COVID-19 Impact in Transport, a Paper from the Railways' Systems Research Perspective

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ABSTRACT

This paper analyses the possible impacts of COVID-19 on the transport sector and specifically on the railways. It aims at investigating how the sector should approach the "new normal". The pandemic had repercussions not only on the interaction between producers and consumers but also on the environment, therefore changing the supply chain. The health crisis halted passengers' mobility and limited air and sea freight capacity significantly, consequently producing a positive impact on the environment. However, the low production trend of GHG emission is expected to reverse once containment measures are lifted. Transport will have an important role in the predicted rebound effect of GHG emissions; thus, the development of green new mobility is essential. In light of these aspects, this study argues that a new resilient paradigm of mobility must be developed for future health emergencies which meets environmental demands. This paper introduces the five "R" - Resilience, Return, Reimagination, Reform, and Research - as the necessary steps the rail sector will need to address to better continue to provide services throughout future crises. In particular, the paper highlights new avenues for research which can play an essential role in enhancing rail competitiveness and resilience within future crises. In conclusion, this paper reminds that the pandemic might be considered as a testing ground for upcoming crises and an opportunity to introduce the discussion about a new green and public paradigm of mobility.

Keywords: COVID-19, Railway, New normal, Green recovery, Mobility, Pandemic

INTRODUCTION

China was the first country hit by the 2019 Coronavirus disease (COVID-19). In response to the outbreak, Chinese authorities placed Hubei and other provinces on lockdown, and restricted economic activity in national and international economically significant areas. With the expansion of the Coronavirus SARS-CoV-2 to other countries, including European Member states, similar policies have been implemented in Europe. Several millions of people have been recorded infected by the virus, and several hundred thousands have lost their lives worldwide. (*1*). The current coronavirus outbreak is the greatest humanitarian challenge the European Union has ever faced. In this turbulent and volatile situation, it is difficult to estimate how long the pandemic will last and how long will the current restrictions remain in place.

However, it is also an economic challenge. Looking at the case of China, which has significantly reduced the cases of COVID-19, it is possible to draw some conclusions on the magnitude of the effects of the imminent economic crisis in Europe. The Chinese industrial output contracted by 10.9% quarter on quarter in the January-March period, and forecasts show that Chinese growth in 2020 will be a mere 1%. Such a scenario would also have extreme consequences for the economies of many European countries (i.e., the UK, France, Italy, Spain). In particular, a prolonged stop in touristic activity would precipitate exceptional levels of poverty in some of these countries, with extreme impacts on the tertiary sector and correspondingly low levels of mobility.

This paper analyses the impact that COVID-19 will have on the transport sector on the assumption that the current emergency situation will last until 2021. However, it also gives a prospect on how the transport sector should approach the "new normal", which will follow the health emergency and should be resilient in case of future outbreaks. It is necessary to highlight that relevant constraints to mobility characterise this scenario until the end of 2021, and it could be compatible with the potential applications of preliminary research results.

This proposal refers to a phase of full and unconditioned operation of railway passenger systems, which must be enhanced swiftly, by accepting temporary social distancing only where technically possible and necessary. It is also necessary to highlight that emergency health measures play a crucial role on the psychology of passengers regarding the possibility of restoration of a reliable plan for personal mobility against the present uncertainties and the fear of social intimacy, even beyond the actual potential risk. As such, railway transport and integrated public transport as a whole need to provide a seamless continuous experience both in space and time without physical or technological barriers. This proposal believes the future of integrated public transport and railway depends on the capacity of maintaining and increasing these attitudes. Ineffective, intrusive measures will act as limitations in the context of public transport and will reduce the natural advantages of rail as a seamless barrier-free experience and thus push end-users back to individual mobility or air transport.

This position against limitations to mobility reflects the risk assessment on COVID-19. (*2*). As in the first phase, extreme measures have been put in place to safeguard national healthcare systems. Such measures will have to be gradually reduced as the risk for the healthcare systems decreases. As indicated by the European Centre for Disease Prevention and Control, the risk of "severe disease associated with COVID-19 in the EU/EEA and UK is currently considered moderate for the general population". Therefore, measures should be focusing on "populations with defined risk factors associated with elevated risk" and not overestimate the risks COVID-19 involves for the general population. Before the virus outbreak, other risks were habitually and continuously accepted in daily life and particularly in the use of transport systems, once compared with the exceptional benefits of socialising and freedoms. This correct and healthy approach to risk management has to endure in the future and become radicalised on extreme positions.

METHODOLOGY AND STRUCTURE

This paper employs the so-called "action research method" because of its specific advantages of supporting and encouraging behaviour changes during the research process. This method has been chosen as it enables to develop collaborative data collection and micro-level impacts of initiatives that aim at countering the effects of COVID-19. The main benefit of this methodology lies in its nature of applied

research, which is particularly useful in developing theory from practice. This contribution employs highly diverse sources with specific focuses on different subjects related to COVID-19's effects on transport, logistics and consumers' behaviour. In particular, the paper levarages the contributions of EURNEX members as research partners in the process of collaborative data collection.

The contribution is composed of three parts. Firstly, it analyses the impacts that the COVID-19 pandemic had on three macro-areas: consumer behaviour, the transport sector and the environment. Secondly, it dives deeper into the transport sector part and analyses the effects of the pandemic on the rail passenger and freight transport sectors, together with the opportunities which the new normal might provide for rail services. Lastly, this contribution approaches the avenues for future research and provide practical guidelines for the rail sector's correct approaching to similr future health crisis through the mentioned five steps of resilience, return, reimagination, reform and research.

OBSERVED IMPACTS

Impact on global consumer behaviour

The impacts of the COVID-19 pandemic significantly altered global consumer behaviour, affecting the timing, breadth and volume of purchases. (3). As such, the interaction between producers and consumers changed significantly, and in the future context distribution channels are expected to play a crucial role. Supply chains, in particular, must adapt and be more flexible to cope with the current challenge. In most affected countries, people decided or were compelled to leave their homes as little as possible; thus, the COVID-19 outbreak gave a tremendous push to the eCommerce sector (4), which only in Italy experienced a 97% and 101% growth in the first and second weeks of lockdown, respectively. While it is still unclear how long this trend will last, China (*5*), the United States (*6*), France (*7*), Germany and Sweden (*8*) are experienced a strong growth in the eCommerce sector. China is particularly noteworthy as already high shares of eCommerce before the virus outbreak grew significantly even in rural areas.

What COVID-19 has shown is that passengers and goods traffic can still suffer serious setbacks, with implication on a global scale. However, looking at the "new normal", it is clear that the transportation sector will continue playing a fundamental role in tomorrow's society. Still, it will be necessary to transform and adapt transportation to allow recovery to take place.

Impact on the transport sector

An analysis of the effects of the pandemic on the transport sector highlights how certain transport modes suffered a more severe slowdown than others. As a whole, future mobility might need to develop a new paradigm to cope with the effect of the virus whilst ensuring mobility to end-users.

In general, before the virus outbreak, it was estimated that passenger transport would have grown by 42% between 2010 and 2050. Freight transport was expected to grow by 60% during the same period. (*9*). However, the transport sector has been hit hard by the impact of COVID-19: both passengers transport and freight have suffered severe setbacks from the crisis.

Passenger transport within the EU Member States and between the European Union and the rest of the world has been partially or entirely closed.

Air transport has been one of the sectors which suffered most. In Europe, passenger air traffic fell by 90%. (10). Several airlines have grounded nearly all their fleet and explored the possibility of deploying passenger aircraft as freighters. Nevertheless, freight forwarding has been limited as it suffers from extremely limited connections. Overall, the crisis has limited the airfreight capacity between China and Europe to 40% of its original capacity. (*11*).

Road transport faced several problems as well, and its efficiency plummeted. The decision of closing crucial border crossings in March 2020 to passenger transport with the objective of carrying out health controls, resulted in long queues of trucks. The closing of the Brenner pass, for example, generated queues up to 90 kilometres in length on the Italian side of the border. Land transport has been subject to disruptions and slowdowns, as a result of both border controls due to sanitary measures and driver unavailability.

Taking into account passenger transport, the following estimates try to show the importance of air and road transport on an EU-wide scale. In 2016, passenger cars accounted for 82.9% of the inland passenger transport in the EU (including therefore all transport modes but air and maritime transport), while motor coaches, buses and trolleybuses accounted for 9.4%, measured by the number of inland passenger-kilometres (pkm) travelled. (*12*). On the other hand, considering that more than 1 billion passengers travelled by air in 2017, half of the air passenger transport concerned extra-EU-27 flights (50 %) while national transport and international intra-EU-27 transport accounted for 16 % and 34 % of air passenger transport, respectively. Before the COVID-19 outbreak, the role of the air transport sector was also expected to increase in the future, with an annual passenger increment of 3,5% each year. (*13*).

Regarding freight transport, road transport accounts for more than half of the total freight transport activity within the European Union, with 75% over the total tonne-kilometre (tkm) transported. Road transport is followed by rail with 18% and maritime 6%. (*14*), (*15*), (*16*).

The pandemic also compromised the maritime cargo transport. Being mainly a concern for the transportation of goods between Europe and China, the crisis had repercussions on production in both regions. In particular, the ocean freight industry has responded to the lack of demand for goods from and to China by reducing the supply of shipping services. European ports are expected to be running at 20-30% of their full capacity in the coming months, thus reducing the demand for ocean liners with a capacity of ten thousand containers.

In the context of EU – China freight transport, long-distance trans-Eurasian rail lines appeared to be mostly untouched by the negative consequences of the crisis. Contrary to other transport modes, trans-Eurasian rail is, in fact, experiencing a growth period. Before the health crisis, its services were eight times cheaper than air freight while taking a triple amount of time. (*17*). At the same time, while rail transport was two times more expensive than sea freight, its transit time was half the time needed for ocean freight to reach Europe from China. (*18*). The crisis has led not only to elevated air shipping prices but also to longer transit times in both air and ocean freight, thus increasing the competitivity of rail transport. As a result of the lack of viable transport modes between EU and China because of the COVID-19 crisis, trans-Eurasian rail lines became a reliable choice and economical option for companies that need to receive and send goods. (*11*).

Impact on the environment

The COVID-19 pandemic also has consequences for the environment: greenhouse gas emissions (GHG) have decreased and air quality has increased. Contingency measures have been indeed associated with improvement in air quality, clean beaches and environmental noise reduction. (*19*). At the same time, the pandemic also produced negative secondary aspects such as the reduction in recycling and the increase in waste.

Optimism on the effects of COVID-19 on the environment is misplaced. As UN Secretary-General Antonio Guterres highlighted, “We will not fight climate change with a virus”. The current drop in carbon emissions is expected to coincide purely with the virus outbreak. GHG emissions are forecasted to rise again once the pandemic has finished, paving the way for a rebound effect similar to what followed the 2008 financial crisis. In this instance, the crisis caused a 1% drop in CO2 production, but emissions increased by 5% once the crisis passed. Therefore, it is expected that - once the virus disappears - those measures which have been put in place for its containment will be dismissed, and with them the incidental benefits on the environment.

Nevertheless, some new habits may have come to stay, even if on a voluntary basis. Companies which were sceptical about the introduction of teleworking will now understand the possibilities of this working mode, resulting in less need for commuting and less space needed to conduct business. As such, companies might be tempted to maintain the teleworking approach and save on rents and utilities. This could have an impact on GHG production, albeit a rather limited one. At the same time, the rise of home delivery and e-Commerce will also have implications for the environment, creating more GHG both as a result of a larger fleet of vehicles delivering goods to the end-user and the higher use of packages and waste. (*20*). At the same time, it is not clear if lower levels of private transportation will meet the increase in

eCommerce transport, as the eCommerce's role in GHG production largely depends on the customer behaviour after purchasing online orders. Whether customers consume cheaper consumer goods at a higher rate when shopping online, or how would consumers use their time that was previously spent shopping retail, are factors that vary greatly but have high relevance in estimating the impact of eCommerce on the environment.

The pandemic environmental impacts are strictly connected to the drop in mobility levels across Europe. Nižetić revealed how the reduction in air transport mobility directly affected the reduction of CO2 emissions. (*21*). The relationship between the transport sector and carbon dioxide emissions has been troublesome, and the pandemic happened at a time in which the European policy towards clean transport failed to achieve a reduction of GHG emissions. Unlike other sectors such as agriculture or industry, GHG emissions from the transportation sector have increased dramatically since 1990. (*22*).

To avert the "return to normality" vis a vis GHG production once the threat of the virus has been eliminated, it will be necessary to introduce structural changes in transportation, to avoid the mistakes made after the 2008 financial crisis. Any stimulus spending that might follow the COVID-19 outbreak should not boost fossil fuel consumption.

WORKING HYPOTHESES AND FORECASTS FOR RAILWAYS

We will now briefly analyse the effects of the COVID-19 outbreak on the passenger and freight transport sectors as a whole. Subsequently, this contribution will analyse the impacts that this crisis might pose to the rail transport sector in the contexts of urban, suburban and long-range mobility, together with the opportunities the new normal might provide for the sector.

Passenger transport

As of November 2020, virtually every European government has taken two policies as references to prevent the spread of the COVID-19.

On one side, policies have been based on the scientific consensus that social distancing is the only form of prevention against the COVID-19 due to the absence of vaccination or effective drug therapies. In the last ten months, almost every country – not only in Europe but all around the world – has promoted social distancing measures, as they proved to be effective in halting the pandemic.

On the other side, European policies have followed the cases of China, South Korea and the US and attempted to developing geotracking systems using Bluetooth perimeters and big data, capable of calculating the risk for a specific individual to have been in contact with someone carrying the virus. After concerns over privacy issue seem to have settled, such tools might be effective in identifying new outbreaks of the virus and allow quarantine measures for suspected new cases.

The omnipresence of these policies in the European political debate reflects on the transport sector. In particular, in the context of increased need for physical distancing, the European transport sector as a whole had to provide new solutions to meet these unexpected demands. At the same time, sustaining the effectiveness and capability of new technologies to safeguard public health plays a crucial role in determining which transport mode will be safer in the upcoming period. Similarly, the transport sector as a whole had to adapt to severe health controls before the passengers boarding. Body temperature controls had been put in place on almost every public transport and became mandatory for travellers before entering the train/coach/aeroplane. Likewise, entrance restrictions have been introduced, similar to the retail industry, and new guidelines have been implemented to provide deep cleaning and sanitisation of each transport mode.

The rail sector might have an advantage over road and air transportation in these aspects. Because of the composition of passengers' wagons, the adaptation of the layout regarding passengers' seats might be fast and efficient. Railways can also provide safe, independent compartments in which a small number of passengers can travel and apply social distance measures. Furthermore, by tracking passengers within the different compartments, rail might be able to provide accurate data to detect which passengers could have been exposed to the virus during their journey. Lastly, rail provides a cost-efficient transport mode in relation to the new requirements on health controls. In this sense, it is possible to implement smooth and

fast security controls, safeguarding both passengers and health operators prior to their access to the train station platforms. As such, the rail transport system can install thermal cameras to measure body temperature to several people at the same time. Furthermore, because of the characteristics of the passengers' wagons, it is also possible to provide deep cleaning and sanitisation of the wagon between each new journey.

Urban mobility

In the context of urban mobility, since the beginning of the pandemic end-users had to face a decision regarding which mode of transport to choose between private transport (i.e., cars, bicycles) or public transportation. On one side, demand pushed forward private mobility as a result of the fear of infection and interaction with other users. (*23*), (*24*). However, the use of private mobility as automobiles is not self-evident. The crisis hit automotive manufacturers worldwide hard, which have then been forced to shut down operations on the vast majority of their production plants. After an initial supply shock, the auto industry is now experiencing a global demand shock. Predictions (*23*) show that automotive sales most likely will decrease by 14-22% among the markets in China, US and Europe in 2020.

While it is still uncertain to which outcome the crisis will push the automotive industry, auto companies may be forced to divert capital to continuing operations, thus "starving R&D funding for advanced technology initiatives". (*25*). In particular, while technologies as autonomous driving or innovative fuels might be put on hold, it is unclear if the automotive sector will continue the push towards electric vehicles. In this context, on one side automotive companies already asked the European Commission to postpone CO2 targets related to the production of hybrid and electric vehicles. (*26*). On the other side, Member Countries as Italy are planning to increase the fiscal bonus to consumers willing to buy an electric car from 6.000 to 15.000€. (*27*). However, we argue, both solutions are short-sighted.

Firstly, because focusing on vehicles production rather than environmental protection means to delay the effectiveness of environmental measures and lower the competitiveness of innovative solutions such as electric cars. In particular, if the EU were to postpone environmental measures to focus on protracting the production of an obsolete vehicles fleet – which will have to be forcefully shelved in a relatively short period – this would not only undermine the industry competitiveness on the world markets but also undermine the consumers' credibility in the EU.

Secondly, in the context of an economic crisis where families are affected by a lower purchasing power, the introduction of large investments from the Member States for an industry which is not able to compete yet with traditional combustion vehicles, both for range and availability of charging station, might have serious consequences. On one side, it might create a dangerous division between segments of the population. The highest end-price of an electric vehicle, compared to cars with a combustion engine, is likely to be a constant factor in the immediate aftermath of the crisis. A lower purchasing power from the hardest-hit sections of the populations will likely be matched with an uneven distribution of charging stations across the Union. The result might be a situation in which those benefiting from the economic incentives in purchasing EVs would also be those not in need of financial aid and closer to economic strongholds within the region. On the other side, such measures would drain important resources which could be poured in providing safe, affordable and environmentally friendly public mobility.

Despite the previous considerations on the effects of the policy approaches towards the automotive sector, the fear of health risks and health controls strongly boosted the trend of private mobility in 2020, which coincided with under usage of public transportation. (*28*).

In the European context, those cities which might give priority to private mobility with cars could face the possibility of seeing their mobility collapse, as most European pre-COVID-19 cities already suffer from their congested streets. Green private mobility as electric bicycles or electric scooters may play an important role in urban mobility, as the decision of New York regarding the legalisation of e-bikes and scooters shows. (*29*). However, several cities across Europe still lack adequate legislation on the regulation of electric vehicles as scooters and bicycles. (*30*). Furthermore, not only these mobility solutions are still relatively expensive and remain mostly private, but their capacity in replacing public mobility in a very

short time is still unproved. Policymakers will have to decide whether to continue the current policies on restrictions regarding polluting vehicles or update the legislation vis a vis electric smart mobility.

In the context of public urban mobility, COVID-19 resilient policies might include the rail sector to provide deep interconnection with micromobility services such as electric scooters and bicycles (lightweight devices operating at speeds typically below 25 km/h), playing a key role in the concept of Mobility as a Service. Furthermore, policies must be in place to avoid the risk of underuse of public transportation. In this context, railway services might continue providing mobility services without the drawbacks of private cars usage, if capacity constraints were to be reduced to a minimum. The economics of rail supply must equally need to be kept into consideration, as those parameters are important for end-users. Performance and train length, must be re-evaluated.

When comparing railways with other public transport services, rail present advantages over road mobility. Due to its station-based infrastructure, in fact, metro services can provide adequate space for carrying out health controls operations, if needed. Moreover, rail does have the advantage of being able to increase train capacity by adding cars. It can thus provide more effective social distancing measures than other transport modes while maintaining the same number of passengers as before the pandemic. The trade-off between distancing and density is, therefore, less significant in railways than in other public transport modes and has to become a regular concern in the planning of urban transport.

On the other hand, a reduction in the capacity of trains might lead to an increase in private transport. It is therefore essential to improve the frequency and availability of trains, to avoid a dangerous shift of commuters to cars. In the context of a high shift to private mobility, rail will be able to offer cleaner, safer and more punctual mobility services than private vehicles could. A sustained increment towards the usage of private cars needs to be avoided especially in the context of cities increasingly facing problems caused by transport and traffic. (*31*). Especially in the case of metro services, the usage of an infrastructure network not shared with private transport greatly reduces the risk of congestions.

If fears over the spread of COVID-19 result in a sustained trend in which travellers prioritise private car over public transport, European cities will experience a dangerous shift, which might lead to the collapse of the urban transport system in the major European cities and the need of massive subsidies. This would have a number of negatives consequences, such as a more dangerous environment – both for road users and CO2 production – productivity and economic loss due to increased time in traffic congestions and worsening of quality of life for the inhabitants.

Suburban mobility

Similarly to what has been highlighted in the urban mobility scenario, end users might prefer private mobility as a result of the fear of infection and interaction. However, in this scenario, private mobility might also be limited in comparison with the urban mobility environment, by the higher price in the automotive sector, while economic incentives for the purchase of electric vehicles might be less effective amongst the population living in suburbs or towns within commuting distance than amongst the population living inside the city centre. The lower effectiveness of economic incentives is expected mainly as a result of two reasons. On one side, the low capillarity of charging station on the suburban territory might not allow a comfortable shift from traditional to electric vehicles. On the other side, the current regulation in several EU Member States does not provide economic sanctions towards polluting automobiles out of the main city areas as much as within the city limits. As such, while economic incentives push the population living within city limits toward the choice of purchasing an electric - and at the same time, economic sanctions discourage the consumers in maintaining vehicles with older technologies as diesel engines - the population living outside of the city limits only have limited incentives and faces infrastructure deficit.

At the same time, in the context of suburban mobility, the choices of private mobility such as electric bicycles or scooters are extremely limited due to the nature of commuting distances.

In this context, public transportation in general and rail services, in particular, might play a major role in ensuring passenger mobility. Therefore, similarly to the urban scenario, the re-evaluation according

to the new context of important parameters such as frequencies, performance and train length might ensure high efficiency for the sector.

Leisure and work-related long-distance travels

The words from the EU Commission President Von der Leyen, which recommended "waiting before making plans" on holiday reservations are indicative of the state of the touristic sector in Europe. Long-distance travel is expected to be taboo until 2021 at least, but the development of the situation might postpone the date further on. The long-term effects of the COVID-19 crisis on tourism are still unclear, as it heavily depends on the economic measures the Member States and the European Council will implement to safeguard this business from the economic crisis. So far, the best-case scenario is characterised by a severe reduction of long-distance travel for leisure and short-term tourism. This decline might have impacts on every transport mode. International journeys are expected not to recover until the emergency has ceased, while the impacts on long national journeys might be less drastic.

The air transport sector is likely to be the heaviest-affected transport sector, as not only it is extremely demanding and expensive for air companies to provide effective measures to ensure social distance and health controls, but it will also be challenging to maintain crew and operators' safety and provide deep cleaning and sanitisation to the aircraft. The economic model of airlines must adapt to the new health requirement. The limited economic resilience of the air transport sector will likely be the main factor in the decrease of share for the future of the sector. (*32*). The number of passengers allowed on board is expected to be much lower than the pre-crisis level, to facilitate social distancing measures. As such, the aggressive yield management at the base of airlines business operation will likely be reduced, raising the price of aeroplanes tickets consistently.

While railway services might share the same issue of reduced capacity as airlines for a short period, their business model presents advantages as it allows an easier adaptation to the new circumstances than the business model which airlines employ. At the same time, airlines orders for new aircraft are expected to plummet. Therefore, together with the production of aeroplanes, the R&D of new models is likely to drop steadily. As both Boeing and Airbus - the two main aircraft manufacturers in the world - will probably leave the crisis in need of state aids, it will be necessary for the two companies to reduce employment and restructure their supply chains. (*33*). The crisis will heavily influence the air transport sector for years to come, with unclear effects on airline companies and aircraft manufacturers alike.

In the context of long-distance journeys, railways might provide the best service level amongst public transport, taking into consideration the new health standards and regulations. As such, rail operators might be able to apply social distance measures, contribute to data collection in order to help detect and avoid eventual new outbreaks, and allow smooth, fast and secure health controls prior to the departure respecting both passengers and operators health.

However, we argue, the role of railways in ensuring long-distance mobility might involve new services such as night-train specifically modified to ensure the correct adherence to the new health regulations. The design and adoption of "COVID-19 intelligent" sleeping cars in individual and familiar compartments might provide a smooth journey while complying to health protection regulations. Furthermore, this measure could be implemented with a limited cost, as the introduction of such a wagon would rely on relatively inexpensive modifications or a quick rebuilding of already existing wagons. By introducing long-distance night services, it will be possible for families and groups to travel seamlessly without renouncing to long-distance journeys and remaining in accordance with health regulations. Such an arrangement is, on the other hand, extremely unlikely in air transport, due to the higher costs of adaptation of the aircraft, which will greatly affect the ticket price for the end-user. Rail might be able to compete with air transport on long distances as a result of several factors: prices for rail services might be lower than the price airlines might charge for, CO2 emissions will be noticeably lower than the ones resulting from air transport, and at the same time, compliance with health controls will be higher than the aircraft can assure. Similarly, night trains will eradicate the need for an overnight stay in certain instances, thus diminishing the need for social contact. To enhance the effectiveness of these measures, it is necessary

to identify those routes where rail competitiveness over air traffic can be highest. This necessary step might allow an effective substitution of air transportation by long-distance trains.

Higher controlling of individuum mobility patterns

As highlighted in each scenario involving passengers, transport modes might have to work together with new technologies to contain the spread of the virus. Amongst them, there could be the support to geotracking systems capable of calculating the risk for a specific individual to have been in contact with someone carrying the virus. Other technologies will require thermal cameras to measure health parameters such as body temperature before the passenger enters the station, always respecting privacy. Computer vision technology could be used to detect when transit workers or passengers breach social distancing norms at stations and in vehicles. The transport sector could also employ air filters and fans to ensure air circulation to flow vertically from ceiling to floor throughout the compartment rather than horizontally from one passenger to others, thus minimising the possibility of spreading the virus within the transport carrier. Transportation might be required to support these systems. The rail sector might have an advantage over other public transport modes, and especially airlines, in implementing such measures.

Firstly, rail might accommodate technical equipment with limited constraint due to the size or energy consumption of the vehicle, while these solutions would be harder to implement in the cases of coaches or aeroplanes.

Secondly, rail might employ an external infrastructure such as a train or metro station, which is more sophisticated than the one supporting coaches but in need of less human interaction for its proper functioning than airports. The advantage of this infrastructure lies on the possibility of its employment for carrying out security measures to give access to the rail services to those passengers which do not present symptoms of COVID-19. At the same time, these measures can be carried out with complete respect of the healthcare professionals' wellbeing and the passengers' privacy.

Thirdly, dedicated, innovative tools for the prevention, the recovery and the containment processes might be developed to control the virus during mobility activities. In this context, passengers and rail staff can be individually protected by dedicated supports, while the rail car or train cabin can be equipped by automatic disinfection systems. Novel research fields for the rail transport sector might involve safety barrier development, intelligent personal protective equipment - like masks, full wetsuit, helmet, gloves - integrating dedicated sensors and actuators to support the control of the spread of the virus, and intelligent systems for the automatic decontamination of seats, hand support, grab bars or rail cars.

However, the existence of emergency health measures would also play an important part in shifting the perception of passengers' vis a vis railway and push them instead toward the choice of personal mobility instead.

If necessary, under extreme circumstances, the rail sector is able to provide health measures. However, we argue that railway transport services need to provide a seamless continuous experience without the physical and technological barrier that solution such as emergency health measures would promote. Long-distance travels could be, for a very short time, compatible with constraints and invasive health controls. However, this is not true especially in the context of urban and suburban mobility, where ineffective and intrusive measures might only reduce the advantages of rail, de facto promoting individual mobility. Strong incentives will be necessary to limit the overestimation of COVID-19 in comparison with other risks and restore passengers' psychology vis a vis their general acceptance of risk to the pre-crisis level. Historically, the European urban mobility system managed to limit the private use of cars by providing services capable of connecting the end-users with their multiple destinations without having to use a car. If barriers or limitations such as temperature screenings and overcrowded wagons will decrease the public transport efficiency, most users will rather elect to drive a car. As urban transit and intercity rail services alike must reduce the probability of virus transmission to be able to complete with private mobility, key parameters such as train length, frequencies and performance must be seriously re-evaluated.

However, while this contribution firmly advises against the unnecessary deployment of invasive systems to over-protect passengers' health in the entire public transport sector, it also underlines how rail

has an advantage over other public transport modes, and especially airlines, if such systems are implemented.

Freight and logistics

In March 2020, 75% of companies globally reported interruptions in their supply chain due to transport restrictions, 46% of companies of international logistics have experienced significant delays in the shipment from Chinese ports. Furthermore, significant delays have been experienced in the shipments to China for 86% of the companies, 74% in Europe, and 44% in North America. (*34*). The first disruption concerned the Chinese lockdown, but since then the problem has moved to Europe. The crisis is causing effects on the entire logistics chain of shipments with heavy disruptions of entire supply chains. The picture is expected to be more fragile in light of the upcoming global recession, which will have consequences on advanced and emerging economies alike. As a result, global value chains are expected to be restructured, following a trend of regionalisation of supplies. As such, WTO estimates that in 2020 world trade will decrease by up to 32%, thus producing profound effects on international logistics companies.

As economic activities will be likely to operate under difficult conditions in the near future, higher prices in production are expected. As the entire production chain will suffer from either lower workforce or higher prices compared to the pre-crisis level, production is still likely to remain lower and more expensive. Higher prices will also be a result of the challenges the transport sector will encounter. Road transport, in particular, may suffer the consequences of controls at the borders, forced quarantine for drivers and higher insurance prices. Traffic jams of up to 60 km length on the German-Polish border or 90 km on the Brenner pass illustrate the vulnerability of road transport in times of tightened border controls in the Schengen area.

Sea transport is also likely to encounter challenges, such as personnel restrictions or the limited number of containers to be transported. This last aspect, in particular, plays a key role in sea transport competitiveness as the size of vessels must be adapted to the transport demand to be competitive. This may force some shippers to operate with smaller vessels such as Panama and Post-Panamax and berth new high-capacity New Panamax and Ultra Large Container Vessel. This transport mode is also likely to suffer consequences on higher insurance prices. Prolonged overcapacity at a time of limited demand may be a source of vulnerability for individual logistics and container transport companies. At the same time, as the 2016 bankruptcy of Hanjin showed, these factors can be a liability for the entire maritime transport system. However, sea transport might take advantage of the crisis to introduce intelligent systems as AI, robotics, automatic handling and navigation. (*34*).

Rail freight will also face significant challenges, particularly related to the slowdown in industrial output. Measures might have to be put in place to prevent the disappearance of operators and capacity, possibly through State support in the short-term. The freight sector proved to be resilient to the crisis, and thus operators decided to shift capacity from seaports traffic to intra-European transport. (*35*). At the same time, the European Commission decided to provide Green Lanes at border-crossings to expedite the transportation of goods within a short timeframe, (*36*) albeit further efforts are required in addressing train drivers as strategic workforce thus allowing smooth border-crossing operations. (*37*). Rail freight proved to be able to play a significant role also in sectors where its presence is not yet consolidated: rail has rapidly adapted to transport types of goods which have not typically been part of their core business. As an example, the North-South Rail corridor has been essential in allowing railways to become a fast delivery mode of break bulk products. Rail has been able to transport essential food as pasta from Italy to Germany on short notice, ensuring that supply chains in Europe were up and running. In this instance, rail gave the manufacturer the reassurance that its products could be delivered. Rail also provided the retailer with the ability to respond flexibly to supply bottlenecks and allowing consumers to maintain their shopping habits.

In this context, European logistics must focus on the "recovery" phase, with priorities such as boosting internal consumption, supporting export and new investments. Investments on infrastructure are considered as a countercyclical tool in a time when the economic slowdown restrains consumption, investments and trade. Infrastructure development is a pivotal component of future development, as it increases potential output, productivity and competitiveness. Investments might have to be implemented

focusing on transformation and technological modernisation in light of sustainability needs and international competitiveness. Infrastructures play a fundamental role in this scenario. Both in the Member States and at the EU level, it is necessary to implement a fast and functional regulatory framework able to provide an immediate start for projects. Furthermore, it is of paramount importance to push forward digital and physical infrastructures to support the mobility of citizens and goods, both at national and European level, with a focus on efficiency and respect for the environment.

As the TEN-T network has yet to be completed, it classifies as a precious set of investments ready for implementation. The crisis highlighted the needs for enhancing the audacity of the project and pushing forward aspects related to environmental respect and intelligent systems. It is necessary to seek for a modern, efficient and sustainable infrastructure system as it is an essential factor for improving European competitiveness, efficiency and quality of life. (*38*). Likewise, every step towards a coherent and interoperable TEN-T network improves the resilience of Europe not only against pandemics but also against every other regional, national or global crisis.

Guidelines for a future approach / Avenues for future analysis

As already seen, the transport sector has suffered the adoption of unprecedented measures since the outbreak of the COVID-19 crisis in Europe. Travel and manufacturing have been restricted significantly to avoid the spread of the virus. Diminished production and disrupted cross-border supply chains influenced rail operators heavily. However, the Union-wide lockdown proved the critical role the transport and logistics sectors continue to play in delivering essential products, and in particular the resilience and competitiveness of the freight sector.

When re-thinking the near future of rail, it is necessary not only to adapt the European railway sector to the new challenges, but it is rather indispensable to reconsider the role that railway can play in the continent mobility. As we will now see, it becomes recommendable for the European rail sector to undergo the following steps to better continue providing services throughout future crises:

- Resilience
- Return
- Reimagination
- Reform
- Research

Resilience

The European rail industry might need in the immediate term to address cash management challenges, SMEs require support from EU institutions to cope with the shutdowns and the economic effects which are expected after the crisis. This requires the development of new abilities for rail transport systems as plasticity and learning to adapt as quick as possible their mobility missions accordingly. Measures might be introduced to make the European rail industry more robust against pandemics and similar threats. In the long term, a higher grade of automation in operations might provide a different, but less vulnerable system, as will measures of predictive maintenance concerning resilient infrastructure. Valuable impacts in this sense might be provided by the introduction of electronic ticketing systems able to address cash management challenges and information campaigns.

At the same time, the current period of reduced timetables might be exploited as a chance of focusing on maintenance and renewal of the current fleet, as it is a major challenge on congested networks.

Return

The European Union institutions might need to create a detailed plan to return the business to scale quickly, as the virus evolves, and knock-on effects become clearer. Indicators or indexes might be developed in order to control the evolution of the instability recovery, to determine the short-term, medium-term and long-term prevention, recovery and containment actions, to assess their impacts and to redefine them if necessary.

Reimagination

Both the EU institutions and the rail industry might have to re-imagine the "new normal", to adapt the rail sector to the aftermath of the pandemic, provide service and maintain competitiveness. Considering a future perspective, it might be necessary to provide further funding for research and development activities in the context of disaster management. Universities, research institutes and companies might be able to expand their work and produce scientific innovation in a scenario, such as the COVID-19 pandemic, never imagined before.

It might also be necessary to focus on the policy measures that ought to be considered both during the current crisis and during the transition to the "new normal". In this sense, it might be necessary to align policies that promote economic growth and transport policies and to promote economic recovery while also pushing for changes in behaviour such as the promotion of walking and cycling.

Reform

The European Commission New Industrial Strategy for Europe and the Green Deal date back to before the COVID-19 crisis. A reform of the mobility policies in light of the pandemic, its consequences on the public transport sector and on the environment might be necessary to provide the adoption of best practices in the new context of financial instability and green recovery.

Research

The challenges faced by the European rail system during and after the pandemic show the need for research in the context of railway transport. With the aim of providing innovative solutions in rail technologies, improving the competitivity of European research, aligning needs of the rail industry and methods of the academia and forming the new generations of researchers, further research might address the following areas.

Research efforts are necessary on the digitalisation and automation of vital processes dependent on manual operations (i.e. use of IoT and robotics for track and rolling stock monitoring and maintenance, ATO and automated driving, integration of A.I. and Big Data). In strict connection with the need for digitalisation and automation, this crisis highlights the need for research on developing pandemic or disaster-related training schemes for the rail workforce.

At the same time, research must cover the necessity of detailed multi-dimensional analysis of urban mobility patterns after the COVID-19 pandemic. Furthermore, there is a need for research in terms of operational supply side and demand side (user perceptions) related to the COVID-19. It will be necessary to address the way in which this crisis will affect private rail firms running services.

Especially relevant for rail freight is the need for additional research efforts for producing studies on reducing operational costs via new transport policies and legal actions.

Further research efforts are also necessary to learn valuable lessons from errors in the COVID-19 pandemic management. Changes in actions require immediate answers, and interdisciplinary research actions can provide guidelines for railway transport. Logistic, contribution to dismiss the propagation and disinfection are some of the lines of interdisciplinary cooperation between research centres and universities based on the tools available over the concepts of digitisation; but also design and manufacturing resources such as 3D printing and generative design that provide experimentally based solutions compatible with railway technology schemes.

Research can also focus on the traceability of logistics using learning and predictive models capable of offering prognosis on sources of propagation in transport, together with the optimisation of the resources of the railway community. Decision-making in access to the railway services, the distribution of the users in trains and stations, the optimisation of work conditions and the operation management are the main overview of request for research, but also in making the resources of the railway community available to the public health demands.

Likewise, the pandemic exposes the urgency in investing in interdisciplinary research on the development and use of self-cleaning materials on trains (such as photocatalytic coatings used by Japan on

train and station interiors, or recent applications on e-scooters). Research into materials that minimise the capacity for viral infection on surfaces that can be touched by transport users (doors, seats, ticketing machines, etc.) and the purification of air through suitable air-conditioning methods and air filter design in closed indoor areas and vehicles in sanitation and disinfection concepts compatible with railway regulations and public health criteria are other lines of action towards preventing and stopping the spread of disease.

CONCLUSIONS

Despite the burden the pandemic placed on the European transport sector; we argue the current situation can be an opportunity. It might be the occasion for the rail sector to improve its competitiveness, moving a step towards a vision of railway as a backbone of European mobility. During the early phases of the pandemic, rail services have been characterised by lower cases of disruptions than the other transport modes. Thus, we argue railways might also provide an effective role in ensuring mobility while limiting the spread of the virus.

It might also be necessary to match the need for governments to avert a deep recession and the needs for safeguarding the environment. In this context, it will be vital to safeguard environmental protection and mobility necessity at the same time, actively promoting a shift from transport modes which are not environmentally sustainable to transport modes which are environmentally friendly. In these cases, rail services are able to provide support in achieving new policies shifting away from the intensive use of carbon fossil fuels for transportation and avoiding a dangerous rebound effect during the upcoming recovery phase. As economic growth is expected to resume, it might be necessary not to delay research and investments to improve the role of rail in public transportation.

Lastly, the transport sector as a whole, and railway in particular, need to reflect on the pandemic crisis and generate a map to navigate these unchartered waters. As such, this paper contributes to the strategic planning of the sector with the production of the five “R”s: resilience, return, reimagination, reform and research.

AUTHOR CONTRIBUTIONS

All authors reviewed the results and approved the final version of the manuscript.

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