sustainability

MDPI

Review

Comprehensive Literature Review on the Impacts of COVID-19 Pandemic on Public Road Transportation System: Challenges and Solutions

Isaac Oyeyemi Olayode [1,*], Alessandro Gaetano Severino [2], Tiziana Campisi [3] and Lagouge Kwanda Tartibu [1]

[1] Department of Mechanical and Industrial Engineering, University of Johannesburg, Johannesburg P.O. Box 2028, South Africa
[2] Department of Civil Engineering and Architecture, University of Catania, 95123 Catania, Italy
[3] Faculty of Civil Engineering and Architecture, Kore University of Enna, 94100 Enna, Italy
* Correspondence: olayode89@gmail.com

Abstract: The COVID-19 pandemic is a significant public health problem and the leading cause of reduction in the demand and supply of public transit in the last three years. It has caused an unprecedented reduction in the demand for public road transportation, and it has changed passengers' perceptions from positive to negative when it comes to using public transportation amenities. There is an increasing concern that the public road transportation systems are witnessing a new horizon, especially now that developed and developing countries are trying to resume their daily activities post COVID-19 pandemic. In this research, we focused on the overview of literature reviews of research within the past three years that focused on the challenges and solutions of the impact of the COVID-19 pandemic on public road transportation systems, especially when it comes to the enforcement of physical distancing in public transportation, usage of face masks and government interventions. The inclusion and exclusion criteria were used in reviewing the articles used for this literature review, and an original 140 articles were reduced to 100 articles that were used in this literature review. This research aims to create an overview literature review that highlights the impact of the pandemic on public transportation and identifies strategic ways in which urban planners and public road transportation researchers can develop constructive and efficient public road transportation planning to ensure the sustainability of public transportation systems in the post-COVID-19 era. This literature review extends our knowledge of the COVID-19 pandemic in public road transportation. It also provides additional evidence concerning the effectiveness of physical distancing and the use of face masks to prevent the COVID-19 virus in public road transportation networks.

Keywords: COVID-19; pandemic; public road transportation; physical distancing; face masks

Citation: Olayode, I.O.; Severino, A.G.; Campisi, T.; Tartibu, L.K. Comprehensive Literature Review on the Impacts of COVID-19 Pandemic on Public Road Transportation System: Challenges and Solutions. *Sustainability* **2022**, *14*, 9586. https://doi.org/10.3390/su14159586

Received: 1 July 2022
Accepted: 29 July 2022
Published: 4 August 2022

1. Introduction

A pandemic can be defined as a global disease outbreak found in both developed and developing countries, which at the time of the outbreak had no cure or vaccine to reduce its effect on the human body or the chances of hospitalization [1–3]. It can lead to enormous absenteeism, changes in a country's socio-economic landscape, and a limitation in its medical solutions, thereby causing an interruption in the global supply chain. All of these adverse effects of a pandemic can have enormous effects on the day-to-day activities of large multinational companies and the sustainability of large, medium, and small-scale transportation companies. It also highlights a compelling research question: can we say that preparing for a global pandemic is different from preparing for natural hazards such as hurricanes, earthquakes, and hazardous chemical spills? The answer is yes; due to the influence of disasters such as earthquakes, tsunamis, and oil spillage, they can influence infrastructural development and significantly affect human beings and transportation

structures. However, it is important to know that Global pandemics affect both natural and human resources.

In early 2020, China reported 80,000 COVID-19 infections [4,5]. These COVID-19 cases were discovered in a city called Wuhan, located in the Hubei province of China [6]. At that current period, an additional 10,500 COVID-19 cases were discovered and confirmed internationally in more than 75 countries [7]. On 30 January 2020, the WHO announced the COVID-19 outbreak as a pandemic and referred to it as a Global Public Health Emergency. They automatically started applying the ArcGIS GeoEvent Server to add updates to a single characteristic several times per 24 hours, irrespective of the time of the day. On 14 February 2020, it officially spread to the continent of Africa. Egypt was the first African country to record a positive COVID-19 case [6,7]. In comparison, the SARS-CoV and the MERS-CoV outbreak, also known as Middle East Respiratory Syndrome-related coronavirus, occurred between 2002/2003 and 2012/2014. According to the World Health Organization (WHO), the COVID-19 virus has been scientifically proven to spread extremely quickly.

While MERS infected 1000 people in about two years and SARS in about four months, the novel SARS-CoV-2 infected 1000 people in just 48 days [8]. Figure 1 depicts the number of daily casualties by geographic area. There was a significant spread of COVID-19 in Asia in early April, with the first African COVID-19 case reported in May (an elevated increase in the number of COVID-19 cases was reported in July). On 30 January 2020, the World Health Organization issued a statement regarding the second meeting of the International Health Regulations Emergency Committee with regard to the outbreak of the novel coronavirus (2019-nCoV) in Geneva, Switzerland [9]. One of the most severe ramifications in the road transportation system during COVID-19 has been a decrease in the demand for transportation facilities by passengers because of the combination of lockdowns by various governments and the risk of contracting and transmitting the COVID-19 virus when using public transportation systems [10,11].

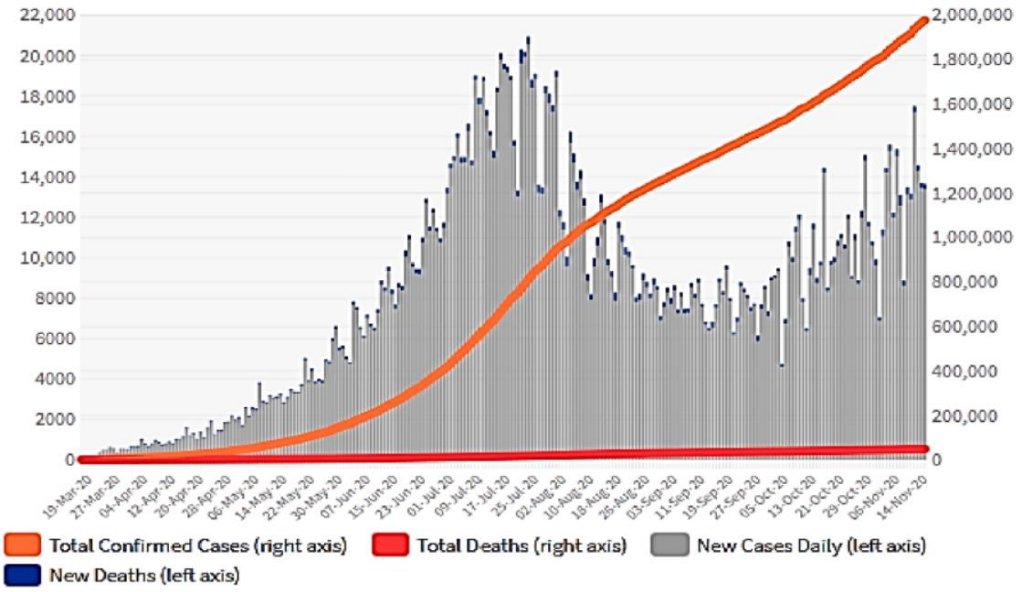

Figure 1. Africa Confirmed COVID-19 cases and deaths in 2020. Reprinted with permission from ref [12]. Published by Elsevier B.V. Copyright © 2021 Elsevier Ltd. All rights reserved.

However, COVID-19 cases were reducing back in early July 2020, and then it gradually increased again exponentially; this is illustrated in Figure 1, this change indicates some government policies when it comes to stopping the spread of COVID-19 are working. The graph in Figure 1 illustrates the overall total number of confirmed COVID-19 cases and deaths in Africa as of 2020. Various federal governments try to put strict measures in place to stop the spread of this virus by enforcing strict lockdowns and social distance measures in cities to prevent and decrease COVID-19 infections [13]. Asweto et al. conducted a

regression analysis in which they stated that lockdowns in major cities drastically affect urban mobility in both public and residential areas. For example, there was a decrement in residential mobility during the lockdown of more than 10%. Furthermore, the change in public transportation (the introduction of social distancing inside public transport) resulted in about 170 fewer cases of COVID-19, while the "total lockdown" embarked upon by some governments led to 580 fewer cases of COVID-19 [14]. By July 2022, policies introduced by various governments have led to a reduced number of COVID-19 cases [15].

Public transportation is the foundation of most urban cities, and it provides significant services to sustain most cities' socio-economic development. Public transportation is also regarded as an investment that creates job opportunities while reducing greenhouse gas emissions, improving road safety, especially around roundabouts [16], and creating accessibility to job opportunities and other socio-economic activities [17]. From recent research, it has been shown that the habits of humans significantly affectpublic transportation notable among these habits is a limitation in transportation accessibility which can dictate the increase and decrease in COVID-19 infections. This is shown in Figure 2. Many studies are being conducted to investigate the effect of COVID-19 on mobility and accessibility. It has been discovered that the more the transportation accessibility of an area, the easier it is for the virus to spread [18]. Others attempt to establish a link between infected patients and human mobility. They find a connection between the percentage of old-aged people and the number of COVID-19 infections. This assumption is based on a theory that well-connected areas have an increased chance of being infected first [18].

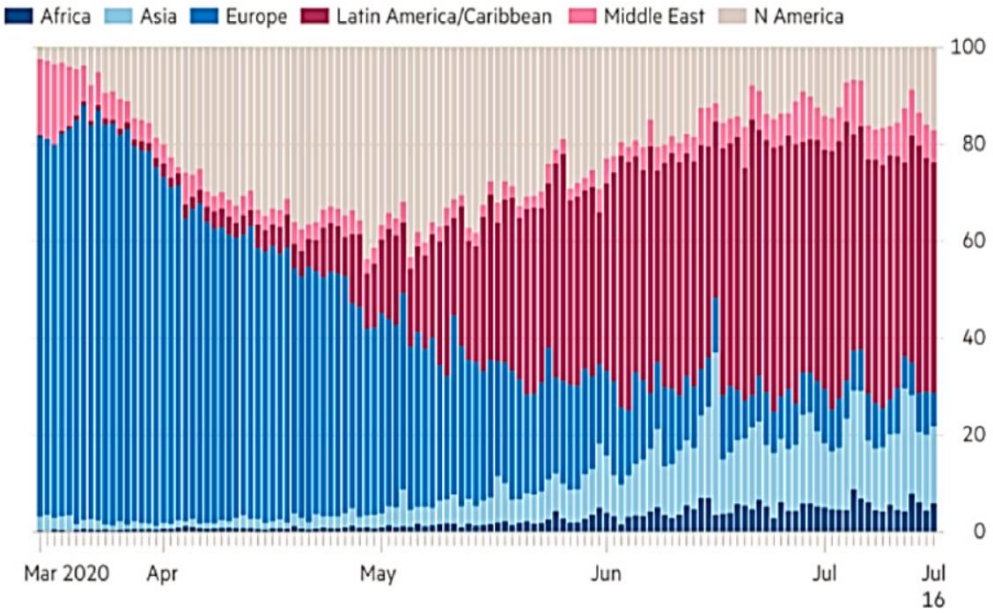

Figure 2. Daily proportions of COVID-19 related deaths by region (%). Source: ECDC COVID-19 tracking project, https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases (accessed on 15 February 2022).

In recent months, many new terms and expressions have insinuated themselves into our collective lexicon. Previously, terminology such as "lockdown," "furlough," "pandemic," and "social distance" were unfamiliar. The COVID-19 virus is still alive and well. A flattening of the curve is required to avoid another COVID-19 wave. There are numerous questions: Are there adequate transportation infrastructures to maintain social distance? Are they secure and disinfected on a regular basis? Unfortunately, there is still a lack of confidence, particularly in developing nations, with residents needing to make routine trips to and from their place of work.

Throughout the world, public transportation has evolved into a service available to all city dwellers, not just a select few. It's one of the long-term strategies of sustainable

transportation. Lockdowns are also putting enormous strain on public transportation systems around the world, lockdowns such as the closure of schools (universities, colleges, high schools, etc.), shopping centres, and the closure of public transport networks [19,20]. The number of people using public transportation has dropped from 50 to 90 percent [21]. For example, the rigorous lockdown imposed in the United Kingdom [7] resulted in a 95 percent reduction in underground train journeys in London. Various emotional and psychological effects have reduced the propensity to use public transport, increasing the use of private transport or of walking and cycling [5,22]. Given its limited resources, Africa has a variety of ways to deal with a crisis of this magnitude. Numerous datasets are available for African nations, including the International Health Regulations Monitoring and Evaluation conceptual framework, which claims that Africa "performs worst in almost every decade when it comes to health sustainability." All of these groups were formed with the goal of studying the effects of different types of diseases. In comparison to other regions, cases in Africa remained low by 30 [7]. (see Figure 2 Our World Data website, 2020).

According to anonymized cell phone data, South Africans in all provinces significantly curtailed their mobility in reaction to the Government's lockdown directives, resulting in decreased COVID-19 infections [23]. In Africa, only ten African countries offer free and universal health care to their citizens, according to a report from the Africa Centres for Disease Control and Prevention, whereas twenty-two [24] African countries have neither free nor universal health care. However, most African countries' transportation sectors adhere to the same regulations that appear to reduce the spread of COVID-19. Many such agencies in Africa strive to collect data daily to aid policymakers in choosing the best solution [24]. The analysis of the disease's mutual impact includes public transportation and school closures, travel reduction, and restrictions on movement from one country to another. The pandemic's direct impact on travel behaviour, such as the number of passengers in transit stations, parks, and outdoor areas, has also been studied. For four months, data from an Oxford study was applied with real-time updates [25]. To highlight changes in the effect, this study looks at the monthly effect on the last days of each month.

1.1. Research Motivation

COVID-19 virus can be found under the family tree of coronaviruses, and they are comprised of respiratory diseases that are highly contagious and which spread faster whenever they are airborne. The first cases of COVID-19 infection were reported in late 2019 [26]. The World Health Organization (WHO) declared the COVID-19 virus a pandemic in early 2020, leading many developed, developing, and under-developed countries to implement heavy lockdown measures and physical distancing guidelines to stop or reduce the spread of the virus [27]. Lockdowns included closing schools (universities, colleges, high schools, etc.), malls and shutting down public transportation networks [28,29]. The effect of this lockdown and physical distancing has had significant adverse effects on public transportation in passenger ridership and the passenger capacity of public transit. Public transportation organizations such as the international public transport association have expressed concern over the travel demand of public transit during COVID-19, especially for passengers regarded as high risks (diabetic and suffering from terminal diseases). The organization regarded this as one of the primary challenges public transportation might experience when public transportation networks resume operation [30]. This literature review paper highlights the adverse impact of COVID-19 on public transportation in terms of travel demand and proposes solutions to curb the impact of this pandemic on public transportation networks. In this research, we identified research focusing on the impact of COVID-19 on passenger public transportation demand by using academic databases such as Google Scholar, Scopus and Web of Science. This systematic literature review will answer the following research questions:

- What are the consequences of physical distancing implemented by developed, developing, and underdeveloped countries on public transportation systems?

- What are the primary public transportation techniques that have been applied to address the issues of physical distancing guidelines?
- What research gaps should transportation researchers and public transportation planners focus on post-COVID-19?

In this research, we conducted a systematic literature review using emerging literature on COVID-19 with academic databases such as Google Scholar, Scopus, and Web of Science. It is important to note that limited research articles discuss the relationship between public transportation and COVID-19. However, the literature review focuses on challenges and solutions surrounding the adverse effects of COVID-19 on public transportation networks in terms of physical distancing, Government lockdowns, and face masks. Another significant contribution to this research is that our aim is not to provide a comprehensive literature review on techniques associated with public transportation planning but rather to expose the paradigm shift in public transportation services, especially in this pandemic era. If the readers are interested in an exhaustive literature review that focuses on public transportation planning techniques, they can read the studies done by [31–35].

1.2. Research Organization

The overall structure of the research takes the form of six sections, including this introductory section which contains the research objectives and organization. The second section deals with the inclusion and exclusion criteria used in the methodology section of this study. The third section is concerned with the effects of COVID-19 pandemic and the guidelines for public transportation. The fourth section begins by laying out the theoretical dimensions of this study and looks at how the challenges of COVID-19 infections affect the socio-economic aspects of public transportation. The fifth part deals with the solutions comprising of policy directions and research guidelines to curb the effect of the COVID-19 pandemic on the public road transportation system. The sixth part includes a discussion of the implications of the literature review for future research in this area. The final section draws upon the entire literature review, tying up various theoretical and empirical strands to give a summary, critique of the literature review, and identified areas for further research.

2. Methodology

This literature review uses a systematic style of review to achieve its primary aim. Figure 3 above shows the different stages of the methodological framework used in this literature review. A systematic literature review is defined as a comprehensive, inclusive protocol used for improved and enhanced data reliability and for developing the different types of knowledge that include diversity in a specific field of research [36–38]. To achieve the primary objectives of this study, this study was created and developed to give a systematic literature review of the impacts of the COVID-19 pandemic on public transportation systems by considering the following:

- COVID-19.
- Pandemic.
- Public road transportation and physical distancing

A comprehensive plan of study consisting of the aim and objectives and five keywords was created. The objectives of this research were created in such a way as to evaluate the relationships among the various effects of COVID-19 on public transportation, and future fields of future study were identified. For this study, we focused on keywords such as “COVID-19” OR “pandemics” OR “Public Road transportation” OR “Physical distancing” OR “Face Masks.” To achieve the primary aim of this literature review, we used the inclusion method to search for peer-reviewed research journals in the English language. An online academic database of thorough studies was conducted by applying keywords such as ‘COVID-19,’ ‘pandemic,’ ‘Physical distancing,’ and ‘Public transportation.’ This study was populated with distinct types of academic databases such as Scopus, Google Scholar, and Web of Science. We also used materials such as reports from government institutions and international organizations such as the WHO and editorial papers. The

journal articles used in this literature review study are all peer-reviewed, and the search for journal articles was carried out between January 2020 to January 2022. This study focuses on journal articles published within the last two-and-a-half years when the COVID-19 pandemic started and which is still ongoing. The search of journal and conference papers used in this research are all peer-reviewed.

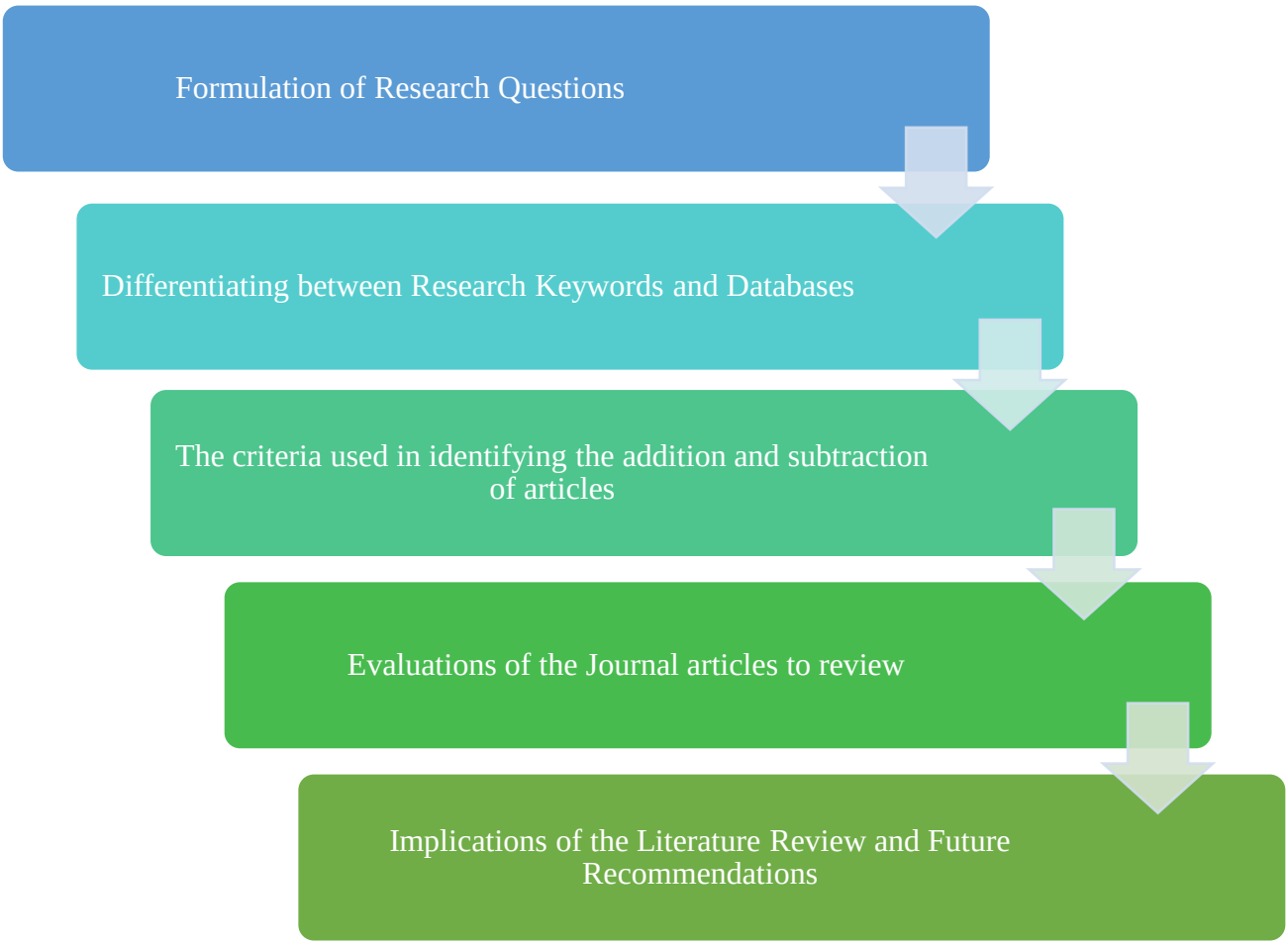

Figure 3. The five stages of methodologies used for the literature review.

The study uses various types of searches via the combination of different types of keywords. The keywords were divided and categorized into two groups. The first group is related to the title of the journal and conference articles, and the second group deals with the abstract of the journal. The resultant search keywords were first validated by combing through the abstract of the journal and conference articles and, furthermore, by reading the full text of the journal and conference articles comprehensively. This is done to verify their scope and aims against the research objectives.

In accordance with what was stated by [39], they explained that when conducting literature review research, it is important to apply different types of academic databases to ensure that necessary academic journals and conference articles are duly consulted and investigated. In this study, we use three academic databases, Scopus, Web of Science and Google Scholar, to thoroughly search journals, conferences, and Government websites with keywords such as COVID-19, pandemic, Public transportation, and Physical distancing. These journals, conferences, and government organization reports were separated by applying a criterion based on a method called inclusion and exclusion. According to the study done by [40], it was concluded that the overall success of the analysis of these articles is based on the quantity and quality of the academic journals and conferences obtained from these academic databases, which makes it significant that a suitable inclusion and

exclusion guideline is adhered to. The research done by [41] stated that the inclusion and exclusion criterion is used for data screening and cleaning of the data obtained to achieve the objective and separate the data obtained to ensure that appropriate data are not combined with the inappropriate ones.

The inclusion and exclusion method was developed and used over the years to separate journal articles, choose common characteristics of journal articles, and select the most useful articles among the journals or conference articles downloaded from these databases. For example, an article written about 20 years ago differs from one just written three years ago. This might be due to advancements in the field or more solutions or problems discovered over the years. Table 1 depicts the inclusion and exclusion method used in this study and how these articles are separated according to different criteria. It is significant to note that these journal and conference articles are separated depending on the relevance of our search keywords to the content in the articles. This is to ensure that the articles used for this literature review are relevant to our aim and objective and are not used outside of the scope of this literature review. A total of 140 journal and conference articles were obtained using academic databases such as GOOGLE SCHOLAR, WEB OF SCIENCE, and SCOPUS academic databases. We narrowed and filtered it to 100 journal and conference articles depending on if the articles were written in the English language, and we also focused on studies that were peer-reviewed and not non-peer-reviewed articles. Figure 4 shows the step-by-step application of PRISMA in the literature review study.

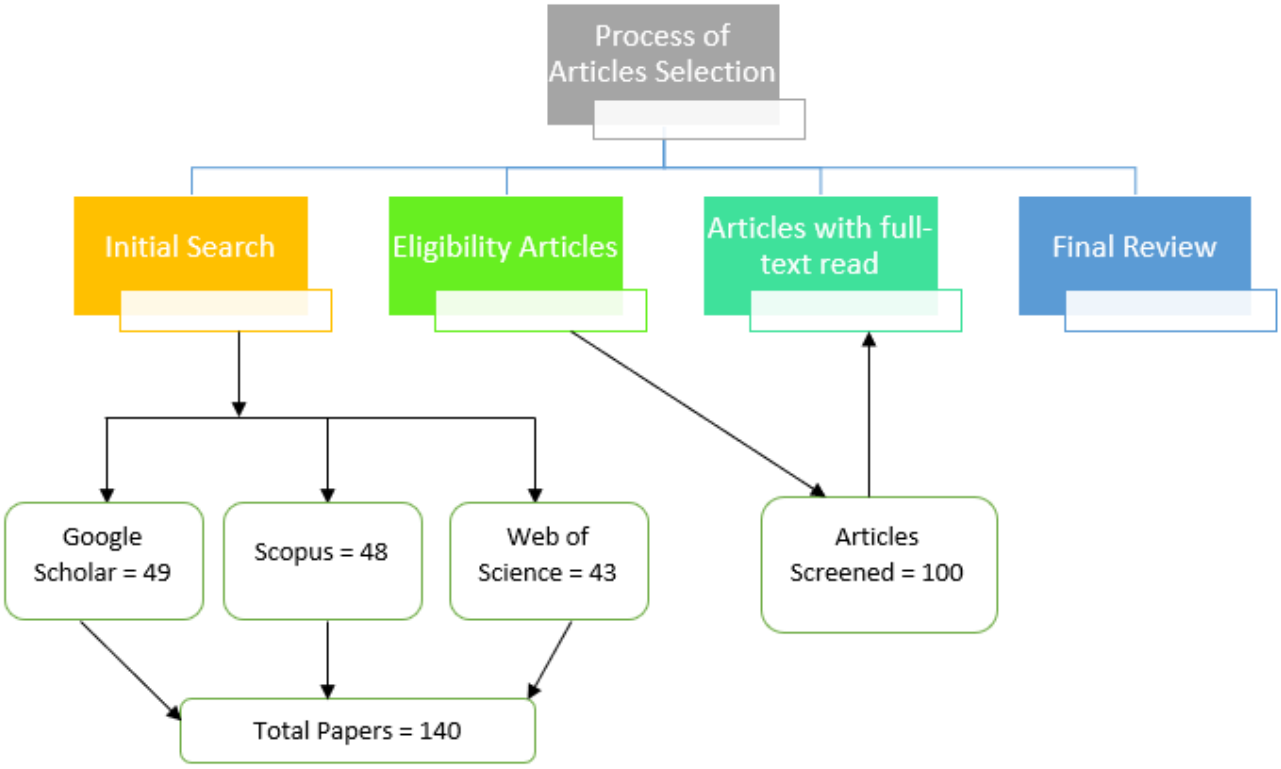

Figure 4. A PRISMA schematic diagram used in the research.

PRISMA; Identification of the Articles on Google Scholar, Scopus, and Web of Science; Screening of the articles; Eligibility of the articles to the Research; Inclusion and Exclusion Criteria

The comprehensive search was conducted by using these academic databases and applying our search keywords which are "Public road transportation" OR "COVID-19 "pandemic" OR "Physical distancing" OR "face masks") in order to identify research that is focused on the effect of the COVID-19 pandemic on public transportation. The step-

by-step stages of how the journal and conference articles are broken down are shown in Tables 1 and 2.

Table 1. Inclusion and Exclusion Techniques were used in searching for these research articles.

	Inclusion Criterion	Exclusion Criterion
1.	High peer-reviewed articles	Articles that are not peer-reviewed
2.	Original articles	Duplicate articles
3.	Articles written in English language	Articles not written in English language
4.	Possessing one or more search keywords in the abstract or keywords of the article.	Articles not having any of the search keywords in their abstract or titles.

Table 2. Compilation of the selection and inclusion of articles used in this research.

Academic Database (s)	Search Keywords	Selected Articles	Deleting Non-peer-Reviewed Articles	After Deleting Duplicated Articles	After Deleting Non-English Articles
SCOPUS	COVID-19	10	6	6	5
	pandemic	11	8	7	6
	Public road transportation	10	8	3	2
	Face masks	7	7	7	6
	Physical distancing	10	16	9	7
GOOGLE SCHOLAR	COVID-19	10	7	10	8
	pandemic	8	10	9	8
	Public road transportation	12	14	8	7
	Face masks	9	9	11	10
	Physical distancing	10	12	10	8
WEB OF SCIENCE	COVID-19	12	9	8	7
	pandemic	13	5	8	7
	Public road transportation	9	4	7	7
	Face masks	3	5	8	6
	Physical distancing	6	5	8	6
Total		**140**	**125**	**119**	**100**

Table 2 shows the tabulated format of how the articles were compiled using the inclusion and exclusion criteria based on deleting non-peer-reviewed articles, duplicated articles, and non-English articles. Figures 5–7 show the bar chart graphs of the search keywords against the number of articles used in this research. For example, from the figures below, it can be deduced that the articles containing "pandemic" were the most downloaded from the SCOPUS database.

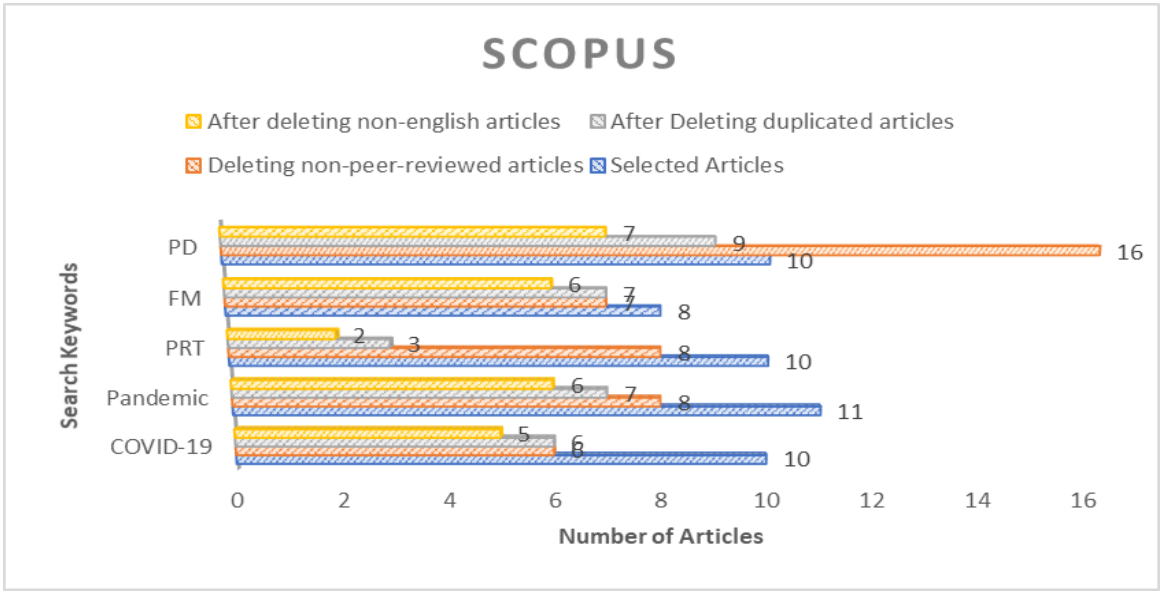

Figure 5. Scopus.

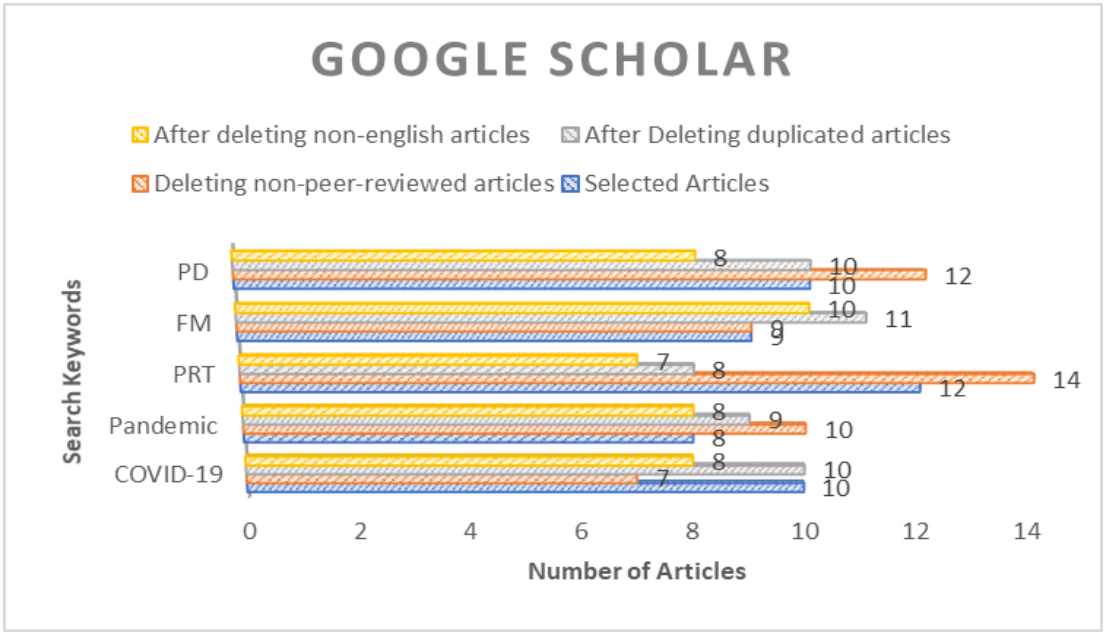

Figure 6. Google Scholar.

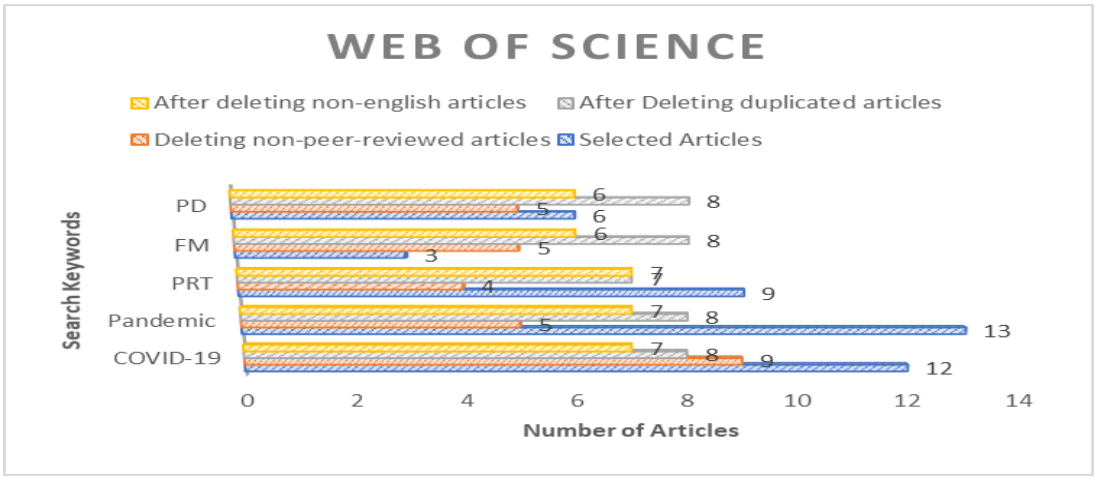

Figure 7. Web of Science. Note: PRT = Public Road Transportation. FM = Face Masks. PD = Physical Distancing.

3. The Effects of COVID-19 Pandemic and New Guidelines for Public Transportation

3.1. Physical Distancing

COVID-19 and other respiratory illnesses are spread through droplets of between 5–10 µm, and aerosols less than 5 m in size. These are exhaled by infected people while breathing, speaking, coughing, and sneezing [42]. Several authors have established airborne transmission in closed environments, even though there is still much mystery about the numerous transmission methods in which COVID-19 infection occurs [42–47]. As a result, closed environments are more dangerous than open environments when it comes to the COVID-19 virus [48,49]. Aerosols can undergo accumulation and remain infectious in closed environment air for hours [42], making public transit and the resumption of daily human activities in other closed environments the most difficult challenges during the COVID-19 pandemic. Guidance on the resumption of activities in the workplace, for example, emphasizes the importance of natural ventilation, air filtration, and employees adhering to stringent hygiene protocols, as well as the cleaning and disinfection of public surfaces, among other things [50]. Physical distancing (also known as social distancing)

has been one of the most extensively used non-pharmaceutical methods for preventing COVID-19 transmission. To limit the risk of COVID-19 transmission, the WHO recommends keeping a physical distance of at least one meter from other people [51]. Still, some health organizations recommend a physical distance of two meters [52]. COVID-19 infection is significantly reduced when people maintain at least a two-metre distance from each other [53]. Physical distancing is the most significant and consequential non-pharmaceutical preventative method to reduce the spread of COVID-19 in transportation systems for pedestrians and public transportation users [54]. Physical distancing significantly lowers the number of vehicles and public transit stations to take passengers from one point to another (Figure 8). In summary, physical distancing is incompatible with the idea of public transportation [55].

Figure 8. Physical distancing in public transit. Reprinted with permission from [56]. Published by San Jose State University Library. Copyright © 2020 SJSUL. All rights reserved.

According to current research, keeping two m from other people as a social distance measure is appropriate for outdoor activities. However, the benefits of the social distance guidelines have been debated because people still get infected even if the social distance is more than two metres [46]. A typical example of this is a bus excursion in Ningbo, China, in January 2020, where a single asymptomatic person was suspected of spreading COVID-19 to twenty-two passengers over a 100-min travel time. However, it is important to note that passengers were not wearing face masks in this scenario. According to current studies [42,57], however, it remains unknown how the probability of contagion grows as a function of the duration of exposure. This is especially important when using public transportation to clarify the inherent risks of trips. Overall, without face masks, regular cleaning, and proper air ventilation, public transportation meets all the criteria for a top viral spreader: it is a closed environment where people may be trapped for an extended amount of time. Social distancing can limit the number of persons infected in this situation; however, it will not stop the infection from spreading.

3.2. Face Masks

The use of face masks by asymptomatic people as a viral containment technique has been a divisive topic, especially during the early months of the COVID-19 pandemic [58,59]. The usage of face masks have faced a lot of public controversies such as reduced validation of their efficacy, usage abuse because of inadequate information on how to wear them ap-

propriately, and the likelihood of experiencing risky health behaviours while using masks are all arguments against recommending broad usage of face masks [59]. In the early days of the COVID-19 pandemic, the WHO suggested using face masks solely for respiratory diseases and workers in the medical field [51]. WHO updated its guidelines on 5 June 2020, recommending the application of fabric masks in public settings, including public transportation (Figure 9), and medical masks for people susceptible to respiratory diseases [60].

Following WHO's recommendation, the CDC initially suggested that the public should not wear masks in public, but this was reviewed and updated in early 2020 to recommend the usage of fabric masks in public [52], presumably as a substitute due to a surgical mask shortage [59,61] investigated the efficiency of different textiles in filtering aerosol particulates, finding that when numerous layers are employed and various types of combinations of fabrics, the level of filtration can be comparable to surgical masks. Even though many countries had reservations about using face masks, particularly in the early days of the COVID-19 pandemic, a new study reveals that face mask use is important for COVID-19 prevention. Face masks can considerably lower the quantity of infectious COVID-19 viruses in exhaled breath, especially in asymptomatic and mildly ill persons [42,43,53]. Fabric masks were shown to have a filtering capacity of more than 80% for particles smaller than 300 nm and more than 90% for particles larger than 300 nm, with certain combinations of common textiles such as cotton, silk, chiffon, and flannel [61].

Figure 9. People using face masks on a bus. Reprinted with permission from ref [62]. Published by Springer Nature B.V. Copyright © 2020 Springer Nature Ltd. All rights reserved.

The "precautionary principle" has recently been used to advocate for widespread usage of face masks during the COVID-19 pandemic, claiming that the potential benefits to public health will likely outweigh the risks) [58,59]. In the last few months, information based on epidemiological features shows that countries that have successfully halted the spread of COVID-19, such as Taiwan, Japan, Hong Kong, Singapore, and South Korea, have mandated compulsory usage of face masks in both public and indoor environments [42]. Simulation models have predicted that there is a high efficiency of prevention percentage of using face masks in the human population in decreasing the death rate caused by COVID-19 [63,64]. Because incorrectly fitted masks can impair aerosol filtering efficacy by 60%, education on proper mask use is just as important as ensuring universal face mask usage [61]. As a result, the research suggests that wearing a face mask on public transportation can be an effective strategy to prevent transmission of COVID-19, but only if the masks are appropriately fitted and handled logically. A campaign to promote the use

of face masks must ensure that appropriate face masks are inexpensive and that people are well-informed on how to use them. Although eye protection devices minimize the risk of COVID-19 infection [53], their use for public transport passengers has not been enforced.

3.3. Proper Hygiene, Regular Sanitization, and Open Ventilation

Regarding adequate hygiene and improved levels of cleaning, it has been discovered that COVID-19 infections can last longer than anticipated, albeit on various types of surfaces such as plastic and steel [65,66]. Therefore, having contact with physical surfaces that have been exposed to the COVID-19 virus is a likely carrier of the COVID-19 spreader. This means that public transportation and bus stations' regular cleaning of public surfaces is a proposed preventive solution. The sanitization of public transportation has been widely acknowledged worldwide depending on the different types of stages of intensity based on the availability of resources. Some countries' regulations on COVID-19 already advised pedestrians and motorists to make sure that they sanitize potentially infected surfaces and dressing and meeting room surfaces, not excluding management offices [30,67]. Aggressive investigations on these cogent guidelines in public transportation systems are seriously inadequate. During Post COVID-19 lockdown, it is important to have personal hygiene protection equipment and materials in public and office places to safeguard staff and motorists and also improve their confidence in using public transportation systems for their day-to-day activities, even though the risk of being infected is at an elevated level [30]. Appropriate and useful information needs to be provided to motorists and pedestrians, including the conduct of hygiene, the appropriate ways to use a face mask in public, and what to do when a passenger exhibits COVID-19 symptoms [67].

What is still undetermined is whether an air conditioner can escalate the spread of COVID-19 in a closed outdoor environment or spread using recirculated air in closed ventilation. Insufficient evidence suggests that air conditioners are a super spreader of COVID-19 in indoor activities such as open mic bars and hotels [68]. The US Centres for Disease Control and Prevention (CDC) has suggested that air conditioners should be applied in an environment that uses non-recirculation of air [69]. Regular ventilation in closed places is usually recommended, especially in public spaces like bus stations, as a preventive measure for COVID-19 [47,57,69]. These preventive measures are imperative to public motorists who spend several minutes with people inside public vehicles. However, suppose there are inadequate precautionary measures in public transportation systems. In that case, the efficient air flow of ventilation for public buildings should be adhered to, usually around ten persons, which means litre/seconds/person of ventilation air excluding recirculation; this was stated by the United Kingdom Government [57].

4. The Challenges of COVID-19 Infections on the Socio-Economic Aspects of Public Transportation

4.1. Financial Implications

During the early days of the COVID-19 pandemic, the virus spread rapidly in a matter of days, becoming the largest socio-economic crisis for public transportation systems in more than 20 years. The drastic decline in the use of public transportation systems due to COVID-19 has been compounded by high expenses because of new cleaning hygiene regimens. Due to these circumstances, many public transportation institutions, both public and private, have faced financial hardship, leading to pressure on governments. Due to the COVID-19 pandemic, the biggest US public transportation institution (the New York Metropolitan Transportation Authority) asked the US government for a bailout totalling about four billion dollars ($) [70].

In some South American countries like Chile, the Chilean government came out with a package to compensate operators of the public sectors in Santiago for the financial loss they incurred during COVID-19 [71]. In Europe, the Netherlands came out with a financial package of up to €1.5 billion to soften the financial impact of COVID-19 on the Dutch Railway System and the major public transportation stations in the three most developed

and congested cities, Amsterdam, the Hague, and Rotterdam [72]. In addition to this, the Swedish Government spent 3 billion SEK to compensate for the nation's losses incurred in the reduction of prices of public transit tickets [73]. Another significant problem most public transportation organizations face is the inability to secure funds from the government; this is due to the decimation of so many countries' economies due to the impact of COVID-19. This has led to inadequate funding from governments because of the competition from other socio-economic sectors also requiring financial assistance from the government.

With regard to the payment of public transit fares, new regulations and guidelines for public transportation usage may have detrimental effects on revenue reduction. Principles such as requiring mandatory boarding using the rear door can be suggested to reduce and eliminate physical contact between pedestrians and drivers if drivers are not separated physically from their commuters. This principle has been applied in major metropolises since 2020, like Santiago in Chile, Montreal in Canada, and some parts of Holland. However, in public transportation systems that are dependent on commuters entering the bus from the front door to pay their fare, this can lead to enormous financial implications, for example forcing non-payment bus rides. Also, further problems such as the conventional bus ticket checking of commuters if they hold a genuine bus ticket might not be feasible due to the increased likelihood of being infected by COVID-19 [30]. This problem may increase transport fare evasion if no optional transportation fare payment is feasible.

The most striking problem to be experienced by public transportation operators is primarily because of the decrement in demand and the consequences of financial bankruptcy if they are not bailed out financially by the government. Some developed and developing countries may have the financial capacity to bail out their public transportation systems. Unfortunately, the majority of developing countries do not have that capability. It might be due to inadequate regulations regarding public transportation and poor public hygiene on these systems. Most of the time, the ability of the driver to earn more money depends on the number of commuters they can carry in a day [74,75]. The financial implications of such a general framework and the people pertaining to such framework are primarily dependent on the COVID-19 pandemic being over.

4.2. Differences in Social Equities

COVID-19 has exposed a fundamental difference between jobs that attract high salaries and those with lower salaries. For example, during the early months of the pandemic, most people working in jobs with a higher salary were privileged to have access to remote working situations, as reported in countries such as the United States [76], Canada [77], and Chile [78,79]. According to recent research, surveys carried out based on data obtained from twenty thousand questionnaires in developed countries such as the United Kingdom and the United States [80] concluded that high school certificate workers and the female gender are more affected by the pandemic in the employment market. According to documented reports from *The Economist*, COVID-19 has been projected to further expose the disparities and gaps between developed and developing nations in recovering from the COVID-19 pandemic [81].

COVID-19 has exposed the gap between social integration and social segregation and highlights the need for more Government or private organizations efforts to make public transportation a synergy between the social integration of intelligent transportation systems in public transportation. Due to the pandemic, people have neglected public transit usage for their day-to-day activities. However, this neglect only applies to people with high-income jobs. Recent research was carried out by comparing data collected before and during the COVID-19 pandemic in one of the developed cities, Santiago. This research concluded that there is an increment in the number of people living in high salary earner households that have abandoned the usage of public transit usage due to the fear of being infected by the COVID-19 virus. This cause-and-effect led to a drastic fall in public transportation usage to about 30%, not to exclude the reduction in public transportation system usage by people from high salary earning families by more than 80% [82]. These

figures validate the statement that people who stopped using public transportation systems during the pandemic have alternatives to choose from, such as remote working. Instead of going to the market, they can afford other public transportation alternatives such as ride-hailing, private vehicle ownership, and shopping on online marketplaces. At the same time, those individuals that continue using public transportation tend to be from low-income households. This disparity in travel behavior between various social groups is bound to continue during this pandemic unless drastic steps are taken to address the social equities in public transportation.

4.3. Sustainable Mobility

The drastic decrease in the use of public transportation in recent years due to the physical distancing introduced by so many countries to curb the spread of the COVID-19 virus and the fear of passengers in been infected with the virus has exposed future research questions around the sustainability of transportation options and intelligent transportation systems in many major cities in both developing and developed countries. Developing a sustainable plan that will address these issues during the COVID-19 pandemic and the post-COVID-19 era requires systematic, well-coordinated efforts from transportation researchers, public transportation organizations, urban planners, and pedestrians. The primary aim is to ensure that the safety of travellers and drivers in public transportation is assured so that commuters who have no other viable options for public transportation can be accommodated.

A real-life scenario will be if buses and trains are not filling up at an increasing rate compared to before COVID-19. The socio-economic effectiveness of most countries will be severely affected. The only soft landing would be to provide sustainable mobilities to lower-earning income households due to having only public transportation as a viable alternative. Furthermore, due to physical distancing and public transit occupancy guidelines being introduced to curb the spread of COVID-19, there has been a drastic reduction in passengers occupancy in public transportation. This has been evident in major European cities (Copenhagen, Brussels, Paris, and Berlin), Asia (Seoul and Tokyo), and some countries in Southern and Northern Africa.

5. The Solutions: Policy Directions and Research Guidelines

This section discusses the policies and research outlines that need to be created, developed, and applied to address the questions and research gaps associated with COVID-19 in public transportation systems.

5.1. Public Health Measures to Consider in Transportation Planning and Control in COVID-19 Pandemic

5.1.1. Integrating Public Health Measures into Service Planning

The transportation of commuters in public transit where individuals are prone to share the same transit facilities and public vehicles is likely susceptible to spreading COVID-19 if proper prevention guidelines are not adhered to. This is especially true for public transportation systems where many commuters with different backgrounds and places are moving from one place to another in a crowded public place. The primary question is what kind of preventive measures the public transportation organizations can come up with to minimize the spread of COVID-19 and mitigate the risks related to public health when it comes to contagion. Even though it causes uneasy feelings among stakeholders in the public transportation sector, societies still have the responsibility of protecting commuters' health. Although it has associated risks, especially since it is related to choosing moral choices, it is still novel in the transportation sector, as stated by [83].

5.1.2. Introduction of Social Distancing in Public Transportation

At the peak of the COVID-19 pandemic, there was a consensus worldwide that public transportation should not be used unless necessary. However, as the public transportation

systems resumed in various countries, they introduced physical distancing to mitigate the risk of the virus spreading among passengers. The limited research materials in these areas do not offer conclusive evidence on the impact of physical or social distancing in environments that have closed ventilation in public transportation layouts. Evidence is limited to support the significance of physical distancing in public transportation. Suppose some non-medical preventive measures are taken into consideration. In that case, an example is that face mask usage improved personal hygiene or, in extreme cases, the elimination of talking in public gatherings. However, it has been proven that COVID-19 can be spread in closed ventilation even if a physical distance of two meters is enforced [46], and this has been explained further in epidemiological research studies [42,45,84]. In addition, there is a probability of COVID-19 being transmitted if a face mask is not always worn. Physical distancing can be effective if there is an infected person in the environment by reducing the number of infections in the locality. Furthermore, it has been proven in recent epidemiological studies that face masks can be efficient in drastically reducing the transmission of COVID-19 [42,43,53].

Most public transportation networks are dependent on attracting large occupancies to generate revenue while adhering to the spacing between passengers by using the 2 m of physical spacing. Evidence has demonstrated that wearing masks reduces the transmission rate of COVID-19 from research using Japan as a case study. In Japan, it was discovered that many COVID-19 transmissions occurred in restaurants and bars and gym classes; no evidential COVID-19 infection was caused in public transportation. This is evident in the conclusion that having a close discussion with people in public transportation is not shared. It has been proven by virologist Hitoshi Oshitani based on his experimental findings [85]. This research results have made Singapore come out with a decision that affects public transportation in that country by stating that everybody must wear masks and avoid making conversation inside public buses unless necessary. This is different from what western countries are enforcing, such as physical distancing. Although the increase in health safety from the usage of face masks is enormous, it has not been validated how public transportation is safer if commuters wear various types of facemasks such as cloth-made masks and N95 ones.

This situation is important when it comes to appropriate occupancy levels for public transportation. This aspect is crucial to the socio-economic and operational implications of COVID-19 on a country's public transportation system. When rephrased differently, it means that if the ideology of two meters physical distancing does not prevent the spread of COVID-19 just because people do not wear a face mask, then the research question been asked is 'what is the maximum number of commuters a public transportation bus should adhere to, if all commuters are wearing a face mask?' The present reality in developed cities in Asia (Tokyo and Seoul) has proven that enforcing physical distancing of 1 metre with compulsory face masks is the right way to prevent the spread of the virus. However, the prevalence of the transmission of the virus in these places has not been proven. The rapid development of such a preventive approach to public transportation usage without enforcing stringent guidelines of physical distancing should be closely studied to clarify the rudiments of the conditions that would permit such replication in developed countries.

It is important to point out that there is a scarcity in the amount of research related to the transmission and infection of COVID-19 in public transportation and the prevention approaches that can be used to curb it. However, we believe there will be enough research in the next few years on this aspect of COVID-19 prevention. The issue related to the new maximum number of commuters in public transit because of physical distancing is a multifaceted issue reliant on the application of face masks, clean hygiene, adequately ventilated closed environments, and proper sanitation rules. However, conditions could change depending on if the commuters correctly adhered to the proper usage of face masks. Therefore, below are the assumptions we concluded based on the present-day reality when it comes to physical distancing in some developing and developed countries.

5.2. Comparison between Service Efficiency and Robustness in the Case of the COVID-19 Pandemic

As evident in these times of COVID-19 pandemic, the connection between different modes of transportation is not only crucial. It is a stepping stone that can build the interrelationship to exchange creative ideas and services; however, it can also motivate adversity; a typical example is the COVID-19 pandemic. The robustness of a system is determined by its capability to experience shock and recover functionality. The availability of public transportation in these times of pandemic is dependent on the trade-offs that occur between effectiveness, such as the availability, ease of use, and services offered, and robustness, which involves the health hazards related to moving from one point to another via public transit, and efficiency, which comprises the overall number of resources required for the supply of services.

There is usually conflict between robustness and efficiency. This is due to the latter being dependent on reserves and more considerable margin designs, indicating redundancy under appropriate circumstances. This is especially important due to the already negative financial implications that various public transportation organizations have experienced in the case of adhering to physical distancing guidelines and reducing the capacity of the standard of public transportation. The comprehensive solutions will comprise of lack of efficiency from the angle of the public transportation operator; however, it also involves ineffectiveness since it resulted in the disintegration of public transportation services because of less frequency and thus includes longer waiting times in public transportation systems in the post-COVID-19 era.

5.3. Evaluating the Resilience of Public Transportation Systems and Their Capability to Ensure Functionality

Due to the significance of public transportation systems as significant transportation infrastructure and their importance to the movement of goods and services (Homeland Security 2010), it is crucial to create measures to curb the effects of the COVID-19 pandemic in public transportation networks while ensuring their objectives as a significant branch of road transportation systems. There is a model created by Mc Daniels (2008) that is also known as the bathtub model. This model was developed to create a foundational conceptual framework for evaluating the evolution of the performance of a system in case there is a disruption in the system. In the case of public transportation networks, transportation network performance is determined by the original capacity provided, the overall number of commuters moved from one location to another, and the overall loss of time accumulated when there is a disruption in the transportation of commuters.

The conceptual framework and evaluative analysis and the never say die attitude of public transportation networks during this pandemic has been chiefly directed towards the supply of transportation and the ease of accessibility of commuters, not excluding their connectivity [86,87]. The COVID-19 pandemic has caused a disruptive shock to the transportation systems, which has led to a drastic reduction in the system performance of public transportation with adverse effects on its primary responsibilities. However, some countries worldwide are presently witnessing distinct types of recovery from the COVID-19 pandemic. The period of recovery has experienced an elevated increase in the system performance of public transportation, even though there is no obligation that:

- The recovery of the transportation systems will adhere to a monotonic structure, with drawbacks such as additional restrictive measures due to the third and fourth waves of the COVID-19 pandemic.
- Public transportation networks will return to their status-quo, i.e., return to the pre-COVID-19 era. This highlights the need for the creation of conceptual frameworks and approaches to investigate the resilience of the public transportation networks while considering its effects on public health considering the ease of usage, passengers' equity, and the sustainability of public transportation systems.

5.4. Evaluating the Spread of COVID-19 in Public Transportation

It is significant to understand and have clarity on the spread of COVID-19 in public transportation systems. This knowledge will assist urban planners and transportation researchers in evaluating the challenges and solutions to reduce or eliminate the adverse effects the virus is having on public health. There is an urgent need to find the solution to this transportation problem by developing or creating applicable transportation and epidemiological models that can analyze the COVID-19 pandemic curves and their spatial adverse effects on the health of passengers [88,89]. Their work came up with a contact network that reflects the set of commuters an individual might have met in public transit. The transportation model they developed will assist transportation researchers with travel demand in transportation networks. The output used in the research can be applied in the epidemiological model, which is further applied in updating the segment states of the population of the travel demand of commuters.

In this research, they characterized individual commuters as either (a) not infected and not susceptible; (b) infected and travelling frequently in public transit; (c) passenger is quarantined and not travelling; and (d) the passenger is immune to COVID-19and is using public transportation again. The demand for commuters can then be reallocated to the transportation network to evaluate the evolution of the COVID-19 pandemic and obtain a significant performance index such as the number of commuters that have been infected by COVID-19 or the number of days in the week required to eliminate the increase in the number of new COVID-19 cases. However, it is important to evaluate individual commuters' trajectories and the crowding level in public transit. Researchers such as [90] stated in their working paper that this could be achieved by applying comprehensive intelligent card information. They concluded from their research that each commuter undergoes a sort of life changing experience during their journey on public transit and the probability that a passenger is sitting closer to someone infected by the COVID-19 virus is high.

5.5. Implementation of Contact Tracing to Curb the Spread of COVID-19 in Public Transportation

To curb the spread of the COVID-19 virus among people, it is important that more COVID-19 testing is implemented in various public hospitals and health care centres, and faster and more efficient diagnoses should be the primary objective of medical practitioners in reducing the likely spread of the COVID-19 virus in public transportation. By implementing all of this, the number of infected passengers in public transit will be reduced drastically, thereby leading to a safe, healthy environment for other passengers that rely on public transportation for their day-to-day activities. Also, contact tracing of passengers that have been infected or have been in the proximity of another passenger with COVID-19 can reduce the exposure period of COVID-19 and prevent the further spread of the COVID-19 virus in public transportation networks. Various governments have implemented contact tracing application software, and it is also about to be implemented in some developing countries. Using public transportation as a case study, the validation of smart card data applications in contact tracing has been researched by [90]. They used the Washington DC Metro system as their location of study. They collect traffic information on fare data because it gives a clearer picture of research on contact tracing and encourages the identification of contact tracing networks depending on the trajectories of commuters. In public road transportation systems that needed card tap-in only (countries such as Australia and Finland) and offer station-dependent transportation services. The usage of a lightning station and vehicle inference techniques will be significant.

6. Discussions

Pandemics are more severe and cause more deaths when compared to other pathological medical viruses or diseases. pandemics comprise different types of health challenges and devastating occurrences. Since the Second World War, the world has not experienced any global health challenges as severe as the COVID-19 pandemic. SARS-CoV-2 occurred in

the early 21st century. The SARS-CoV-2 can be defined as an elevated fundamental number of reproductions. It comprises a specific route of droplet-borne air that can be transmitted by air and is severely contagious to human beings. However, because of no prior experience on how the COVID-19 virus spreads or how it can be controlled to a minimum level, coupled with the unavailability of vaccines that can curb the spread of the COVID-19 virus among humans, the COVID-19 pandemic has led to a lot of human fatalities. Many people become prone to SARS-CoV-2, which led to the decision taken by the WHO and other healthcare organizations in emphasizing social distancing of at least 2 m in public spaces and on public transportation, the consistent use of face masks outdoors, and self-quarantine as a form of protective measures against COVID-19. The WHO put these health policies to reduce COVID-19 infections before a vaccine is manufactured. Also, it is important to note that during the height of the COVID-19 pandemic, many countries enforced a strict lockdown policy for major cities to reduce the number of COVID-19 fatalities and infections. Even though the introduction of strict lockdowns reduces the spread of COVID-19, it has severely affected the socio-economic sector of most developing and developed countries (such as with high unemployment rates and increase in the price of food).

The WHO has stated that it is important for all countries to continue to ensure that health policies and guidelines that will continue to reduce or slow the spread of the COVID-19 virus are implemented. The health measure of partial and complete lockdowns has still been implemented in Asian countries such as China and Hong Kong. But countries such as South Africa, Canada, the United Kingdom, and the United States of America have partially or completed stopped their lockdowns and even decided not to make face masks compulsory in public transportation spaces as long as one has received the two doses of the Pfizer vaccines or the one dose of the Johnson & Johnson vaccine.

Furthermore, passengers who use public transit regularly for their international and local travels must spend some time in isolation depending on the country they are travelling to. Some countries like the United Kingdom require seven days, while some are 14 days. A report stated that during the height of the COVID-19 pandemic there was a 70% reduction in people that used air transportation due to various countries' total lockdowns, especially in early 2020 (BBC news report, 2020). Also, with the restriction placed on public transportation, there has been a reduction in public gatherings of any kind. Some African countries deployed military personnel to enforce their lockdowns, and these actions were condemned by the United Nations and various humanitarian NGOs.

This period of the COVID-19 pandemic has significantly affected public transportation. The steady fall in demand for public transit has been shown to be due to the passengers' perceptions of being infected with the virus. However, the silver lining about the impact of the COVID-19 pandemic on public transportation has been the drastic reduction in public transit fatalities on the road, the reduction or non-existence of traffic congestion such as recurrent or non-recurrent [91,92] on freeways and road intersections that are usually busy in pre-COVID-19 pandemic, and the sharp fall in the prices of public transit tickets due to lower demand for it. A typical example of this is the City of Budapest which witnessed an enormous 90% reduction in the demand for public transportation and an astonishing 50% decline in road traffic congestion caused by public transportation. Major European countries like Italy, Switzerland, and Germany experienced a drastic reduction in registration for public transit operations by public transport operators due to low demand for public transportation services in 2020.

Scientifically, before the COVID-19 vaccine was developed, appropriate methods that could create strong health guideline decisions on public transportation systems were substandard. Thus, even after most developed and developing countries lift their strict lockdown rules, it is advisable that physical distancing should still be enforced on public transit, and more efforts should be directed into creating more commuters' vehicles. Also, the government must introduce strict rules for mass gatherings and traffic controls on busy freeways and road intersections. Measures should be taken to ensure that ride-hailing services such as Uber and Taxify are mandatory. Transportation engineers and urban

planners should encourage various governments to ensure that transportation industries are compensated for experiencing enormous financial loss during the losses resulting from the COVID-19 pandemic.

Novel research methodologies and government health policies need to focus on short and enforced lockdowns of COVID-19 hotspots in major cities. Appropriate and adequate personal protective equipment should be provided for the passengers in public transportation systems. And the various governments should focus on stopping disinformation about the COVID-19 vaccines and promote media coverage on the advantage of taking the vaccines. Another effective solution to stopping the spread of COVID-19 in public transportation would be to encourage working from home policies. This will reduce the usage of public transit by employers and allow them to work from the comfort of their homes without the fear of being infected with the virus.

Most developed countries are experiencing issues when enforcing the use of face masks in public places. Various individuals and NGOs have sued countries like the United Kingdom and the United States of America over the mandatory use of face masks in public spaces. They argued that the government infringed on their rights, including that to free movement. The only way to tackle this issue is for various governments of these countries to increase awareness of the usefulness of face masks in preventing the spread of COVID-19. Furthermore, more efforts should be directed towards creating and improving research on COVID-19 to discover scientifical-proven and appropriate ways of developing new health policies that can be applied in public transportation systems and that can be used to improve the psychological and physical wellbeing of commuters.

7. Conclusions and Recommendations

The main goal of the current study was to give an overview of how the COVID-19 pandemic has adversely affected public transportation systems and to focus on challenges and solutions. This study focused on evidence from the last three years (2019–2021) on the influence of various features on reducing the spread of the COVID-19 virus. The following conclusions can be drawn from the present literature review:

- The study has shown that the COVID-19 pandemic has significantly and negatively impacted the public's perceptions towards public transportation, especially when it comes to the physical distancing enforced by various countries in stopping the spread of the virus on public transit systems.
- The relevance of using face masks is supported by the current research on the spread of COVID-19. However, NGOs and individuals resist using it in public spaces (malls, supermarkets, and schools). This can negatively affect the government's intervention to stop the virus's spread in public transportation.
- One of the most significant findings to emerge from this study is that the government needs to provide special funds for public transportation operators in coping with the aftermath effect of the COVID-19 pandemic on the demand and supply of public transportation systems. Most operators of public transportation have been severely ruined financially due to lockdowns enforced by various countries during the beginning of the pandemic and not excluding countries such as China and Hong Kong that are still enforcing strict lockdowns to stop the spread of the virus.
- The second significant finding was that the response of developing countries (primarily African countries) during the COVID-19 pandemic has been poor. The lack of creating actionable awareness by African countries regarding the COVID-19 vaccine has been average or not even non-existent.
- In general, therefore, there seems to be a significant paradigm shift in the usage of public road transportation amenities. This has changed the way commuters view public transportation due to the fear of being infected by the COVID-19 pandemic. Currently, most passengers even try not to sit too close to another passenger because of the fear of being infected by the virus.

- Finally, it is important to note that a significant risk is looming over public road transportation systems. These risks can be viewed from the perspective of inadequate transitioning into the physical distancing inside public transportation and the government's inability to address the negative effects of the COVID-19 pandemic on public transportation, both financially and sustainability.

7.1. Recommendations

- It would be interesting to evaluate the effects of the COVID-19 pandemic on the traffic flow of vehicles, bicycles, and motorbikes before, during, and after the pandemic, focusing on road intersections and freeways.
- Further research could assess the long-term effects of the COVID-19 vaccines on the physical well-being of drivers and passengers in public road transportation networks.

7.2. Limitations

- The reader should bear in mind that the study is based on the keywords used in the search for journal articles and that these keywords might have omitted some appropriate journal articles needed for this research.
- The author's unintentional personal bias could have influenced the findings of this literature review.

Author Contributions: The authors confirm contribution to the paper as follows: study conception and design: L.K.T., A.G.S., T.C. and I.O.O.; data collection: I.O.O., T.C., A.G.S. and L.K.T.; analysis and interpretation of results: I.O.O., L.K.T. and A.G.S.; draft manuscript preparation: I.O.O., L.K.T., T.C. and A.G.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Approval for the study was not required in accordance with local/national legislation.

Informed Consent Statement: Approval for the study was not required in accordance with local/national legislation.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Park, S.-J.; Lee, K.-T.; Im, J.-B.; Kim, J.-H. The Need for Smart Architecture Caused by the Impact of COVID-19 upon Architecture and City: A Systematic Literature Review. *Sustainability* **2022**, *14*, 7900. [CrossRef]
2. Cruz, C.O.; Sarmento, J.M. The impact of COVID-19 on highway traffic and management: The case study of an operator perspective. *Sustainability* **2021**, *13*, 5320. [CrossRef]
3. Strielkowski, W.; Zenchenko, S.; Tarasova, A.; Radyukova, Y. Management of Smart and Sustainable Cities in the Post-COVID-19 Era: Lessons and Implications. *Sustainability* **2022**, *14*, 7267. [CrossRef]
4. British Asia News. An Article about: Beijing Orders 14-Day Quarantine for All Returnees. Available online: https://britishasianews.com/beijing-orders-14-day-quarantine-forreturnees/ (accessed on 24 March 2020).
5. Campisi, T.; Basbas, S.; Skoufas, A.; Akgün, N.; Ticali, D.; Tesoriere, G. The impact of COVID-19 pandemic on the resilience of sustainable mobility in Sicily. *Sustainability* **2020**, *12*, 8829. [CrossRef]
6. Li, Q.; Guan, X.; Wu, P.; Wang, X.; Zhou, L.; Tong, Y.; Ren, R.; Leung, K.S.; Lau, E.H.; Wong, J.Y.; et al. Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. *N. Engl. J. Med.* **2020**, *382*, 1199–1207. [CrossRef] [PubMed]
7. Egypttoday. Egypt Announces First Coronavirus Infection. Available online: https://www.egypttoday.com/Article/1/81641/Egypt-announces-first-Coronavirus-infection (accessed on 14 March 2020).
8. Boulos, M.N.K.; Geraghty, E.M. Geographical tracking and mapping of coronavirus disease COVID-19/severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) epidemic and associated events around the world: How 21st century GIS technologies are supporting the global fight against outbreaks and epidemics. *Int. J. Health Geogr.* **2020**, *19*, 1–12.
9. WHO. *Statement on the Second Meeting of the International Health Regulations (2005) Emergency Committee regarding the Outbreak of Novel Coronavirus (2019-nCoV)*; WHO: Geneva, Switzerland, 2020.
10. Tirachini, A.; Cats, O. COVID-19 and public transportation: Current assessment, prospects, and research needs. *J. Public Transp.* **2020**, *22*, 1. [CrossRef]

11. Elhenawy, Y.; Hafez, G.; Abdel-Hamid, S.; Elbany, M. Prediction and assessment of automated lifting system performance for multi-storey parking lots powered by solar energy. *J. Clean. Prod.* **2020**, *266*, 121859. [CrossRef]
12. Elbany, M.; Elhenawy, Y. Analyzing the ultimate impact of COVID-19 in Africa. *Case Stud. Transp. Policy* **2021**, *9*, 796–804. [CrossRef]
13. Milken Institute. Data and Charts. Available online: https://covid19africawatch.org/data-andcharts/ (accessed on 12 December 2021).
14. Asweto, C.O.; Onyango, P.O.; Alzain, M.A.; Wang, W. Effects of increased residential mobility and reduced public spaces mobility in containing COVID-19 in Africa. *J. Glob. Health Rep.* **2020**, *4*, e2020075. [CrossRef]
15. Le, N.; Le, A.V.; Brooks, J.P.; Khetpal, S.; Liauw, D.; Izurieta, R.; Reina Ortiz, M. Impact of government-imposed social distancing measures on COVID-19 morbidity and mortality around the world. *Bull. World Health Organ.* **2020**, *10*, 1–20.
16. Severino, A.; Pappalardo, G.; Curto, S.; Trubia, S.; Olayode, I.O. Safety Evaluation of Flower Roundabout Considering Autonomous Vehicles Operation. *Sustainability* **2021**, *13*, 10120. [CrossRef]
17. OECD Policy Responses to Coronavirus (COVID-19). Making the Green Recovery Work for Jobs, Income and Growth 2020. Available online: https://www.oecd.org/coronavirus/policy-responses/making-the-green-recovery-work-for-jobs-incomeand-growth-a505f3e7/ (accessed on 14 March 2020).
18. Cartenì, A.; di Francesco, L.; Martino, M. The role of transport accessibility within the spread of the Coronavirus pandemic in Italy. *Saf. Sci.* **2021**, *133*, 104999. [CrossRef]
19. Basbas, S.; Campisi, T.; Georgiadis, G.; Al-Rashid, M.A.; Tesoriere, G. COVID-19 and public transport demand trends in Sicily: Analyzing external factors and governmental recommendations. *Eur. Transp. Trasp. Eur.* **2021**, *83*, 1–15. [CrossRef]
20. Campisi, T.; Tesoriere, G.; Trouva, M.; Papas, T.; Basbas, S. Impact of Teleworking on Travel Behaviour during the COVID-19 Era: The Case Of Sicily, Italy. *Transp. Res. Procedia* **2022**, *60*, 251–258. [CrossRef]
21. Welle, B.; Avelleda, S. Safer, More Sustainable Transport in a Post-COVID-19 World. Available online: https://www.wri.org/insights/safer-more-sustainable-transport-post-covid-19-world (accessed on 23 April 2020).
22. Basbas, S.; Georgiadis, G.; Campisi, T.; Tesoriere, G. Factors Influencing Public Transport Demand in Sicily During COVID-19 Era: A Study of Commuters' Travel and Mode Choice Behaviors. In *International Conference on Computational Science and Its Applications*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 339–353.
23. Carlitz, R.D.; Makhura, M.N. Life under lockdown: Illustrating tradeoffs in South Africa's response to COVID-19. *World Dev.* **2021**, *137*, 105168. [CrossRef]
24. Africa CDC. Available online: https://africacdc.org/ (accessed on 14 March 2020).
25. IIAG. Report COVID-19 in Africa: Data and Analysis. Available online: https://mo.ibrahim.foundation/covid-19 (accessed on 14 March 2020).
26. Du Toit, A. Outbreak of a novel coronavirus. *Nat. Rev. Microbiol.* **2020**, *18*, 123-123. [CrossRef]
27. Xu, S.; Li, Y. Beware of the second wave of COVID-19. *Lancet* **2020**, *395*, 1321–1322. [CrossRef]
28. Anderson, R.M.; Heesterbeek, H.; Klinkenberg, D.; Hollingsworth, T.D. How will country-based mitigation measures influence the course of the COVID-19 epidemic? *Lancet* **2020**, *395*, 931–934. [CrossRef]
29. Lewnard, J.A.; Lo, N.C. Scientific and ethical basis for social-distancing interventions against COVID-19. *Lancet Infect. Dis.* **2020**, *20*, 631–633. [CrossRef]
30. UITP. COVID-19 Pandemic—Resuming Public Transport Services Post-Lockown. Available online: https://www.uitp.org/sites/default/files/cck-focus-papers-files/Knowledge_Brief_-_Covid19_0.pdf (accessed on 30 May 2020).
31. Ibarra-Rojas, O.J.; Delgado, F.; Giesen, R.; Muñoz, J.C. Planning, operation, and control of bus transport systems: A literature review. *Transp. Res. Part B: Methodol.* **2015**, *77*, 38–75. [CrossRef]
32. Iliopoulou, C.; Kepaptsoglou, K.; Vlahogianni, E. Metaheuristics for the transit route network design problem: A review and comparative analysis. *Public Transp.* **2019**, *11*, 487–521. [CrossRef]
33. Olayode, O.I.; Tartibu, L.K.; Okwu, M.O. Application of Adaptive Neuro-Fuzzy Inference System Model on Traffic Flow of Vehicles at a Signalized Road Intersections. In Proceedings of the ASME 2021 International Mechanical Engineering Congress and Exposition, Virtual, 1–5 November 2021; Volume 9. Engineering Education, V009T09A015.
34. Olayode, I.; Tartibu, L.; Okwu, M.; Uchechi, U. Intelligent transportation systems, un-signalized road intersections and traffic congestion in Johannesburg: A systematic review. *Procedia CIRP* **2020**, *91*, 844–850. [CrossRef]
35. Isaac, O.O.; Tartibu, L.K.; Okwu, M.O. Prediction and Modelling of Traffic Flow of Human-driven Vehicles at a Signalized Road Intersection Using Artificial Neural Network Model: A South Africa Road Transportation System Scenario. *Transp. Eng.* **2021**, *6*, 100095.
36. Rowley, J.; Slack, F. Conducting a literature review. *Manag. Res. News* **2004**, *27*, 31–39. [CrossRef]
37. Brereton, P.; Kitchenham, B.A.; Budgen, D.; Turner, M.; Khalil, M. Lessons from applying the systematic literature review process within the software engineering domain. *J. Syst. Softw.* **2007**, *80*, 571–583. [CrossRef]
38. Bask, A.; Rajahonka, M. The role of environmental sustainability in the freight transport mode choice: A systematic literature review with focus on the EU. *Int. J. Phys. Distrib. Logist. Manag.* **2017**, *47*, 560–602. [CrossRef]
39. Bramer, W.M.; Rethlefsen, M.L.; Kleijnen, J.; Franco, O.H. Optimal database combinations for literature searches in systematic reviews: A prospective exploratory study. *Syst. Rev.* **2017**, *6*, 245. [CrossRef]
40. Lam, R.W.; Kennedy, S.H. Using metaanalysis to evaluate evidence: Practical tips and traps. *Can. J. Psychiatry* **2005**, *50*, 167–174. [CrossRef] [PubMed]

41. Mallett, R.; Hagen-Zanker, J.; Slater, R.; Duvendack, M. The benefits and challenges of using systematic reviews in international development research. *J. Dev. Eff.* **2012**, *4*, 445–455. [CrossRef]
42. Prather, K.A.; Wang, C.C.; Schooley, R.T. Reducing transmission of SARS-CoV-2. *Science* **2020**, *368*, 1422–1424. [CrossRef]
43. Leung, N.H.; Chu, D.K.; Shiu, E.Y.C.; Chan, K.H.; McDevitt, J.J.; Hau, B.J.; Yen, H.L.; Li, Y.; Ip, D.K.; Peiris, J.S.; et al. Respiratory virus shedding in exhaled breath efficacy of face masks. *Nat. Med.* **2020**, *26*, 676–680. [CrossRef] [PubMed]
44. Han, Q.; Lin, Q.; Ni, Z.; You, L. Uncertainties about the transmission routes of 2019 novel coronavirus. *Influenza Other Respir. Viruses* **2020**, *14*, 470. [CrossRef]
45. Morawska, L.; Cao, J. Airborne transmission of SARS-CoV-2: The world should face the reality. *Environ. Int.* **2020**, *139*, 105730. [CrossRef]
46. Shen, Y.; Li, C.; Dong, H.; Wang, Z.; Martinez, L.; Sun, Z.; Handel, A.; Chen, Z.; Chen, E.; Ebell, M.; et al. Airborne transmission of COVID-19: Epidemiologic Evidence from Two Outbreak Investigations. Available online: https://www.researchgate.net/publication/340418430_Airborne_transmission_of_COVID-19_epidemiologic_evidence_from_two_outbreak_investigations (accessed on 14 March 2020).
47. Buonanno, G.; Stabile, L.; Morawska, L. Estimation of airborne viral emission: Quanta emission rate of SARS-CoV-2 for infection risk assessment. *Environ. Int.* **2020**, *141*, 105794. [CrossRef] [PubMed]
48. Nishiura, H.; Oshitani, H.; Kobayashi, T.; Saito, T.; Sunagawa, T.; Matsui, T.; Wakita, T.; COVID, M.; Team, R.; Suzuki, M. Closed environments facilitate secondary transmission of coronavirus disease 2019 (COVID-19). *MedRxiv* **2020**. [CrossRef]
49. Qian, H.; Miao, T.; Liu, L.; Zheng, X.; Luo, D.; Li, Y. Indoor transmission of SARS-CoV-2. *Indoor Air* **2021**, *31*, 639–645. [CrossRef] [PubMed]
50. CDC. Coronavirus Disease 2019 (COVID-19): COVID-19 Employer Information for Office Buildings. Available online: https://www.cdc.gov/coronavirus/2019-ncov/community/office-buildings.html (accessed on 9 July 2020).
51. WHO. Coronavirus Disease (COVID-19) Advice for the Public. Available online: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public (accessed on 4 June 2020).
52. CDC. Coronavirus Disease 2019 (COVID-19): How to Protect Yourself&Others. Centers for Disease Control and Prevention (CDC). Available online: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html?CDC_AA_refVal=https%3A% (accessed on 31 July 2020).
53. Chu, D.K.; Akl, E.A.; Duda, S.; Solo, K.; Yaacoub, S.; Schünemann, H.J.; El-Harakeh, A.; Bognanni, A.; Lotfi, T.; Loeb, M.; et al. Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: A systematic review and meta-analysis. *Lancet* **2020**, *395*, 1973–1987. [CrossRef]
54. Du, B.; Zhang, C.; Shen, J.; Zheng, Z. A Dynamic Sensitivity Model for Unidirectional Pedestrian Flow with Overtaking Behaviour and Its Application on Social Distancing's Impact during COVID-19. *IEEE Trans. Intell. Transp. Syst.* **2021**, 1–14. [CrossRef]
55. Musselwhite, C.; Avineri, E.; Susilo, Y. Editorial JTH 16–The Coronavirus Disease COVID-19 and implications for transport and health. *J. Transp. Health* **2020**, *16*, 100853. [CrossRef]
56. Cohen, A. Considerations for Social Distancing on Public Transportation during the COVID-19 Recovery. Available online: https://transweb.sjsu.edu/sites/default/files/2065-Cohen-Social-Distancing-Public-Transit.pdf (accessed on 20 February 2020).
57. SAGE. *EMG: Transmission and Control of SARS-CoV-2 on Public Transport*; Environmental and Modelling Group (EMG) for Scientific Advisory Group for Emergencies (SAGE): London, UK, 2020.
58. Javid, B.; Weekes, M.P.; Matheson, N.J. COVID-19: Should the Public Wear Face Masks? *BMJ* **2020**, *369*, m1442. [CrossRef]
59. Gruer, L. Face masks for the public during the COVID-19 crisis. *BMJ* **2020**, *369*, m1435.
60. WHO. Advice on the Use of Masks in the Context of COVID-19: Interim Guidance. Available online: https://apps.who.int/iris/handle/10665/332293 (accessed on 5 June 2020).
61. Konda, A.; Prakash, A.; Moss, G.A.; Schmoldt, M.; Grant, G.D.; Guha, S. Response to letters to the editor on aerosol filtration efficiency of common fabrics used in respiratory cloth masks: Revised and expanded results. *ACS Nano* **2020**, *14*, 10764–10770. [CrossRef] [PubMed]
62. Lewis, D. Mounting evidence suggests coronavirus is airborne—But health advice has not caught up. *Nature* **2020**, *583*, 510–513. [CrossRef]
63. Ngonghala, C.N.; Iboi, E.; Eikenberry, S.; Scotch, M.; MacIntyre, C.R.; Bonds, M.H.; Gumel, A.B. Mathematical assessment of the impact of non-pharmaceutical interventions on curtailing the 2019 novel Coronavirus. *Math. Biosci.* **2020**, *325*, 108364. [CrossRef] [PubMed]
64. Eikenberry, S.E.; Mancuso, M.; Iboi, E.; Phan, T.; Eikenberry, K.; Kuang, Y.; Kostelich, E.; Gumel, A.B. To mask or not to mask: Modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. *Infect. Dis. Model.* **2020**, *5*, 293–308. [CrossRef] [PubMed]
65. Jiang, F.-C.; Jiang, X.-L.; Wang, Z.-G.; Meng, Z.-H.; Shao, S.-F.; Anderson, B.D.; Ma, M.-J. Detection of severe acute respiratory syndrome coronavirus 2 RNA on surfaces in quarantine rooms. *Emerg. Infect. Dis.* **2020**, *26*, 2162. [CrossRef]
66. Van Doremalen, N.; Bushmaker, T.; Morris, D.H.; Holbrook, M.G.; Gamble, A.; Williamson, B.N.; Munster, V.J. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N. Engl. J. Med.* **2020**, *382*, 1564–1567. [CrossRef]
67. GIZ. Standard Operating Procedures (SOPs) for Bus Transport Post COVID-19 Lockdown. Available online: https://www.sutp.org/publications/standard-operating-procedures-sops-for-bus-transport-postcovid19-lockdown/ (accessed on 4 May 2020).

68. Lu, J.; Gu, J.; Li, K.; Xu, C.; Su, W.; Lai, Z.; Zhou, D.; Yu, C.; Xu, B.; Yang, Z. COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020. *Emerg. Infect. Dis.* **2020**, *26*, 1628–1631. [CrossRef] [PubMed]
69. CDC. Coronavirus Disease 2019 (COVID-19): Protect Yourself when Using Transportation. Available online: https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/using-transportation.html (accessed on 3 August 2020).
70. Goldbaum, C. MTA, Citing Huge Drop in Riders, Seeks $4 Billion Virus Bailout. *New York Times*, 17 March 2020.
71. DF. MTT Agrees Payment Mechanism with Former Transantiago Operators due to Drastic Drop in Revenue. Available online: https://www.df.cl/noticias/empresas/industria/mtt-acuerdamecanismo-de-pago-con-operadores-del-ex-transantiago-ante/2020-05-19/195247.html (accessed on 22 May 2020).
72. NOS. 1.5 Billion Euros in Corona Compensation for Public Transport Companies. Available online: https://nos.nl/artikel/2336334-1-5-miljard-euro-coronacompensatie-voor-ov-bedrijven.html (accessed on 14 March 2020).
73. Sverigesradio. The Government Provides Money so that Public Transport can Run as Usual. Available online: https://sverigesradio.se/sida/artikel.aspx?programid=4916&artikel=7470922 (accessed on 11 May 2020).
74. Tirachini, A. South America: The challenge of transition. In *A Research Agenda for Transport Policy*; Edward Elgar Publishing: Cheltenham, UK, 2019.
75. Gwilliam, K. Public Transport in the Developing World—Quo Vadis? In Proceedings of the International Conference Series on Competition and Ownership in Land Passenger Transport, Cape Town, South Africa, 1 January 1999.
76. Valentino-DeVries, J.; Lu, D.; Dance, G.J. Location data says it all: Staying at home during coronavirus is a luxury. *The New York Times*, 3 April 2020.
77. Tanguay, G.; Lachapelle, U. Remote work worsens inequality by mostly helping high-income earners. *The Conversation*, 20 May 2020.
78. Astroza, S.; Tirachini, A.; Hurtubia, R.; Carrasco, J.A.; Guevara, A.; Munizaga, M.; Figueroa, M.; Torres, V. Mobility changes, teleworking, and remote communication during the COVID-19 pandemic in Chile. *Findings* **2020**, 13489. [CrossRef]
79. MOVID-19. What Has Been the Response of the Population to the Quarantines? *The Impact of Inequalities on the Effectiveness of Health Policies.* Available online: https://www.movid19.cl/informes/mesasocial3.html (accessed on 9 June 2020).
80. Adams-Prassl, A.; Boneva, T.; Golin, M.; Rauh, C. Inequality in the impact of the coronavirus shock: Evidence from real time surveys. *J. Public Econ.* **2020**, *189*, 104245. [CrossRef]
81. The Economist. COVID-19 Threatens Europe's Success at Fighting Inequality. Available online: www.economist.com/europe/2020/06/06/covid-19-threatens-europes-success-at-fighting-inequality (accessed on 9 June 2020).
82. Tirachini, A.; Guevara, A.; Munizaga, M.; Carrasco, J.; Astroza, S.; Hurtubia, R. Survey on the Effects of the COVID-19 Pandemic on Mobility, Activities and Concerns of People. Available online: https://isci.cl/wp-content/uploads/2020/04/Encuesta-Movilidad-ISCI-Abril-2020_v02.pdf (accessed on 14 March 2020).
83. Chorus. Moral Decisions and the Corona Crisis—Insights from the BEHAVE-Research Program. Available online: http://behave.tbm.tudelft.nl/index.php/2020/03/28/moral-decisions-and-thecorona-crisis-insights-from-the-behave-research-program/ (accessed on 28 March 2020).
84. Setti, L.; Passarini, F.; De Gennaro, G.; Barbieri, P.; Perrone, M.G.; Borelli, M.; Palmisani, J.; Di Gilio, A.; Piscitelli, P.; Miani, A. Airborne transmission route of COVID-19: Why 2 meters/6 feet of inter-personal distance could not be enough. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2932. [CrossRef]
85. Normile, D. Japan ends its COVID-19 state of emergency. *Scienceinsider*, 26 May 2020. [CrossRef]
86. Jenelius, E.; Cats, O. The value of new public transport links for network robustness and redundancy. *Transp. A Transp. Sci.* **2015**, *11*, 819–835. [CrossRef]
87. Bešinović, N. Resilience in railway transport systems: A literature review and research agenda. *Transp. Rev.* **2020**, *40*, 457–478. [CrossRef]
88. Barabási, A. Network Science Spreading Phenomena. 2014. Available online: https://barabasi.com/f/617.pdf (accessed on 30 June 2022).
89. Colizza, V.; Barthélemy, M.; Barrat, A.; Vespignani, A. Epidemic modeling in complex realities. *Comptes Rendus Biol.* **2007**, *330*, 364–374. [CrossRef] [PubMed]
90. Krishnakumari, P.; Cats, O. *Virus Spreading in Public Transport Networks*; Working Paper; Transport Institute TU Delft: Delft, The Netherlands, 2020.
91. Olayode, I.O.; Tartibu, L.K.; Okwu, M.O.; Severino, A. Comparative Traffic Flow Prediction of a Heuristic ANN Model and a Hybrid ANN-PSO Model in the Traffic Flow Modelling of Vehicles at a Four-Way Signalized Road Intersection. *Sustainability* **2021**, *13*, 10704. [CrossRef]
92. Olayode, I.O.; Tartibu, L.K.; Okwu, M.O. Traffic flow Prediction at Signalized Road Intersections: A case of Markov Chain and Artificial Neural Network Model. In *2021 IEEE 12th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT)*; IEEE: Piscataway, NJ, USA, 2021; pp. 287–292.