many experts argue that online working and shopping will become more dominant in people's future lives. Regarding car usage, 14.8% of experts disagreed or fully disagreed that car dependence would increase. Such disagreement may be reasonable, for example, if people change their activity patterns without using more cars. Because of fear about virus infection, we expecte a significant number of people to out-migrate from populated cities and live far from city centers. This expectation is supported by about 20% of experts: out-migration from populated cities (22.2%) and living far from city centers (20.4%) were reported, respectively. The experts' opinions above suggest that policymakers should make efforts to prevent increased car dependence due to adverse reactions to public transport services after the pandemic. Such a trend may be further strengthened by more people wanting to live outside of city centers in suburban and exurban settings. More out-migration from megacities will translate into increased vehicle use per capita. A primary strategy to combat this is to support investment in active transport infrastructure and walkable urban design within cities. Transfer to online activities will help to mitigate some of the increase in demand for vehicle use. [13] According to some recent transport surveys, 27% of home-workers expect to work from home more often in the future. In addition, 20% of people expect to cycle and walk more and 20% expect to fly less in the future. These findings show that the coronavirus crisis might result in structural behavioural changes, although future longitudinal analyses are needed to observe these possible structural effects. [14]

The accelerated shift to working from home (WFH) is expected to continue as both employees and organisations benefit. The economics of smaller facilities are obvious for companies along with the higher degree of control over working hours for some of the employees, but it is unclear whether the new challenges resulting for the management and employees can be addressed in the long run, and from the transport point of view, the coordination of the days away from the office, so that congestion relief is equally present on all five days of the working week. The balance of the push and pull factors will be unclear for some time. The second major change has been the reduction in the use of public transport and an increase in cycling during good weather (see figure 3). The cycling boom from spring to autumn in 2020 was attested not only by the GPS sample, but also by reports of massively increased bicycle sales and some of the ongoing urban cycling counts. [20]

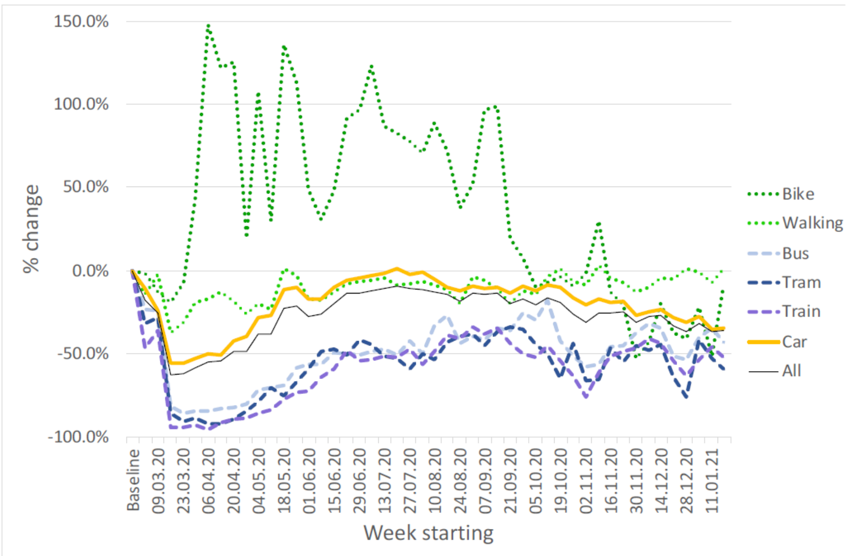

Fig. 3 Change in passenger-kilometres (PKm) by mode against baseline in Switzerland (autumn 2019) [12]

Source: https://ivtmobis.ethz.ch/mobis/covid19/en/

There is a danger that COVID-19 and reactions to it will pathologize mobility in general and ignore the various kinds of joy and opportunity that arise from the ways we move. In hard hit Milan, the city government announced 22 miles of experimental cycle routes in space formally given over to cars. In India there has been a dramatic resurgence in cycling in a society that had valorized automobile ownership as a sign of prestige and success. Even the general idea of a commute has been missed by those who can no longer commute. COVID has allowed us to reimagine many things in the hope that what happens after COVID, or more precisely when COVID is successfully managed, might form a 'new normal'. [20]

A general revaluing of mobility is inevitable, as an effect of the 'new mobilities paradigm'. [20] Public transport is one of the sources of virus transmission (Wang, 2014), and its use has therefore been suspended or limited by either restrictions or voluntary measures. Still, many citizens rely on public transport as their primary or only means of transport, resulting in both further spread of the virus and in inequality of risk (De Vos, 2020; Laurencin and McClinton, 2020). In order to combat the spread and the associated inequalities it is adamant that we increase our understanding of which citizens continue to use public transport and plan proactively. [17,18]

A correlation analysis was computed to assess the impact of the pandemic on transportation and economic, social and religious activities in the state of Lagos, Nigeria, in the context of a study which relied on a dedicated survey. There was a positive correlation between transportation affected by the pandemic and its impact on economic, social and religious activities of the people: $r = 0.442$, $n = 329$, $p = .000$. The increased cost of transportation, shortage/lack of transportation mode and traffic congestion were identified as the major impact of COVID-19 on Transportation in Lagos State. The 'avoid–shift–improve' framework has been used to discuss the mitigation measures that arose from the study's findings and to focus on the mobility needs of the people. The framework provides a balanced set of transport options to maximise the development benefits (Burns, 2020), which is relevant during these challenging times. It highlights the need to maintain the existing infrastructure and make it sustainable as we cope with the impact of the pandemic, whereas improve suggests action plans, albeit a long-term plan, to improve sustainable transportation. [15]

As an important supplement of public transport in most megacities, taxies can record the exact time and location of departure and arrival, and the boarding and alighting locations of taxi passengers are closer to the origin and destination of trips compared to other public transport modes. The 24-h continuous operation of taxies can reflect the demand and dynamic change of urban trafic. Therefore, it is more suitable to use data of taxi travel to conduct the travel temporal-spatial analysis based on the several reasons mentioned above. Point of interest (POI) is the precise positioning of urban function points, which has been proved to have a strong correlation with travel behaviors. Taxi trajectory data combined with POI data is usually used to analyze the relationship between travel behavior and urban land use in many studies. The trip information and travel behavior are related to POI by the GIS method. The spatial econometric model is introduced to evaluate the change of taxi travel driving force and the relationship between the spatial-temporal evolution of travel and urban functional structure during the epidemic period. In addition, the analysis of the differences of the relationship between the monthly income and working hours of taxi drivers during the epidemic period could be evaluated, and other research such as the impacts of COVID-19 on the psychology of drivers or labor supply elasticity should also be considered to carry out immediately. [18]

Triggered by technological advances as well as societal and market changes, urban transport is currently experiencing a major transition. This has opened doors to new mobility services based on digital platforms, such as carpooling and ride-hailing, and eventually paved the way for Mobility as a Service (MaaS). MaaS is based on the seamless integration of all different public and commercial modes of transport and is delivered via a digital interface. MaaS is a tool for directly combating COVID-19 for another reason as well, as it stipulates the integration of electronic/mobile ticketing and payment systems. Thus, it reduces the overall physical contact during the procurement of tickets and conducting payment transactions. [11]

As was seen during the oil and manufacturing shortages in World War II, the 1970's oil embargo, and several other historical moments, crises have generated fundamental changes in society and the economy including in the transportation sector. This has evidently been the case for active transport in response to the COVID-19 pandemic. And as the pandemic has progressed, some governments have taken steps to anticipate and plan for future disruptions, suggesting that they are already looking for ways to adapt practices based on lessons learned from this event. There is an appetite for new methods and new solutions. The transport sector's actions in 2020 point to several issues that dominated the year's policy actions, in addition to the COVID-19 pandemic. Some of these actions were driven by growing recognition of climate change as a crisis. Others, by the widespread awakening about systemic injustices in how transport networks are designed, funded, used, and enforced. All of these separate factors have potential to cause a dramatic and overdue shift in transport policy and planning. [16] Cities around the world responded by instituting a variety of policies and programs meant to address this shift, such as carving out roadway space for non-car uses, putting pedestrian walk signals on recall, reducing speed limits and subsidizing bike share schemes. [16,18,19]

The dilemma of today's transport policy is the contradictory set of aims to be pursued. Investment in the transport systems is aimed at lowering its generalised costs and increasing social welfare by increasing productivity and therefore, as a rule, incomes. The improvement also allows the population to maintain and build its social capital by making joint activities to undertake. The usual measure of this improvement in the policy discourse is "accessibility". There is substantial empirical evidence that improvements in accessibility do increase productivity. [12,13] Two impacts are crucial: the lower attractiveness of public transport and a population shift towards less dense environments. The pandemic has highlighted that crowding in buses and trains, never popular, is also an opportunity for the spread of airborne diseases, such as COVID-19 or the more familiar influenza. It is no surprise that the willingness to travel by bus or train has dropped, especially as their air conditioning systems are not designed for the air turnover that would be required. [12] Experts reported that for all countries/regions, the percentages of cities/towns with guidelines of transport systems for public health threats prepared before the COVID-19 pandemic are 33.5% for bus systems, 27.1% for rail transit systems, 26.8% for aviation systems, and 21.8% for taxi. Policymakers should take such low percentages seriously and examine why there was a lack of preparations, considering that several pandemics had already occurred in the past. [13] Experiences with these new types of activities and ways of travelling and external factors related to COVID-19 and governmental measures could have an influence on people's attitudes as well. The relationship between attitudes and travel behaviour has been studied extensively and it has been shown that attitudes indeed play a role in mode choice behaviour (Gärling et al., 1998; Paulssen et al., 2014). The influence of attitudes on mode choice behaviour was found to be particularly strong in cases where habit is weak (Verplanken et al., 1994). This is particularly interesting in the light of the current COVID-19 situation, as many people are forced to, at least temporarily, break their habits. It may be expected that attitudes have changed as a result of COVID-19. People might for instance have a more negative attitude towards shared travel modes, due to the fear that they might become infected with the virus when using these modes. If this change in attitudes turns out to be a structural, it might have structural effects on travel behaviour. For instance, people might structurally shift from public transport to car for commuting. Such a shift could have negative consequences in terms of both sustainability and accessibility. [14,18]

Recently, the epidemic situation has been gradually alleviated and the economic and social recovery plan has been put on the agenda by the government during the post epidemic period. Under this circumstance, urban transport system plays a crucial role in the process of social recovery and economic recovery as the basic guarantee of the city. Therefore, more attentions should be paid on the impacts of the epidemic on urban transport system as well as the travel behavior. [18] To support the change made by COVID-19, investment has been made in providing the infrastructure required for these means of transport by removing lanes that were previously used for trafic and reducing city center speed limits to 30 km/h. The measures that have simultaneously been taken to maintain social distancing between people means that pedestrian areas have to be redesigned along with crossings and trafic lights, removing buttons and lengthening the crossing time phase for pedestrians, which partly compensates for the reduced capacity caused by a smaller crossing section and thereby avoids the accumulation of pedestrians waiting to cross. These measures will inevitably result in a reduction in the capacity of the infrastructure provided for motorized transport. [19]

For decades now, there has been a massive amount of pollutants in the atmosphere, which is a cause of major concern. The air quality has however enormously improved from hazardous to moderate during the lockdown imposed due to COVID-19. A massive rise of pollutants is expected post-lockdown with increasing number of vehicles on roads with commuters switching to SOV (single occupied vehicle). A sudden drift in the number of vehicles will cause an adverse effect on the traffic system. Although, a massive decrement in the amount of pollutants in the atmosphere has been observed, which was a cause of major concern pre-lockdown.

It has been successfully reduced, improving the air quality from hazardous to moderate. According to the Air Quality Index, the unprecedented growth in the pollutants in the atmosphere has caused not only environmental and health issues but a heavy impact on the economy. [9] It is known that every crisis offers an unprecedented opportunity for structural change for the better. Given the crucial role of transport in modern societies, for economic growth, and for people's health and well-being, the urgency of effective transport policies is highlighted. [11]

These reductions in travel have had similar repercussions on the main externalities normally associated with motorized transport modes, mainly journey times, accidents, and pollution. Data has been published in diferent media revealing reductions of 35% in accident rates in Istanbul (Turkey), where the only action taken during the period of study was to close the schools. Reductions in emissions have also been reported from diferent countries around the world, especially significant in the cases of NOx, CO_2, and PM2.5. In China, for example, the measures to minimize the spread of SARS-CoV-2 have resulted in reductions of 25% in CO_2 emissions, and NO_2 levels were 36% lower than in the same period in 2019. In Italy, significant reductions in NO_2 concentrations have been found to be mainly due to the reduction in the use of diesel vehicles for transport. In France, minimum NOx levels have been reached due to the restrictions adopted to fight COVID-19 in economic activities and transport. During the spread of the COVID-19 pandemic in New York, trafic levels were estimated to be down 35% compared with a year ago. CO_2 levels dropped 5–10%, and significant decreases in the emissions of CO and methane were also detected. After analyzing some model results, the conclusion was that anthropogenic emissions decreased, especially in transport and industry, with a reduction in PM2.5 concentrations. However, the reduction was not enough to avoid the occurrence of severe air pollution events in most of the areas being studied. [19]

Limitations of the research of COVID-19 future mobility mainly relate to the data used in the study. Only the mobility behavior of tech-savvy individuals that know how to manipulate the map and technology services is usually included in the data. On the other hand, important population groups are likely to be underrepresented, such as the lower-income segments, that often do not have access to smartphones and the internet. There is no information on the underlying reasons for changes in mobility behavior. For example, have users avoided public transport out of fear of infection with SARS-CoV-2, because no service was available, or simply because there was no demand for traveling? [11]

4. Conclusions

Use of personal motorized vehicles and its significant contribution to air pollution, greenhouse gas emissions, and fossil fuel consumption are well accepted. The main reason for the increasing use of personal vehicles is the reluctance of the people to travel in Public Transports (PTs) for the inefficiency in maintaining the quality of the transport. Not until this situation was tackled that COVID-19 hit the world, making the situation even worse where even a greater population will now switch to a personal mode of commute, turning the whole situation gross. [9] Therefore, it is important to leverage on the current demand for active mobility and further promote safe and prioritized walking and cycling through the provision of adequate infrastructure. It is also essential to make the cities more pedestrian-friendly and consider walking as an actual mode and means of transport. The COVID-19 pandemic has somehow indeed served to be an eyeopener on the importance of active mobility. [11,16] Realistic technological hypothesis show that a 50% reduction in emissions is a clear possibility and that going further, solely based on new technologies, would require very big advances in zero emission vehicles. [4] Improved technology will generally not require that we change our travel behaviour, and may therefore be the preferred solution to many people. [5,6] The pandemic may encourage more young people to move back to local cities. Transport policy making should pay more attention to local cities within a well-coordinated regional planning framework with industrial policymaking and other public policies, which can, for example, attract new industries to local cities. Once the economy is re-opened, a rapid growth of automation may also be expected. Such trends mean that not only transport systems, but also our life-styles as well as our economies will become much "smarter". It is worth exploring whether the development of a "smart" society will help transport systems and services to work in a more sustainable way, because "smartness" does not necessarily mean the same as "sustainability". [13] Another conclusion is that COVID-19 and the government's policies to stop the spread of the disease will not only have an effect during the pandemic, but may also have structural, long-lasting effects on travel behaviour and people's mobility. There are major immediate changes in outdoor activities, work and travel behaviour due to COVID-19 and related governmental measures. We also conclude that people expect that some of these changes will last into a future without an active pandemic, as about 30% of people expect to work more from home, 20% to cycle and walk more and fly less in the future after the coronavirus crisis. An economic recession may lead to higher unemployment rates, affecting both commuting mobility as well as travel budgets of people for non-commuting trips. [14] The assessment of the impact of the epidemic on public transport and social economy is very important for the reconstruction work in the post epidemic period. The economic development has been slowed down and the transport industry has been seriously impacted due to the epidemic. It is dificult to predict what the city will look like after the epidemic, but it is assured that the economic recovery will not be achieved overnight. Meanwhile, it is necessary to assess the extent of socio-economic and transport impacts caused by the epidemic for the better guidance of the economic recovery. [18]

The effects of the new coronavirus pandemic should make us think on how mobility in cities will be after this crisis. There is a real risk of a decline in the sustainability of mobility in urban areas. The main questions to be answered will be, first of all, when, how, and to what extent the demand levels for public transport systems will recover (if they ever do). The willingness of the user to take over not only collective but also shared transport systems will be another important issue to be assessed. Further questions to be investigated are how this will affect users' perception of different transport services, and what new strategies both public and private sector operators will need to follow to make public transport systems attractive again. Variables such as vehicle cleanliness and hygiene, as well as vehicle occupancy, are likely to increase their prominence in measurements of perceived quality. Finally, it may be interesting to monitor changes in travel production habits: Will teleworking increase? Will travel patterns change for leisure, shopping, etc.? How much of this decreased mobility was really necessary? Research that allows a follow-up and monitoring of these new issues, as well as a before and after comparison, will surely be an important contribution to the state of the art for a better understanding of this kind of event. [19]

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