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Correlations Between Transportation and the Covid-19 Pandemic

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Abstract. COVID pandemic has abruptly changed people habits and lifestyles worldwide, including the usage and perception towards all the different transportation systems; to this date (mid-2021), the pandemic has been going on for over a year now, and there is still no certainty about when it will end. A drastic decline in the number of commercial flights both national and international has happened, as a consequence of the lockdown policies adopted by the various countries around the globe in order to prevent the infection from spreading around, and with variable trends depending on the period and the reciprocal agreements between the various states. Land-side public transportation too has witnessed a backlash mainly due to similar policies or even not leaving home during lockdowns, often working remotely from home, and switching from public transportation to driving, walking or cycling if necessary. COVID-19 and transport are linked by a two-way relationship: if it is true that COVID-19 impacts on transport systems, it is also true that transport systems, in turn, have a very important role in the spread of the pandemic. Swabs first and vaccines recently, are raising new hopes about the pandemic ending soon. The consequences of COVID-19 will in any case be significant, and will revolutionize the way of conceiving transport, meaning new challenges for scientific research.

INTRODUCTION

The abrupt and unexpected way in which the COVID-19 pandemic has changed our lives, has forced us to reconsider the way we have seen transport systems till now. For example, the hypermobility **[1]** that until now was taken for granted and in continuous growth, is now being questioned: given that in an inevitably and increasingly globalized world it is very difficult to step back and rely on geographically confined economies, it will be necessary to intervene in the transportation industry by evolving the design and planning techniques for new infrastructure and systems, as well as in the management and adaptation of anything already existing. With equal importance, transport systems must henceforth be designed in such a way as to minimize the risk associated with them of spreading pandemics. Furthermore, special attention must be dedicated to all those categories of users with disabilities or diseases, such as people with impaired mobility, under dialysis treatment or cancer care, and so on **[2]**. In this sense, Autonomous Vehicles becoming mainstream could contribute to improving the quality of life, for people with special needs and in general. Autonomous vehicles do not require drivers, and can be used to transport people but also goods of sensitive nature, such as drugs, biological samples, contaminated waste, and so on. Human interaction is still required in absence of fully automated loading and unloading systems, but the risk factors are anyways reduced **[3]**. As it can be imagined, the implementation of these and other technological systems, will require multidisciplinary research studies to develop strategies for data collection and analysis, infrastructure upgrades, and so on.

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ESTIMATING COVID-19 IMPACT ON TRANSPORT SYSTEMS

A risk assessment and reduction approach has been adopted by a research study in Japan, using a hazard-based model and exploiting the concept of network centrality **[4]**. Reference dataset were obtained from government websites, and included the date of first COVID-19 case, the proportion of productive age population, Gross Domestic Product, number of Japanese companies listed in Tokyo Stock Exchange, and income per capita. Passenger flow data referred to a 2017 government study. 47 prefectures were categorized under four groups, and the impact of restrictions due to COVID-19 on transportation was estimated by calculating the closeness centrality of each *i* prefecture on the network, as the inverse of the sum of shortest distances to nodes in other prefectures. Risk of importing COVID-19 by each Japanese municipalities was calculated with a hazard-function reported below:

$$1) \quad \lambda_i^{(j)} = \frac{\beta}{c_i^{(j)}} \exp\left(X_i \alpha\right)$$

Where:

- j = 1,2,3
- β = prefecture-common parameter of interest
- X_i = covariate vector
- α = coefficient parameter vector

Eventually, survival time was modeled with a probability density function applied to each of the four groups finding each related likelihood, and adding them up to obtain the total likelihood; the mathematical parameters inside this funcion were calculated with the maximum likelihood method. Further calculations then returned the cumulative risk of COVID-19 importation for each prefecture. **Figure 1** shows the estimated relative risks for four hypotetical scenarios in Japan: H1 if no travel restrictions, H2 for a lockdown based scenario, H3 if deleting the top10 most populous passenger volume edges, and H4 for a restriction of airplane travels scenario.

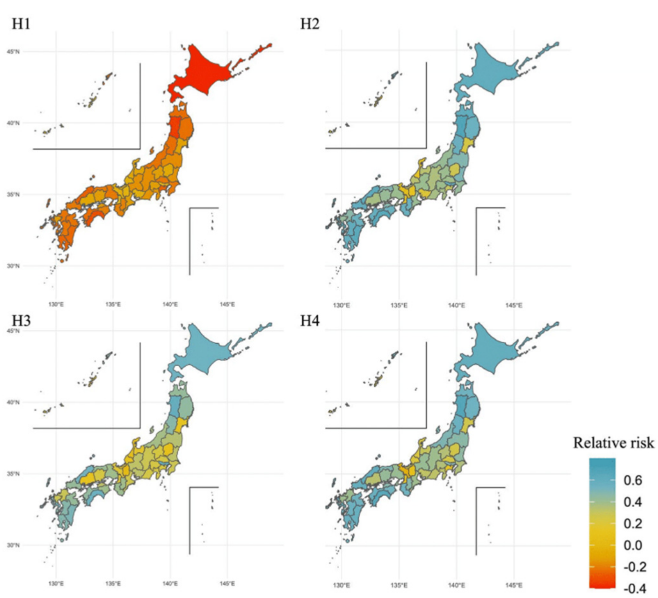

FIGURE 1. Estimated relative risks under four different scenarios **[4]**.

Mathematical models, like for example a Multi-Networked SEIR model, can be also used to estimate the effects of transportation on the COVID-19 spread **[5]**. SEIR is a deterministic model that can be extended to this use, considering parameters such as the share of non-infected, infected but non-tested, and test-confirmed infected people in certain areas, along with the number of recovered or dead people. The obtained model can be applied to attempt forecasting the spread of COVID-19. Future upgrades of the model will consider asymptomatic transmission.

INTELLIGENT TRANSPORT SYSTEMS AND COVID-19

COVID-19 has changed the ways users perceive public transportation, as it’s now often seen as a potential hazard for spreading diseases. Intelligent Transport Systems (ITS) **[6]**, including fully autonomous vehicles, can in this sense bring some benefits to public transport in terms of health. Being operated by computers and algorithms, Autonomous Vehicles don’t require drivers or pilots thus reducing the risk related to human presence. This is particularly useful with the transportation of grocery goods or biological hazardous substances, although the latter would require additional security measures. The risk remains in case of shared public transport, as multiple users share vehicles together, especially if vehicles haven’t been upgraded with glass barriers and other COVID-19 safety devices. Besides, the adaptation of existing infrastructure or construction of new, such as smart cities and highways, is still at an early stage and will require time and costs to be achieved. Attention must be also paid to passenger waiting infrastructure like bus stops, where people usually gather while waiting shared vehicles. Switching to an ITS and Smart City and IoT logics will help with all those operations to prevent diseases, such as crowd monitoring at bus stops, or transporting people with autonomous vehicles **[7]**. Remote working thanks to high-performing internet and smart technology can also permit employees to work from home, thus avoiding them to commute and therefore reducing the risk for contagion and infections; besides, reducing traffic congestion and commuting also mean a reduction in fuel consumption and pollutant emissions, which on a larger scheme will improve people health too. Connected Autonomous Vehicles (CAVs) can play a significant role in the transportation of COVID-19-infected patients, as doctors and nurses often run the risk of getting infected inside ambulances **[8]**. The benefits brought by CAVs are multiple and include the possibility of planning the trip and communicating remotely, calculation of the best route (i.e., quickest) thanks to IT technology, fuel efficiency and reduced costs, reduced use of onboard medical supplies which can be diverted to more urgent operations in hospitals, and touch-free devices boosting the level of hygienic conditions. The scheme in **Figure 2** below shows a comparison between a conventional and smart autonomous ambulance taking an infected patient to the hospital, with the latter reaching destination earlier thanks to an optimized best route calculation: conventional ambulance calculated the best route just according to the briefest spatial distance, not considering however traffic lights and traffic conditions and thus arriving later than the Autonomous ambulance.

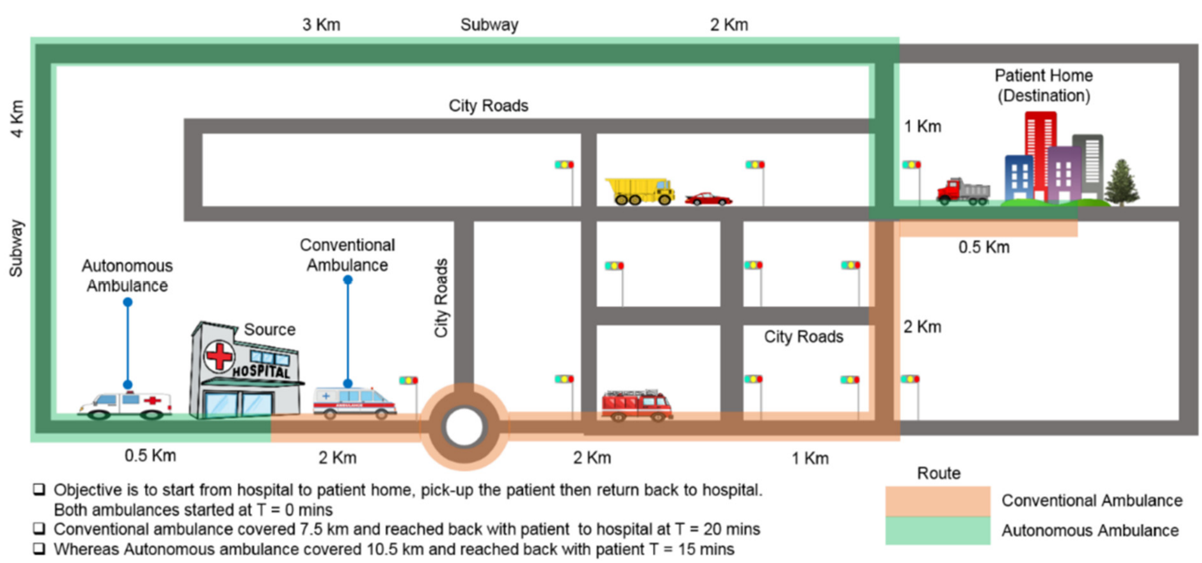

FIGURE 2. Comparison between Conventional and Autonomous Ambulances, showing a better performance for the latter **[8]**.

CASE STUDIES

Two Case Studies will now be presented to show the reciprocal impact between COVID-19 and transportation in two different geographical areas. The first case study **[9]** has been conducted for the cities of Chania and Rethymno in Crete, Greece, characterized by the presence of academic communities and high seasonal tourist flows. The study has assessed the effects of government policies issued after the COVID-19 outbreak on commuting habits and travel mode choice, for two phases (split in four periods) of the pandemic before, during and after the quarantine. During the first phase, at first week of quarantine, private car usage has dropped in favor of sustainable transport means, particularly walking, but also cycling and public transport; as predictable, usage of private and public transport means has dropped in March with the enforcement of policies, although notably travels by walking didn't show significant differences. At the second phase, in April, over half the population from studied sample chose to drive a car for urban trips, neglecting public transport. In June, daily car usage returned to be the main transport mean, whereas travelling by walking dropped from 53.9% to 46.1%. Other results achieved from the research study described travel times, travel mode choice determinants, travel behaviors, participants' attitudes on restricted movement measures, and shared mobility and safety across phases 1 and 2. Graphs in **Figure 3** and **4** show the travel mode choice determinants in % during Phase 1 and Phase 2 respectively.

FIGURE 3. Travel mode choice determinants (%) during Phase 1 **[9]**.

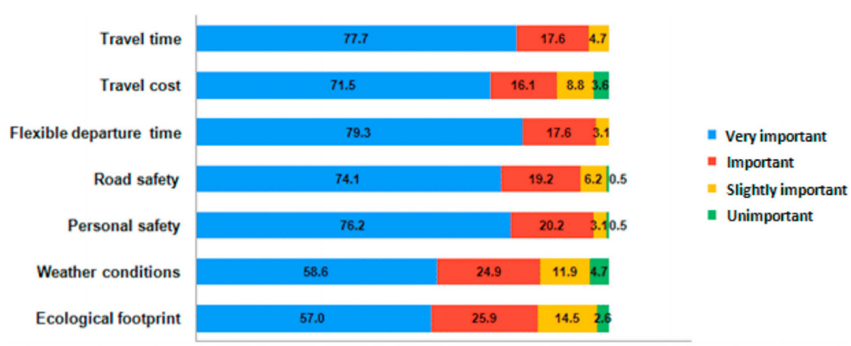

FIGURE 4. Travel mode choice determinants (%) during Phase 2 **[9]**.

The other case study **[10]** assessed the role internal migration and transport infrastructure to the spreading of COVID-19 in China, through the application of a spatial general equilibrium model. Results showed that COVID-19 has spread more within those prefectures which had higher bilateral migration flows and shorter travel distances with the Hubei region (outbreak area); besides, wealthier prefectures with higher incomes were more successful in containing the pandemic at the early stages of the virus spread. It was estimated that the quick expansion of transport infrastructure, sided with removal of migration restrictions and consequent migration flows, was responsible for around the 28% of the infections outside the Hubei province.

DISCUSSION

Epidemics and pandemics have already occurred in human history; however, our age is characterized by a high level of global mobility, associated with a technological progress that makes it possible to move vehicles and people in a very short time anywhere across the globe **[11, 12, 13, 14, 15]**. Combined with the high rate of contagiousness of the COVID-19, this has led to a very fast spread of the virus practically all over the Earth. It is therefore necessary to question ourselves about the impact of transportation in a broad sense on the spread of COVID-19, and vice versa what is the impact of COVID-19 on the transport of goods and people, and on transportation systems. The COVID-19 pandemic has triggered a new multidisciplinary approach towards transport systems, absent until now or in any case not receiving enough consideration, relegating the phenomena related to epidemics mostly to isolated regions and relatively short periods, neglecting or underestimating their risks on a global level **[16, 17, 18,19,20,21,22,23]**. COVID-19 pandemic is believed to have originated at the end of February 2020, and to date (second half of 2021) there is already a fair amount of scientific literature on this matter; however, since the phenomenon appeared in very recent times, the amount of scientific material and mathematical models that can be applied for the prevention of possible future pandemics is relatively scarce. New research studies will need to be developed, which besides will have to be conducted on an international scale given the global nature of transport **[24,25]** and of the spread of pandemics too. Companies will be able to play a participatory role in this, as it has already been seen how pandemics also cause economic damage to the transport industry, and this can be seen as a reciprocal opportunity: of funding research on these issues for the academic world, and of adaptation to a new market with less losses and greater revenues for companies. Speaking of transportation and pandemics, the field is so vast, new, and multidisciplinary that related research topics will not be lacking: from models and algorithms **[26, 27, 28, 29, 30]** of interconnection between transport and pandemic spread, to related human behavior and the effects on the choice of transport modes **[31,32,33,34,35]** to the adoption of green technologies to reduce the pollution and therefore the weakening of human immune defenses, to the application of Internet of Things (IoT) and other technological devices to transportation and so on **[36, 37, 38, 39]**. This fits very well with the idea of sustainability and the achievement of a better world for us and above all for future generations **[40,41,42,43]**.

CONCLUSIONS

COVID-19 outbreak in early 2020 was an unexpected event leading to significant changes in people lives across the globe. Its impact has upset the way in which everyone perceived things often taken for granted or to which no attention was paid, and that now instead will have to be reassessed to reduce future risks of pandemics and their consequences. Transportation and pandemics are strictly interconnected, with pandemics having consequences on the movement of both people and goods, along with human casualties but also financial losses, and with transportation playing an important role on how diseases spread around the world. We are living in a high-mobility and globalized era and pandemics can spread wider and quicker than ever, considering also the advanced level of technology if compared to the past. Existing infrastructure and devices will have to be updated according to these new problems, and new systems and devices will have to be developed focusing on prevention and limiting damages. Technological approach by itself won't be enough, requiring a multidisciplinary approach including governance and policies, education and so on. The role of scientific research in present and future times will be indispensable and fundamental in this sense, facing a world full of new challenges and goals to achieve.

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