Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Public transit usage and air quality index during the COVID-19 lockdown

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ABSTRACT

The people suffering from coronavirus have to lead unprecedented actions including limiting travel especially using public transportation. Therefore, lockdown measures and social distancing to decelerate the distribution of the COVID-19 has become the new norm. Nevertheless, improvement in the ambient air quality of the cities globally has appeared as a key advantage of this lockdown. There is a lack of research in the field of public transportation mobility and the Air Quality Index (AQI) during the COVID-19 lockdown globally. Consequently, this research aims to examine the overall impact of the public transit usage and ambient air quality, i.e. both AQI and indicatory air pollutants, during the lockdown in 12 countries. Data collections for analysis of public transportation usage and air quality status during the lockdown and one year before this period were carried out utilizing public transportation application Moovit and World's Air Pollution. The results demonstrated that the lockdowns of 12 countries led to dramatically decreased human movements and public transit usage up to −90% until the end of March and it had no major changes until the end of May. In the case of ambient air quality, the average values of AQI in the 12 countries within lockdown 2020 for classes I(AQI:0-50), II(AQI:51-100), and III (AQI:101-150) increased by 12%, 9%, and 13% while for classes IV(AQI:151-200), V(AQI:201-300) and VI (AQI:301-greater) decreased by 10%, 27%, and 3% in comparison with the identical time throughout 2019. The results also indicate that throughout lockdown 2020, in the 12 countries, the percentages of indicatory air pollutants of PM2.5, PM10, SO_2, CO, and NO_2 were decreased by 16%, 21%, 41%, 48%, and 35% lower than those in the same time in 2019. Mechanism analysis and comparisons highlighted that the lockdowns of 12 countries led to decreased human mobility and improvement in the AQI around the world.

1. Introduction

Coronaviruses are generally a large family of viruses that results in diseases varying from the prevalent cold to more serious illnesses such as Middle East Respiratory Syndrome (MERS-CoV) as well as Severe Acute Respiratory Syndrome(SARS-CoV). These viruses are generally zoonotic, which means they are usually transmitted among people and animals. Comprehensive research discovered that one of the above-mentioned viruses, i.e. MERS-CoV, coming from dromedary camels to people as well as SARS-CoV was transmitted through another animal which is civet cat to human beings. In this regard, several identified coronaviruses are generally spreading among animals that have not yet been influenced by people (WHO, 2020a).

A novel coronavirus is a new strain that has not been earlier recognized in human beings. The new coronavirus is generated by the virus SARS-CoV-2. Accordingly, although the source of SARS-CoV-2 were probably bats, the mentioned virus jumped from a barrier to human beings via a different animal hosts such as a domesticated wild animal, a wild animal, and/or a domestic food animal which has not been recognized yet. World Health Organization (WHO) proceeds to collaborate with specialists and scientists to recognize research priorities and gaps for the management of coronavirus, and offers suggestions to nations and people on protection measures (WHO, 2020b).

The consequences of the coronavirus outbreak have influenced internal mobility in cities worldwide but have not been taken into consideration in detail till now. Incomplete studies, press notes, news, and so on, were discovered in which a few references have been provided to consider the decrease in mobility and public transportation usage. A worldwide evaluation of mobility has lately been released by Google (2020) and Moovit App (Moovit, 2020), discovering a global decrease of approximately up to 87% in several countries in Asia, Europe, and the Americas. For example, travels on transportation modes

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monitored by this application were down approximately 84 percentages in Madrid, 86 percentages in Lombardy and Milan, and 54 percentages in the New York City metro area (Griswold, 2020). Besides, Delhi (India) and Wuhan (China) have listed reductions of 80–90% in the number of customers. The evaluation accomplished by TomTom published at TomTom Traffic Index (Tom Tom, 2020) determines the congestion ranges in several cities all over the world. They discovered that present congestion ranges are very low because of the coronavirus impact, in which common congestion degrees in these cities are typically close to 50–70% (Aloi et al., 2020).

Although "lockdown" is not a specialized term utilized by public-health officials, it can easily refer to whatever from non-mandatory recommendations to mandatory geographic quarantines to stay at home, closures of specific varieties of organizations and businesses, or prohibits on gatherings and events. In numerous nations such as Denmark, Italy, Spain, and Germany, those earlier enforced limitations led up to increase lockdown actions; however the outcomes have been mixed (Kaplan et al., 2020). The accomplishment of the lockdown scheme applied in the city of Wuhan encouraged the majority of impacted nations to utilize identical actions that limited mobility. In this case, public mobility systems are generally the most prejudiced ones within the mentioned decline, having numerous customers declining to utilize them to decrease the possibility of transmission. Consequently, when restrictions enforced upon the journey, the decrease in the number of travels being created was generally higher percentage-wise regarding public transit compared to personal traffic (Aloi et al., 2020; La et al., 2020; Pirouz et al., 2020).

COVID-19 spreads whenever an infected particular person sneezes, coughs, or exhales tiny droplets packed along with the virus into the air. These types of droplets can easily get into the body via the mouth, nose, and eyes, either after touching a contaminated object or directly. All governments create consistent messages to keep social distancing when people are outside the household especially in public transportation and public area. Restricting face-to-face contact with other people is the greatest method to decrease the distribution of COVID-19. In practice, social or physical contacting is approximately 2 m away from other people while it is different in some countries such as those in European Union (EU) where it is around 1.5 m.

There are generally several instructions and guidelines with details as well as suggestions released by official organizations such as advancing public transport (2020) and national cooperative highway research program (2014, 2020) which offer ideal procedures on preparing and functioning public transit systems under health emergency circumstances. Based on these guidelines, staffs need to be informed about the necessary basic guidelines of individual hygiene including frequently washing hands, coughing, sneezing into the elbow and utilizing paper towels. Public transit operators also need to receive national and/or local guidance for the utilize of face covering besides disposable gloves. In this regard, a decrease of contact and service measures are advised if the risk degree is high just in a verified outbreak in the location. It is essential to follow the details provided by WHO, keeping in close contact with the national health agencies and authorities and following their recommendations (Advancing public transport, 2020).

KPMG (2020) described that Tokyo Metropolitan authorities keep windows opened in almost all public transportations. Disinfection of stations such as stairway handrails, buttons in elevators, and so on is much more frequent. In Netherland, as described by OV-NL (2020), to prevent as significant contact as possible, individuals were requested to keep their telephone/ticket in front of the ticket reader in the meantime of checks. Persons who are generally responsible for verifying the tickets in public transportation do not require to take any telephones or tickets from the passengers for checks. In Rome, Italy, although public transport was usually still operating during the lockdown, people were just permitted to leave the quarantined places, which consist of the whole area of Lombardy and places in four additional regions such as Venice. In addition, quoted accesses to stations, ports, and airports to prevent crowding as well as any feasible possibility for contact (Romero, 2020). In Seoul, South Korea, the Metro authority founded a standard for controlling the congestion degree to manage the specific social distance among travelers and decrease the danger of an outbreak. From the congested degree 1, i.e. over 150%, much more definite limitation of "obligatorily" using the mask in the public transportation modes is actually needed to secure the travelers' health. Throughout rush hours, several metro lines of excessive congestion degree will have extra schedules (Lee, 2020).

Although coronavirus harms public mobility, it has improved air pollution all around the world. Air pollution is a structure combination of carbon monoxide (CO), nitric dioxide (NO_2), Particulate Matter (PM) lesser than 2.5 μm (μm), i.e. PM2.5, as well as lesser than 10 (μm), i.e. PM10, ozone (O_3), and also volatile organic compounds produced through the automobile, indoor pollutants, and industrial emissions (Brandt et al., 2020). PM2.5 and PM10 can be either natural or human-made occurring. PM, such as soot, is released throughout the combustion of liquid and solid fuels. Nitrogen dioxide is a nasty-smelling gas. Some nitrogen dioxide is created normally in the atmosphere by lightning and some other is created by water, soil, and plants. The main origin of nitrogen dioxide is actually the combusting of non-renewable energy sources such as gas, coal, and also oil (Department of the Environment and Heritage, 2005). SO_2 is actually the main air pollutant, and includes a broad level of distribution, generally through the smelting of sulfur-containing ores as well as the combustion of petroleum and coal. CO is tasteless, odourless and colorless gas and produced whenever carbonaceous compounds are usually incompletely burned. Power stations, factory heating furnaces, stoves, automobile exhaust gas, and internal combustion engines are the major options of carbon monoxide. The creation of the urban world O_3 is usually a complex procedure that does not have any direct release resource. For this reason, it is actually created through the reaction of precursors including CO and NOx under suitable climate situations (Biswas et al., 2019; Turner et al., 2016; Xu et al., 2020).

The environmental agency has recognized ambient air quality criteria concerning each of the mentioned pollutants to maintain public health. An air quality index magnitude of X commonly refers to the degree of the air quality standards for the pollutant. The Organization for Economic Cooperation and Development (OECD) forecasts that in 2050 outdoor air pollution will be the major factor environmentally associated with fatalities globally. Furthermore, air pollution has also been categorized as the primary environmental reason for cancer (Marchal et al., 2011). As described in advancing public transport (2020), Aloi et al. (2020), and La et al. (2020) to reduce the dispersal of the coronavirus from its resource, a variety of travel limitations as one of the efficient reaction measures in several nations such as Italy, Spain, France, United Kingdom (UK) and Brazil have been applied and subsequently, Air Quality Index (AQI) has been advanced.

Chauhan and Singh (2020) and Singh and Chauhan (2020) evaluated that throughout the unprecedented lockdown time, the air quality was considerably enhanced. They provided an evaluation of air quality including NO_2, AQI and particulate matter PM2.5, around India utilizing satellite and ground data collection. A noticeable decrease in AQI and PM2.5 was discovered around Mumbai, Delhi, Chennai, Kolkata, and Hyderabad as well as a decreasing trend was discovered in NO_2 quantity throughout the lockdown time in 2020 compared with the same time in 2019. This evaluation demonstrates the mentioned decrease generally because of less movement of individuals to maintain enforced social distancing to manage the distribution of COVID-19. Although some research such as Muhammad et al. (2020), Schwartz (2020), Sicard et al. (2020), and Yongjian et al. (2020) have described the positive effect of lockdown on the air pollution in cities, Wang et al. (2020) pointed out that significant emissions decrease in transportation and a minor decrease in industrial would not support to prevent serious air pollution, particularly when meteorology is undesirable.

There is a bulk of research associated with the influence of the

coronavirus on the ambient air quality including Abdullah et al. (2020), Barcelo (2020), Bontempi (2020), Dantas et al. (2020), Mahato et al. (2020), Zoran et al. (2020). In addition, Chinazzi et al. (2020), Gutiérrez et al. (2020), Huang et al. (2020), Koehl (2020), Loske (2020), Sánchez (2020), and Zheng et al. (2020) carried out some research related to the COVID-19 and transportation sector. Despite this, there is a lack of research in the field of both public transportation mobility and air quality in the coronavirus lockdown around the world. In addition, most of the existing research conducted only for one country such as Abdullah et al. (2020) in Spain, Loske (2020) in Germany, Xu et al. (2020) in China, and so on. Consequently, the objective of this research is to take into account the impact of coronavirus on the both public transit usage and ambient air quality, i.e. both AQI and indicatory air pollutants, during the lockdown in 12 countries including the USA, Brazil, United Kingdom (UK), Italy, France, Germany, Spain, Mexico, Canada, Turkey, Chile, and Sweden. In this study, appropriate statistical data for analysis and comparisons are extracted from the Moovit (2020) application for public transportation usage and the World's Air Pollution (2020) for estimation of AQI and indicatory air pollutants. The procedure of data analysis and comparisons will be described precisely in the methodology.

1.1. Covid-19 and public transportation

One of the biggest negative effect of coronavirus has created on the public transportation systems, with numerous customers declining to use it for prevention of public contact as well as decrease the danger of virus. For this reason, when restrictions were enforced on a journey, the decrease within the number of trips by public transportation has usually been greater compared to personal vehicles. For instance, Delhi, India, or Wuhan, China have recorded a decrease of up to 90 percent in the number of users (Tom Tom, 2020; TUMI, 2020). On 23 January 2020, the government of China applied the severe lockdown measure in the city of Wuhan, and then numerous close urban areas in following days; the lockdowns measure consist of quickly suspending almost all public transit systems such as flights, trains and also buses (Wu et al., 2020). Additionally, several airports and high-speed rail stations include test activities to identify passengers having a fever, particularly people coming from Wuhan, as well as all people with fever were sent to public medical centers (Roosa et al., 2020).

Public transport operators have focused to develop public transit as a more secure approach to traveling during social contacting, allowing people with physically disabled or with no vehicle to journey. Particularly individuals having low-paid careers are actually not capable of working through the residence and consequently maintain utilizing public transit systems (Goldbaum and Cook, 2020). On the other hand, although public transportation operators highly rely on profits through fares, public transportation providers need to be motivated never to significantly decrease public transit capacity and also frequency (because of decreasing customer) but keep a specific range of service allowing passengers in order to retain a secure distance through different passengers. Since several public transportation providers presently have economic issues because of plummeting revenues, government authorities might temporarily offer public transportation providers using economic assistance in doing so. In this regard, if social contacting actions would carry on for longer periods, public transit provider needs to consider reorganizing inside of train as well as buses, for example, creating more distinct sections, therefore travelers will much more easily prevent social distance as well as a journey within a secure way (Badger, 2020; De Vos, 2020).

Zhao et al. (2020) assumed the distribution of coronavirus might be related to the local transit in Mainland China. They analyze and discover the relationship between the number of coronavirus cases proved in various cities and a load of local travelers through the city of Wuhan. The daily quantities of domestic travelers by using transportation such as a vehicle, flight, and train were acquired through the specific database of Tencent Corporation, i.e. Tencent (2020). They computed the everyday average quantity of travelers coming from the city of Wuhan to the other six chosen main urban areas such as Guangzhou, Shanghai, Beijing, Chongqing, Chengdu, and also Shenzhen, from 16 December to 15 January 2020. Zhao et al. (2020) discovered a powerful and substantial relationship between the journey with the train as well as the quantity of mentioned virus cases, while the relationships of another two types of transportation unsuccessful to achieve statistical relevancy. They approximated that a 10-fold rise in the number of train travelers coming from the city of Wuhan is probably related to around 9 raise in the quantity of brought in cases. The results recommended that disease management and reduction measures should be desired in the traveling process by trains.

To examine the function of public transit in the case of transmitting coronavirus, Zheng et al. (2020) explored daily trains, buses, as well as flights coming from the city of Wuhan to other urban areas from January. They also acquired direct line distances among Wuhan and other cities and omitted those more than 1500 km to prevent inappropriate results. Almost whole information was logarithmically changed as well as Pearson's correlation investigation had been utilized to analyze correlations of everyday frequencies of each public transit mode and also the length among the city of Wuhan and other urban areas. Zheng et al. (2020) discovered a substantial and positive relationship between the frequency of public transportation modes such as buses, trains, and flights coming from the city of Wuhan as everyday communication and also the cumulative quantities of coronavirus conditions in some other urban areas with gradually enhanced correlations for buses and also trains. The length among the city of Wuhan and also some other urban areas had been inversely related to the quantities of coronavirus conditions in that urban area.

Aloi et al. (2020) analyzed the effect of quarantine enforced on metropolitan mobility in Santander, Spain. Data were gathered through public transport ITS, traffic counters, environmental sensors and recordings from traffic control cameras to create comparisons among times and journey flows before and through the quarantine. The evaluation discovered general public transport clients decreased by approximately 93%. A review created by INRIX (2020) in Seattle, the USA utilizing information from the middle of March discovered a decline in traveling of up to 60 percent and enhancements in traveling times with a 13% decrease in the vehicle per kilometer. In addition, a worldwide evaluation of mobility was lately released through Google (2020) which shows a global decrease in trips in almost every nation.

De Vos (2020) described the possible implications of social contact on daily journey behavior. It can also be predicted that the need for a journey will certainly decrease as well as persons will journey significantly less by public transportation services. Consequently, cycling and walking can be crucial methods to sustain acceptable ranges of well-being and health. Planners and policymakers need to subsequently attempt to motivate active journey, though public transport operators need to concentrate on developing strategies to securely utilize public transportation.

1.2. Covid-19 and air quality

Tobías et al. (2020) explained modifications in air pollution ranges throughout the lockdown actions in Barcelona, Spain, through researching traffic air quality checking stations as well as the period advancement of atmospheric contaminants registered in the city area. Upon two weeks of lockdown measures, city air pollution substantially reduced however with considerable variations within contaminants. Ogen (2020) analyzed the association between long-term exposure to COVID-19 death cases and NO_2. The spatial method evaluation was carried out on a local range as well as mixed along with the number of mortality conditions obtained via 66 administrative locations in Italy, Germany, France, and Spain. The outcomes demonstrated that the long-term exposure to this particular pollutant may be one of the most

essential contributors to death because of the coronavirus in these kinds of areas as well as perhaps throughout the worldwide.

Bao and Zhang (2020) utilized daily air contamination information as well as Intracity Migration Index (IMI) information in Baidu regarding 44 urban areas in northern Mainland China to analyze how, whether, and to what extent journey limitations impacted air quality. Procedure evaluation highlighted that the decrease of air contamination was highly related to the journey limitations throughout the coronavirus pandemic and on average the AQI reduced by 7.80 percent. The effects of emission reductions because of decreased anthropogenic actions throughout the coronavirus lockdown in Mainland China on air contamination was researched by Wang et al. (2020). It is determined that anthropogenic emission reduces, generally on industry and transportation, led to reduces of PM2.5 levels. Wang et al. (2020) described that the decrease proportions of PM2.5 were lesser compared to the decrease proportions of precursor emissions, to some extent because of the undesirable meteorological situations. Chauhan and Singh (2020) evaluated the particulate matter and trace gases utilizing ground and satellite data in India during March 2020 and compared it with the previous year. The results of the analysis indicated that HCHO, NO2, SO2, CH4, CO, O3 and PM2.5 concentration changed throughout full lockdown.

The impact of lockdown because of coronavirus on air contamination was quantified by Sicard et al. (2020) in four Southern European urban areas i.e. Rome, Nice, Turin and Valencia as well as Wuhan (China) with an emphasis on O_3. Based on this comparison during the same period from 2017 until 2019, the daily O_3 levels have been enhanced in urban areas throughout the lockdown 2020. This raise in O_3 levels are generally described through an unprecedented decrease within NOx emissions resulting in a reduced O_3 titration through NO. This research illustrates the problem of decreasing the formation of secondary pollutants including O_3 despite having strict actions to control main pollutant emissions. Yongjian et al. (2020) discovered the relationship between the COVID-19 and ambient air pollutants from 23 January to 29 February 2020 in China. The outcomes signified that there is a substantial association between air pollution (NO_2, PM10, PM2.5, and also O_3) and coronavirus which could to some extent describe the impact of lockdown actions and offer significance for the control and avoidance of the COVID-19.

Fareed et al. (2020) identified the impact of climate conditions (i.e. average humidity and AQI) for the fatality of this virus in Wuhan, China. They have utilized wavelet evaluation because of its benefits over conventional time series techniques. Results showed that humidity is adversely associated with coronavirus fatalities, and poor AQI results in a rise in this fatality. These types of results are essential with regard to policy management to preserve people's lifestyles through greater knowing the relationship of the coronavirus with the environment. Collivignarelli et al. (2020) analyzed the total and incomplete lockdown measures and their effects on the ambient air quality inside the urban areas of Milan, Italy. Accordingly, serious restriction of individuals mobilities after the partial lockdown, as well as the following total lockdown, identified the substantial decrease of contaminants level, i.e. benzene, PM10, PM2.5, NO_X, and also CO generally because of road traffic. The lockdown measures resulted in a significant decrease in SO_2 level just throughout the urban area of the mention case study though it continued to be unchanged throughout the surrounding locations. Baldasano (2020) described that throughout March and April 2020, people in Spain observed the biggest range of experiments throughout history regarding the ambient quality of air. The lockdown measure has created it feasible to evaluate the restriction of reduction in air contamination due to the extreme decrease in traffic in which it revealed a substantial reduction of 75% in Barcelona and Madrid. These types of outcomes enable researchers to observe the restrictions which can easily be obtained through applying low emission zones, and also the quantity of contamination which should be removed.

2. Material and method

2.1. Case study

In this research, the level of public transit usage and AQI during COVID-19 lockdown in 12 countries were examined. Accordingly, the period of data collection and analysis was conducted from 15 January until 31 May 2020.

These countries were selected because of the following reasons:

1 These are usually the 12 most-affected nations with the greatest quantity of coronavirus total death until the end of May.
2 Although there were other countries such as Belgium, The Netherland, China, India, and Russia with a high level of death, they were eliminated from analysis because of a lack of data in the field of public transportation and air quality.

The two cities for each country (one is the capital and the other one is a city with a high level of the population) were selected. In this research, in order to compare the general effect of coronavirus and ambient air quality, we tried to select the two cities, while because of insufficient data resources and poor data quality only one city was determined for three countries including Sweden, Brazil, and Chile. As a case study, Fig. 1 visualizes the selected countries and cities.

Table 1 shows the selected countries with their information including cities, latitude/longitude, and continental. Although the number of coronavirus active cases and mortality are changing every day, Italy and Spain were the nations with the maximum quantity of coronavirus cases (i.e. during the data analysis period from 15 January until 31 May 2020) around the world. Basic information for each country associated with public transportation is provided as follows:

In the case of transportation, in Washington, the majority of transportation is offered by metro and bus lines while public transportation in Los Angeles is usually desired by tourists. In Sao Paulo, Brazil, public transportation is offered by bus lines and rail systems. It is also frequent to utilize taxis in the city. London, UK is a city in which public transportation is extremely developed. In West Midland, i.e. Birmingham, another main city of the country, private automobile utilization is considerably more frequent in daily transportation.

Italy is one of the nations where the fatality case is substantial. In the city of Rome, the capital of the country and also Milano, public transit lines (bus lines and rail systems) are very well-developed and almost every point in the cities are accessible by public transportation. France is one of the countries where the fatality case related to the coronavirus (during data analysis period from 15 January until 31 May 2020) is excessive. Paris, the capital of France, is a significant port city and the metro line in the city is extremely developed. Marseille is one of the largest and oldest cities to utilize private automobiles. Germany is a nation with a lower fatality case because of coronavirus in comparison with Italy and France. In Berlin, the capital of Germany, the majority of public transit is developed by buses and metro while in Munich, several public transportations such as suburban, tram, and bus lines are very active.

Madrid and Barcelona, Spain are usually the two greatest cities in Spain where buses are regularly utilized as public transportation. Mexico is one of the nations with substantial fatalities wherein Guadalajara and Mexico City as the biggest cities in Mexico, transportation by Metrobus, metro, and bus are regularly desired. In Canada, the fatality level related to the coronavirus is quite high. In the cities of Montreal and Toronto which are usually situated near to each other, public transportations such as the light rail system and buses are frequently popular.

In Ankara, Turkey, the capital of the country, public transit is generally offered by minibusses and buses, while in Istanbul it is offered by rail systems, buses, and sea vehicles. Chile is usually among the nations having an excessive quantity of coronavirus cases. In the capital, i.

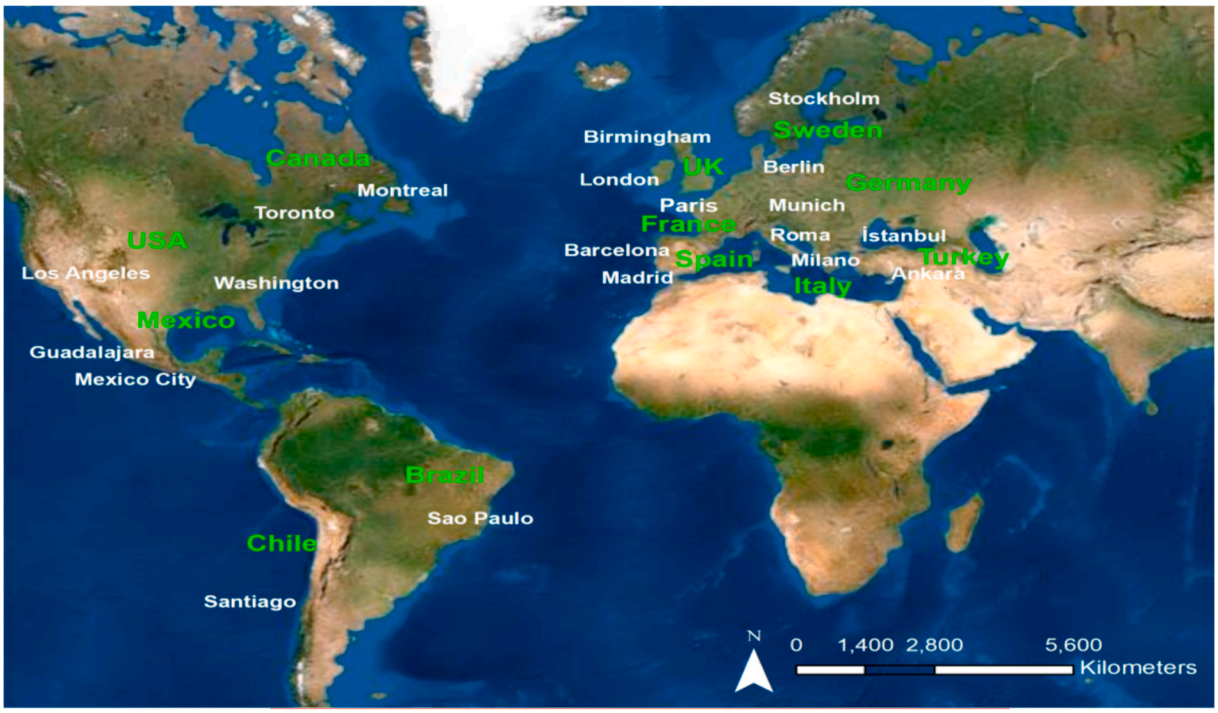

Fig. 1. Countries and cities used in the study.

Table 1
List of countries.

No.	Country	City	Latitude/longitude	Continental
1	USA	Washington	47.7511° N, 120.7401° W	North American
		Los Angeles	34.0522° N, 118.2437° W	
2	Brazil	Sao Paulo	23.5505° S, 46.6333° W	South America
3	UK	London	51.5074° N, 0.1278° W	Europe
		Birmingham	52.4862° N, 1.8904° W	
4	Italy	Rome	41.9028° N, 12.4964° E	Europe
		Milano	45.4642° N, 9.1900° E	
5	France	Paris	48.8566° N, 2.3522° E	Europe
		Marseille	43.2965° N, 5.3698° E	
6	Germany	Berlin	52.5200° N, 13.4050° E	Europe
		Munich	48.1351° N, 11.5820° E	
7	Spain	Madrid	40.4168° N, 3.7038° W	Europe
		Barcelona	41.3851° N, 2.1734° E	
8	Mexico	Guadalajara	20.6597° N, 103.3496° W	North American
		Mexico City	19.4326° N, 99.1332° W	
9	Canada	Montreal	42.7048° N, 1.5070° W	North American
		Toronto	43.6532° N, 79.3832° W	
10	Turkey	Ankara	39.9334° N, 32.8597° E	Europe
		Istanbul	41.0082° N, 28.9784° E	
11	Chile	Santiago	33.4489° S, 70.6693° W	South America
12	Sweden	Stockholm	59.3293° N, 18.0686° E	Europe

e. Santiago, bus lines are regularly desired as public transit because of their reasonable prices. In Stockholm, as the capital of Sweden, public transportation is usually offered by bus lines and rail systems, i.e. underground trains, commuter trains, trams, as well as ferry lines.

2.2. Method

In order to take into account how quantities of public transit users have developed in various urban areas globally during COVID-19 lockdown, appropriate statistic data and graphs are extracted from the Moovit (2020) platform. The information related to public transit usage displays how big urban areas in several countries have encountered robust decreases during lockdown and non-lockdown.

The daily air quality index is generally computed depending upon the whole day average levels for SO_2, PM10, NO_2, PM2.5, CO, as well as the daily average 8-h highest level for the O_3. AQI signifies the greatest pollution sub-index of six individual mentioned pollutants' levels utilizing Equation (1) and Equation (2). In this regard, based on the specific indicatory air pollutants such as PM10, NO_2, PM2.5 and so on, the breakpoint values, i.e. I_{high}, I_{low}, $C_{high,}$ and C_{low}, will be determined fromTable 2 and then AQI will be calculated. The air pollutant that includes the highest AQI magnitude is actually described as the main pollutant on that day (She et al., 2017). The classes of AQI are separated into six levels as follows;

1 Class I, 0-50, good, ambient air quality is usually acceptable as well as polluting of the environment presents no risk or little. (Green)
2 Class II, 51-100, moderate, air quality is usually acceptable but generally, there might be a danger for certain individuals, especially people who are uncommonly vulnerable to ambient air pollution. (Yellow)
3 Class III, 101-150, unhealthy for sensitive groups, members of vulnerable communities may experience health effects. The common people are actually less likely to be impacted. (Orange)
4 Class IV, 151-200, unhealthy, people of vulnerable groups may experience much more significant health impacts. (Red)
5 Class V, 201-300, very unhealthy, wellness alert: the danger of wellness impact is actually greater for everybody. (Purple)
6 Class VI, 301 and greater, hazardous, wellness caution of emergency circumstances: everybody is actually much more likely to be impacted. (Maroon) (Xu et al., 2020).

In order to evaluate the air quality index for selected countries throughout the lockdown 2020 and one year before during the same period, data were collected manually from World's Air Pollution (2020). In this regard, raw data for each criterion, as mentioned above, were gathered and analyzed by applying it into spreadsheets in EXCEL software.

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}} * (C - C_{low}) + I_{low} \quad (1)$$

Table 2
Breakpoints values.

O3 (ppb)	O3 (ppb)	PM2.5 (μg/m3)	PM10 (μg/m3)	CO (ppm)	SO2 (ppb)	NO2 (ppb)	AQI
C_{low}-C_{high} (avg)	C_{low}-C_{high} (avg)	C_{low}- C_{high} (avg)	C_{low}-C_{high} (avg)	C_{low}-C_{high} (avg)	C_{low}-C_{high} (avg)	C_{low}-C_{high} (avg)	I_{low}-I_{high}
0-54 (8hr)	–	0.0–12.0 (24hr)	0-54 (24hr)	0.0–4.4 (8hr)	0-35 (1hr)	0-53 (1hr)	0–50
55-70 (8hr)	–	12.1–35.4 (24hr)	55-154 (24hr)	4.5–9.4 (8hr)	36-75 (1hr)	54-100 (1hr)	51–100
71-85 (8hr)	125-164 (1hr)	35.5–55.4 (24hr)	155-254 (24hr)	9.5–12.4 (8hr)	76-185 (1hr)	101-360 (1hr)	101–150
86-105 (8hr)	165-204 (1hr)	55.5–150.4 (24hr)	255-354 (24hr)	12.5–15.4 (8hr)	186-304 (1hr)	361-649 (1hr)	151–200
106-200 (8hr)	205-404 (1hr)	150.5–250.4 (24hr)	355-424 (24hr)	15.5–30.4 (8hr)	305-604 (24hr)	650-1249 (1hr)	201–300
–	405-504 (1hr)	250.5–350.4 (24hr)	425-504 (24hr)	30.5–40.4 (8hr)	605-804 (24hr)	1250-1649 (1hr)	301–400
–	505-604 (1hr)	350.5–500.4 (24hr)	505-604 (24hr)	40.5–50.4 (8hr)	805-1004 (24hr)	1650-2049 (1hr)	401–500

$$AQI = \max\left(I_1, I_2 \ldots, I_n\right) \quad (2)$$

Where, I = the AQI, C = the pollutant level, C_{high} = the level breakpoint that is ≥ C, C_{low} = the level breakpoint that is ≤ C, I_{high} = the index breakpoint related to C_{high}, I_{low} = the index breakpoint related to C_{low}.

In order to determine the percentage values of changing the indicatory air pollutants during the lockdown 2020 as the current year and one year before, during the same period as the reference year, the following equation can be utilized (Singh et al., 2020).

$$P = \frac{Y_c - Y_r}{Y_r} * 100 \quad (3)$$

Where P is actually the percentage change of indicatory air pollutants, Y_r is the concentration of a pollutant in reference years one year before the lockdown, Y_c is the concentration of a pollutant in the current year during the lockdown.

3. Result and discussion

3.1. Public transportation usage

Globally, public transportation has been devastated by the social distancing and lockdowns associated with COVID-19. Based on the estimations by Google (2020) and Moovit (2020) ridership ranges are actually around −87% than pre-crisis ranges, which includes places dropping much more, particularly on longer-distance services. The information depends on an evaluation of the effective ranges of 750 million customers of Moovit (Raillynews, 2020).

Fig. 2 displays how percentages of public transit usage have evolved in Spain, France, and the UK, as revealed via the Moovit (2020) application. The figure displays how countries have encountered a strong decrease in the public transit ridership as the virus has extended and more limitations have been enforced.

In Spain, the coronavirus was initially verified to have been distributed to Spain on 31 January while the first death was recorded on 3 March and the lockdown was imposed (Chavez, 2020; Minder, 2020). All residents are usually required to stay in their normal residences

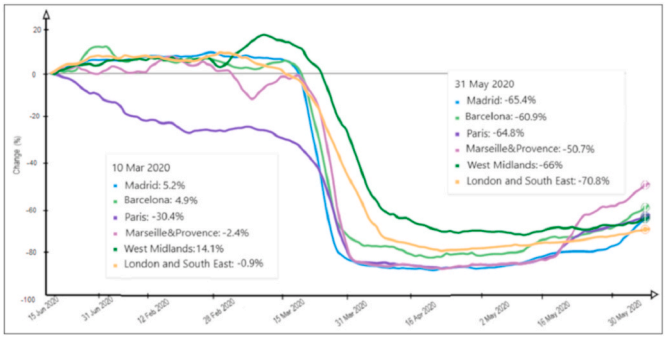

Fig. 2. Public transit usage from January to May in Spain, France, and the UK. (source: www.moovit.com)

except for buying medicines and food, working, or attending emergencies. Lockdown limitations also mandated the short-term closure of non-necessary businesses and shops such as cafes, restaurants, bars, cinemas, and commercial and retail businesses, additionally published that the government will be capable to take over private healthcare providers if required (Guardian, 2020a, 2020b). Based on the lockdown announcement, the percentage of public transit usage dramatically decreased until the end of March, which was approximately −87% and −78% in Madrid and Barcelona, respectively. From late March, the local community in Madrid has registered many confirmed cases as well as fatalities. The fatality ranges throughout Spain exceeded from China, and just that of Italy was greater; therefore, it was announced that starting 29 March, almost all non-necessary employees were being requested to stay at their homes within the following 14 days. For this reason, the percentage of public transit usage was steady-state until the end of April, which was nearly −86% in Madrid and −81% in Barcelona.

The coronavirus was verified to have reached France on 27 December 2019 and the first death was reported on 25 January (Cook, 2020; The Local, 2020). Accordingly, the government announced that almost all universities and schools needed to close from 16 March until an additional notice. They also prohibited events of greater than 100 persons excluding public transportation. Some days after the first announcement, the government requested the closure of almost all non-necessary public locations, such as cafes, restaurants, nightclubs and cinemas as well as obligatory home confinement for 15 days beginning from 17 March. This was extended two times, and finished on 11 May, following a progressive lifting of confinement (Cuthbertson, 2020). Although lockdown in France started from 16 March, public transit ridership in Paris slowly decreased to around −25% from January until the end of February, and then kept continue drastically to nearly −86% until 25 March. The percentage of usage in Marseille, as shown in Fig. 2, decreased to approximately −86% on 25 March and was a steady-state until the end of May.

The initial UK coronavirus cases were verified on 31 January while the first death was reported on 5 March (BBC News, 2020c; 2020d). Following that, the UK government enforced a lockdown on 23 March which was banning almost all non-necessary journeys and contact with persons outside one's home and shutting nearly all business, schools, venues, and places of worship. People were also requested to keep separate in public areas (BBC News, 2020b). Fig. 2 shows that although the percentage of public transit usage in West Midland and London increased to around 17% and 4% until the first week of March, they dramatically declined after lockdown and reached nearly −72% and −80% until 15 April, respectively. Then, an uptick in public transit usage began by 6% in West Midland and 9% in London until end of the May.

In Italy, the coronavirus was initially verified to have been distributed on 21 February through the first fatality was reported on 28 February (Aljazeera, 2020b; Rudan, 2020). Accordingly, the government suspended, i.e. from the end of January, almost all flights to and from China and announced a state of emergency. The procedure of lockdown and quarantine started in February in eleven cities in the north of Italy. Because of the increasing positive cases in some other areas, on 8 March, the government extended the lockdown to almost all

of Italy. Consequently, they banned practically all commercial activities other than for pharmacies and supermarkets. The Italian government also limited the movement of persons and shut down all non-necessary industries and businesses. In this country as one of the nations hit the toughest by the COVID-19, public tranportation usage has taken a remarkable downward. Italy has enforced some of the most stringent lockdown actions worldwide in an attempt to restrict the distribution of the coronavirus (Griswold, 2020). For instance, in Rome, metros, trams, and buses have halted operating at 9 p.m. since 14 March. However, although public transport, train stations and airports were usually still operating, people were just permitted to leave the quarantined places, which consist of the whole area of Lombardy and places in four additional regions including Venice, for health reasons or work (Romero, 2020). In Lombardy (Fig. 3), an area in North of Italy that includes Milan and Venice (i.e. a city with the high development of rail system and bus lines as public transportation); we discovered a decline to approximately −47% in public tranportation usage until the first week of March when the lockdown was started. This trend continued until the end of March where the percentage reached around −88% and then steady-state until the first week of May. From 4 May, the percentage of public tranportation usage slowly increased until the end of May by 20%. As shown in Fig. 3, in Roma, public transportation usage declined to near −90% when the lockdown was announced and it had a trend similar to Milan. In general, countrywide, public transport ridership was declined to around −50% until early March.

In Sweden, although the first confirmed case and death appeared on 24 January and 11 March, as shown by Local (2020) and Rolander (2020), other reference such as CNBC (2020) described that Sweden decided not to apply a strict lockdown, contrary to its Nordic neighbors including Norway, Denmark, and Finland. Furthermore, the government permitted Sweden's schools, restaurants and bars for under 16-year-olds to keep open. It did prohibit large events and goes to elderly-care homes, and recommended good personal hygiene, working from home and social distancing (Magness, 2020). In Stockholm, Sweden, although public transportation usage had a fluctuation from January until the second week of March, i.e. with just only 1.5% decreases; it dramatically fell to around −65% until the first of April. This percentage gradually increased by 7% until the end of May.

In Turkey, the coronavirus was verified to have reached on 10 March and the first death was determined on 17 March (Haber, 2020; Zontur, 2020). Accordingly, the government announced that venues such as discotheques, pavilions, night clubs and would be shut down as well as a countrywide suspension on prayer events in mosques was imposed. In addition, the flight suspends to traveler planes were extended with nations like France, Germany, The Netherlands, Spain, Denmark, Norway, Sweden, Austria, and Belgium. Throughout this period, the government considered that almost all works needed to be terminated quickly throughout the crisis in all groups other than those offering compulsory, basic, and urgent services and goods. Also, small tradesmen needed to be supported, employees needed to be provided paid leave, and unemployment support needed to be offered for the unemployed. Besides, consumer, housing and car loans as well as credit card debts and natural gas, water, electricity, and communication bills ought to be postponed throughout the coronavirus crisis without future interests (Keleş, 2020; TTB News, 2020). In the case of public transportation, Moovit has been considering public transportation usage in cities such as Istanbul, Ankara and analyzed the number of passengers during the lockdown. For example, although in Ankara, the number of public transit passengers increased to almost 20% before 11 of March, it dramatically decreased to −82% until the end of March because of the COVID-19 pandemic. Similarly, this percentage rose for Istanbul until 11.5% before the lockdown announcement while public transportation usage suddenly decreased to −80.5%. As shown in Fig. 3, these percentages changed from decreasing to a steady-state until 11 of May which was the end of lockdown in Turkey. After this time, although some public areas opened, using public transportation had no major changes until the end of May.

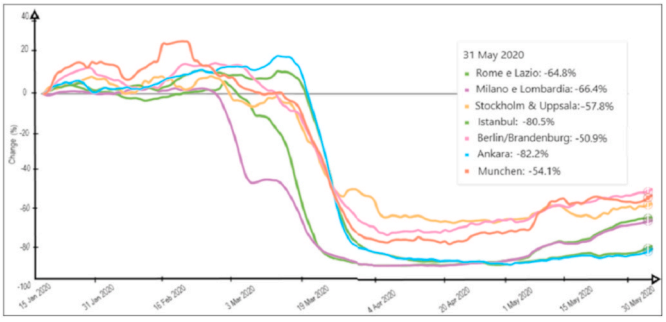

Fig. 3. Public transit usage from January to May in Italy, Sweden, Turkey, and Germany.
(Source: www.moovit.com)

The initial verified case and fatality in Germany were experienced on 27 January and 3 March, respectively (Böhmer et al., 2020; Times, 2020). From 13 March on, in several German states, specific measurements were imposed such as mandating kindergarten and school closures, postponing university semesters, and forbidding visits to nursing houses to secure the elderly. Borders to Denmark, Austria, Switzerland, Luxembourg, and France were shut down. In addition, curfews were enforced in six German states though some other states have forbidden physical connection with more than one individual from outside one's household. Domestic traveling is permitted in organizations, not beyond two persons except if these people are from an identical household. Some states enforced additional limitations permitting people to leave their homes just for particular actions such as traveling to work, purchasing food, or exercising (Robert Koch-Institut, 2020). In the case of public transportation, a fluctuation trend has been observed over the past few months especially from January until 7 March in which the public transportation usage in both Berlin and Munich was similar together. From the second week of March, the percentage of usages drastically decreased because of the lockdown announcement all around the country. The minimum percentage of public transit usage in Berlin and Munich happened on 2 April which was around −74% and −78%, respectively. These percentages slowly improved after 4 May because of beginning to lift lockdown measures and those reached to the −51% and −54% in both cities, respectively.

The initial verified case of local transmission of coronavirus in the USA was registered on 20 January, though the initial known fatalities took place on 6 February (Holshue et al., 2020; news, 2020). For this reason, the Centers for Disease Control and Prevention (CDC) cautioned the public for the initial period to get ready for a regional outbreak. On 16 March, the government informed against any events of more than ten persons, and then they recommended U.S. people to prevent almost all international journeys. In addition, they canceled all large-scale events such as sporting events and festivals, stay-at-home orders, as well as the closure of universities and schools. Large events that took place before widespread closure and social distancing actions were applied (NYTimes, 2020; Schuchat, 2020; Taylor, 2020). Fig. 4 displays that the drop-off in public transit usage throughout the USA was relatively sudden. In the Washington region, where coronavirus was initially recognized in the country, it can be observed a previously and steadier decrease than Los Angeles. In general, public transit ridership in Washington and Los Angeles was down to nearly −75% until 15 April which is clearly because of the virus and also lockdown measurement all around the country.

The coronavirus was verified to have found Canada on 27 February. In the middle of March, almost all of Canada's territories and provinces announced states of emergency. In addition, the government started showing up in public service notices on television and radio, social distancing, urging personal hygiene, and against the unneeded journey.

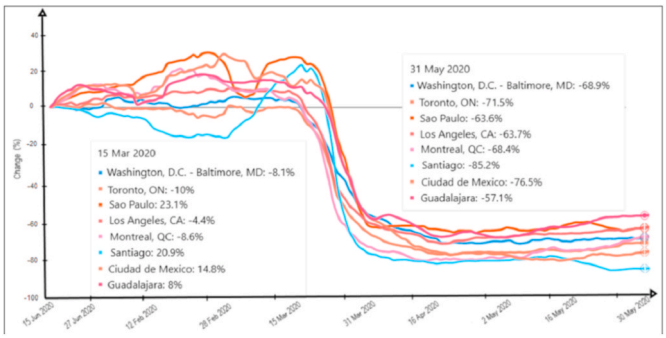

Fig. 4. Public transit usage from January to May in the USA, Canada, Brazil, Chile, and Mexico.
(source: www.moovit.com).

Territories and provinces have, to diverse levels, applied daycare and school closures, prohibitions on events, closures of non-necessary companies, limitations on entry, and mandatory self-isolation for travelers (Chounard, 2020; CTV News, 2020). Based on the Moovit calculations, demand for public transit in Toronto and Montreal communities began to drop from 18 March when the government announced specific measurements about coronavirus. This percentage continued to decline until 13 April when public transit ridership reached to around −77% in Toronto and −80% in Montreal. As shown in Fig. 4, this trend gradually improved until the end of May when public transit ridership reaches −60% and −50% in Toronto and Montreal, respectively.

On 26 February and 16 March, Brazil's initial VOVID-19 case and death were verified and the government announced a state of emergency (Aljazeera, 2020a; BBC News, 2020a). As precautionary measures, they closed non-necessary stores and services (gyms, shopping malls, hotels, restaurants) and halted public transportation, inter-state and inter-city buses, public conferences, theatres, concerts, religious services, and sports events. The State of Sao Paulo announced wide quarantine in which all non-essential services and commerce were to close from 24 March until 7 April and it was later extended (Gardaworld, 2020; Holland and Caldas, 2020). As shown in Fig. 4, the percentage of public transit ridership in Sao Paulo suddenly decreased, when lockdown imposed until the end of March, to approximately −63% and it had a little fluctuation till the end of May.

The coronavirus was verified to have reached Mexico in February, and the first case and death were confirmed on 28 February and 19 March, respectively (Dogantekin, 2020; Muhammed and Busra, 2020). Accordingly, the government published that almost all civic and sporting events, as well as universities and schools from 18 March, would be canceled. As a preventive measure, the government also announced that the Easter break would be prolonged until 20 April as well as nightclubs, bars, museums, and movie theaters were closed (Eluniversal, 2020a, 2020b). As shown in Fig. 4, although the percentage of public transit ridership in Ciudad de Mexico and Guadalajara had fluctuated from January until mid of March, it drastically declined from 19 March until 15 April to around −77% and −68%, respectively.

The COVID-19 was verified to have reached Chile in March. The initial case verified took place on 3 March and then on 21 March the initial fatality occurred (The Canadian Press, 2020; US News, 2020). The cases focused on the Greater Santiago region, and then it broke out in other parts of the country. In May, the entire city of Santiago was put under obligatory lockdown because of an increase in coronavirus cases (Roser et al., 2020). As shown in Fig. 4, the percentage of public transit usage gradually decreased by 15% from January until the last week of February and then it increased until mid of March. Because of the lockdown announcement by the government on 16 March, it dramatically decreased to around −80% until 11 of April. After this date, public transit usage did not change until the end of May due to lockdown measurements in the country.

In general, besides riders preventing journeying to public areas, a further reason for the severe reduces in public transportation utilization is that numerous of the nations hit toughest by the coronavirus have enforced strict suspends on shopping, sporting and cultural events, and the like. Public transit is still an essential part of billions of human lifestyles, and transit organizations worldwide are revamping their sanitization attempts to maintain employees and riders safe. Azienda Trasporti dell'Area Fiorentina (ATAF) and BusItalia have both forbidden utilizing the front doors to access and get off the bus to maintain drivers safety. Tickets can just be bought via self-service stations, offices, and ticketing apps in order to decrease the danger of viruses, and travelers are supposed to keep their distance from each other based on the national regulations. Metropolitan Transportation Authority (MTA) in New York with a yearly customer of 1.68 billion, has been using additional sanitization attempts utilizing specific cleaning services to the wiping its areas daily, and its whole fleet at least every 72 h. In other countries, people have been requested to avoid utilizing public transit except from the cases of emergency. The government has terminated service to universities, schools, and recreation and entertainment places since they are temporarily shut down anyway. In addition, cash is no longer permitted to pay for fares, and the first two rows of buses were closed from the public utilities to decrease the danger for drivers (Moovit, 2020).

3.2. Air quality index

The AQI is actually utilized to evaluate the condition of air quality and its effect on individual health. Table 3 shows the AQI values and their percentages during lockdown 2020 as well as the same time in 2019 in the USA, Brazil, and Mexico. In Washington, USA, the daily AQI during lockdown 2020 for class I ranged 38 followed by classes II = 52-97, III = 104-149, IV = 151-157, V = 0, and VI = 0. In 2019, the daily AQI for class I ranged from 36 to 50 followed by classes II = 55-100, III = 102-142, IV = 151-156, V = 0, and VI = 0. In Los Angeles, AQI during lockdown 2020 for class I ranged 0-50 followed by classes II = 59-99, III = 104-147, IV = 152-160, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I ranged 0 followed by classes II = 52-99, III = 102-144, IV = 151-159, V = 0, and VI = 0. These values and its percentages demonstrate that although the values of AQI (class IV) during lockdown 2020 in Washington did not change significantly, it has improved in Los Angeles where the percentage of classes I and II increased by nearly 21% and 5% as well as the same percentages decreased for classes III, IV.

In Sao Paulo, Brazil (Table 3) the values of AQI within lockdown 2020 for class I ranged 18-48 followed by class II = 65-95, class III = 102-149, class IV = 151-174, class V = 0, and class VI = 0. These magnitudes show that the percentage of class IV during lockdown decreased by around 19% in comparison with the same period in 2019 and other values for classes I, II and III increased by 9%, 7%, and 3%, respectively, which means AQI improved.

In Ciudad de Mexico, the daily AQI during lockdown 2020 for class I ranged 0 followed by classes II = 96, III = 109-149, IV = 151-193, V = 211, and VI = 0. In 2019, the daily AQI for class I ranged 0 followed by classes II = 0, III = 126, IV = 151-200, V = 201-211, and VI = 0. In Guadalajara, AQI during lockdown 2020 for class I ranged 0-50 followed by classes II = 51-87, III = 115-125, IV = 0, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I ranged 0-50 followed by classes II = 51-94, III = 108-129, IV = 159, V = 210-251, and VI = 0. These magnitudes show that during lockdown 2020 the percentage of classes IV and V in Ciudad de Mexico in comparison with the same period in 2019 decreased by around 6% as well as the percentage of classes II and III increased by 3% and 10%, respectively. Similarly, in Guadalajara, AQI improvement took place where the percentage of classes II, III, IV, and V during lockdown 2020 decreased by around 6%, 1.5%, 1%, and 2.5%, and the percentage of class I increased by 11%.

These values demonstrate that the daily AQI in the USA, Brazil and

Table 3
Values of AQI classes in USA, Brazil and Mexico within the lockdown 2020 and during the same time in 2019.

Year	Country/City		Class I		Class II		Class III		Class IV		Class V		Class VI	
			Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.
2020	USA	Washington	1.4	38	43.1	52–97	50	104–149	5.5	151–157	–	–	–	–
		Los Angeles	20.8	0–50	45.8	59–99	22.2	104–147	11.2	152–160	–	–	–	–
	Mexico	Ciudad de Mexico	–	–	2.6	96	11.5	109–149	84.6	151–193	1.3	211	–	–
		Guadalajara	85.9	0–50	11.5	51–87	2.6	115–125	–	–	–	–	–	–
	Brazil	Sao Paulo	15.8	18–48	15.8	65–95	38.2	102–149	30.2	151–174	–	–	–	–
2019	USA	Washington	12.5	36–50	59.7	55–100	23.6	102–142	4.2	151–156	–	–	–	–
		Los Angeles	–	–	40.3	52–99	43.1	102–144	16.6	151–159	–	–	–	–
	Mexico	Ciudad de Mexico	–	–	–	–	1.3	126	91.0	151–200	7.7	201–211	–	–
		Guadalajara	74.3	0–50	17.9	51–94	3.9	108–129	1.3	159	2.6	210–251	–	–
	Brazil	Sao Paulo	6.6	32–35	9.2	72–100	35.5	105–147	48.7	151–174	–	–	–	–

Note: Per = Percentage, Rg. = Ranges.

Mexico during lockdown 2020 in comparison with the same period in 2019 improved because the percentage of classes I and II were estimated to be more than other classes. This was because of specific restriction rules that were announced by governments to prevent utilizing the different modes of public transport during COVID-19.

Table 4 displays the AQI values and their percentages during lockdown 2020 as well as the same time for 2019 in Canada, Chile, and Germany. In Toronto, Canada, the daily AQI during lockdown 2020 for class I ranged 0 followed by classes II = 52-99, III = 102-147, IV = 151-154, V = 0, and VI = 0. In 2019, the daily AQI for class I ranged 50 followed by classes II = 52-92, III = 104-147, IV = 152-163, V = 0, and VI = 0. In Montreal, AQI during lockdown 2020 for class I ranged 0 followed by classes II = 66-99, III = 102-144, IV = 0, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I ranged 0 followed by classes II = 61-97, III = 102-134, IV = 152, V = 0, and VI = 0. These percentages demonstrate that although the values of AQI during lockdown 2020 in Toronto did not change significantly, it has improved in Montreal where the percentage of classes III and IV decreased by nearly 15% and 10% as well as the percentages of class II increased by 25%, respectively.

In Santiago, Chile, the values of AQI within lockdown 2020 for class I ranged 39 followed by class II = 52-99, class III = 124-147, class IV = 151-186, class V = 204-264, and class VI = 0. These magnitudes show that although there was no major change for class IV, other classes had AQI improvement which was around 1.5% for class I, 5% for class II, 3.9% for class III.

In Berlin, Germany, the daily AQI during lockdown 2020 for class I ranged from 19 to 48 followed by classes II = 51-53, III = 0, IV = 0, V = 0, and VI = 0. In 2019, the daily AQI for class I ranged from 21 to 50 followed by classes II = 54, III = 0, IV = 0, V = 0, and VI = 0. In Munich, AQI during lockdown 2020 for class I ranged 25-50 followed by classes II = 54-64, III = 0, IV = 0, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I ranged from 29 to 50 followed by classes II = 51-58, III = 0, IV = 0, V = 0, and VI = 0. These magnitudes show that although the values of AQI during lockdown 2020 did not change in Berlin, it has improved in Munich where the percentage of class I increased by nearly 24%.

As described above, these values and comparisons clarify that the daily AQI in Canada, Chile, and Germany during lockdown 2020 in comparison with the same period in 2019 improved because of COVID-19 and its restriction rules that were announced by governments.

Table 5 shows the AQI values and their percentages throughout lockdown 2020 as well as during the same time in 2019 in Spain, France, and the UK. In Barcelona, Spain the daily AQI during lockdown 2020 for class I ranged 15-41, and classes II until VI ranged 0. In 2019, the daily AQI for class I ranged from 15 to 43. In Madrid, AQI during lockdown 2020 for class I ranged 0 followed by classes II = 76-99, III = 102-149, IV = 151-179, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I ranged 0 followed by classes II = 61-99, III = 102-144, IV = 151-168, V = 0, and VI = 0. These percentages demonstrate that the values of AQI during lockdown 2020 did not change in Barcelona while in Madrid, although the percentage of AQI for class II decreased by around 38%, it improved 23% for class III.

In Paris, France, the values of AQI within lockdown 2020 for class I ranged 0 followed by class II = 92-97, class III = 102-149, class IV = 151-188, class V = 0, and class VI = 0. In Marseille, the values of AQI within lockdown 2020 for class I ranged 0 followed by class II = 71-97, class III = 102-149, class IV = 151-163, class V = 0, and class VI = 0. These magnitudes show that during lockdown 2020 in Paris the percentage of classes II and III improved by around 7% and 11% while in Marseille, the percentage of AQI for classes II improved around 5%.

In London, the UK, the daily AQI during lockdown 2020 for class I ranged 0 followed by classes II = 84-99, III = 102-149, IV = 151-182, V = 0, and VI = 0. In 2019, the daily AQI for class I ranged 0 followed by classes II = 86-97, III = 104-149, IV = 151-191, V = 0, and VI = 0. In the West Midlands, the UK, AQI during lockdown 2020 for class I ranged 45 followed by classes II = 36-57, III = 107-147, IV = 151-172, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I

Table 4
Values of AQI classes in Canada, Chile and Germany within the lockdown 2020 and during the same time in 2019.

Year	Country/City		Class I		Class II		Class III		Class IV		Class V		Class VI	
			Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.
2020	Canada	Toronto	–	–	69.3	52–99	22.7	102–147	8.0	151–154	–	–	–	–
		Montreal	–	–	82.7	66–99	17.3	102–144	–	–	–	–	–	–
	Chile	Santiago	1.3	38	11.7	52–99	3.9	124–147	79.2	151–186	3.9	204–264	–	–
	Germany	Berlin	96.2	19–48	3.8	51–53	–	–	–	–	–	–	–	–
		Munich	92.4	25–50	7.6	54–64	–	–	–	–	–	–	–	–
2019	Canada	Toronto	1.3	50	62.7	52–92	28.0	104–147	8.0	152–163	–	–	–	–
		Montreal	–	–	57.3	61–97	32.0	102–134	10.7	152	–	–	–	–
	Chile	Santiago	–	–	6.5	66–87	–	–	77.9	151–200	14.3	204–264	1.3	306
	Germany	Berlin	98.1	21–50	1.9	54	–	–	–	–	–	–	–	–
		Munich	67.9	29–50	32.1	51–58	–	–	–	–	–	–	–	–

Note: Per. = Percentage, Rg. = Ranges.

Table 5
Values of AQI classes in Spain, France and the UK within the lockdown 2020 and during the same time in 2019.

Year	Country/City		Class I		Class II		Class III		Class IV		Class V		Class VI	
			Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.
2020	Spain	Barcelona	100	15–41	–	–	–	–	–	–	–	–	–	–
		Madrid	–	–	12.1	76–99	56.6	102–149	31.3	151–179	–	–	–	–
	France	Paris	–	–	7.0	92–97	42.1	102–149	50.9	151–188	–	–	–	–
		Marseille	–	–	29.8	71–97	40.4	102–149	29.8	151–163	–	–	–	–
	UK	London	–	–	16.4	84–99	49.3	102–149	34.3	151–182	–	–	–	–
		West Midlands	1.5	45	53.7	36–57	23.9	107–147	20.9	151–172	–	–	–	–
2019	Spain	Barcelona	100	15–41	–	–	–	–	–	–	–	–	–	–
		Madrid	–	–	50.6	61–99	33.7	102–144	15.7	151–168	–	–	–	–
	France	Paris	–	–	–	–	31.6	102–147	68.4	152–181	–	–	–	–
		Marseille	–	–	24.6	82–99	68.4	102–144	7.0	152–166	–	–	–	–
	UK	London	–	–	13.4	86–97	31.3	104–149	55.3	151–191	–	–	–	–
		West Midlands	–	–	47.8	57–99	26.9	102–149	25.3	151–187	–	–	–	–

Note: Per. = Percentage, Rg. = Ranges.

ranged 0 followed by classes II = 57-99, III = 102-149, IV = 151-187, V = 0, and VI = 0. These magnitudes show that during lockdown 2020 in London in comparison with the same period in 2019, the percentage of classes II and III increased by around 3% and 18%, respectively. Similarly, in the West Midlands, AQI improvement took place where the percentage of classes I and II increased by 1.5% and 6%, respectively. These values demonstrate that the daily AQI in Spain, France, and the UK during lockdown 2020 in comparison with the same period in 2019 improved because the percentage of classes I, II, and III were estimated to be more than other classes.

Table 6 displays the AQI values and their percentages during lockdown 2020 as well as the same period in 2019 in Italy, Sweden, and Turkey. In Roma, Italy, the daily AQI during lockdown 2020 for class I ranged 18-38 followed by classes II = 52-97, III = 107-149, IV = 151-160, V = 0, and VI = 0. In 2019, the daily AQI for class I ranged 22 followed by classes II = 61-97, III = 107-149, IV = 151-168, V = 0, and VI = 0. In Milan, AQI during lockdown 2020 for class I ranged from 19 to 31 followed by classes II = 56-97, III = 107-149, IV = 151-181, V = 0, and VI = 0. One year before this period in 2019, the daily AQI for class I ranged 30 followed by classes II = 69-97, III = 107-149, IV = 151-181, V = 0, and VI = 0. These magnitudes show that during the lockdown in Roma in comparison with the same period in 2019, the percentage of class I and also class II increased by around 6% and 15%, respectively. In addition, during lockdown 2020 in Milan, although these percentages for classes I and II had no major change, it decreased by 14% for class III.

In Stockholm, Sweden, the values of AQI within lockdown 2020 for class I ranged 18-50 followed by class II = 53-100, class III = 102-141, class IV = 151-153, class V = 0, and class VI = 0. These magnitudes show that although the percentage of AQI for class II during lockdown 2020 had no change, class I shows a huge improvement and increased to be around 30%.

In Ankara, Turkey, the daily AQI during lockdown 2020 for class I ranged 0 followed by classes II = 57-99, III = 102-144, IV = 151-161, V = 0, and VI = 0. In 2019, the daily AQI for class I ranged 0 followed by classes II = 76-88, III = 104-147, IV = 151-176, V = 0, and VI = 0. In Istanbul, AQI during lockdown 2020 for class I ranged 35-50 followed by classes II = 54-100, III = 107-150, IV = 152-173, V = 0, and VI = 0. One year before this period, the daily AQI for class I ranged 0 followed by classes II = 0, III = 129, IV = 155, V = 217-291, and VI = 306-349. These magnitudes show that the percentage of AQI in Ankara during lockdown 2020 improved where class II increased by 12%. In addition, these values in Istanbul significantly improved where classes V and VI decreased around 91% and 5% while classes I, II, III, and IV increased nearly 7%, 14%, 25%, and 50%, respectively.

As described above, these values and comparisons clarify that the daily AQI in Italy, Sweden, and Turkey during lockdown 2020 in comparison with the same period in 2019 improved because of COVID-19 and its restriction rules that were announced by governments.

3.2.1. *Indicatory air pollutants*

Throughout the following section, the indicatory air pollutants for air quality index for all 12 countries during lockdown 2020 in comparison with the same period in 2019 were also assessed. In this regard, the average levels regarding NO_2, PM10, PM2.5, CO, O_3, and SO_2 throughout these two time periods are described and compared.

Table 7 shows the values of averages and ranges of indicatory air pollutants during lockdown 2020 and one year before in 2019 for the USA, Mexico, Brazil, Canada, Chile, and Germany. During lockdown 2020 in Washington, USA, the maximum indicatory air pollutant was related to the PM2.5 which was ranged and averaged 9-67 (μg m-3) and 37.37 (μg m-3), respectively. The mention concentration in 2019 was in the range of 9–65 (μg m-3) and averaged 28.2 (μg m-3). In general, during lockdown 2020, the averages of CO, SO_2, and O_3 decreased by 30%, 3%, and 10%, respectively. During lockdown 2020 in Los Angeles, the highest indicatory air pollutant was associated with the O_3 which was ranged 16-79 (ppb) and averaged 42.48 (ppb) while in 2019, the

Table 6
Values of AQI classes in Italy, Sweden and Turkey within the lockdown 2020 and during the same time in 2019.

Year	Country/City		Class I		Class II		Class III		Class IV		Class V		Class VI	
			Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.	Per. (%)	Rg.
2020	Italy	Roma	7.2	18–38	54.2	52–97	25.3	107–149	13.3	151–160	–	–	–	–
		Milan	3.6	19–31	21.7	56–97	27.7	107–149	47	151–181	–	–	–	–
	Sweden	Stockholm	31.7	18–50	61	53–100	4.9	102–141	2.4	151–153	–	–	–	–
	Turkey	Ankara	–	–	19.3	57–99	29.8	102–144	50.9	151–161	–	–	–	–
		Istanbul	7.1	35–50	14.0	54–100	26.3	107–150	52.6	152–173	–	–	–	–
2019	Italy	Roma	1.2	22	39.8	61–97	34.9	107–149	24.1	151–168	–	–	–	–
		Milan	1.2	30	22.9	69–97	41.0	107–149	34.9	151–181	–	–	–	–
	Sweden	Stockholm	1.2	7–50	61	55–99	25.6	102–149	12.2	151–170	–	–	–	–
	Turkey	Ankara	–	–	7.0	76–88	43.9	104–147	49.1	151–176	–	–	–	–
		Istanbul	–	–	–	–	1.7	129	1.8	155	91.2	217–291	5.3	306–349

Note: Per. = Percentage, Rg. = Ranges.

Table 7
Indicatory air pollutants values for USA, Brazil, Mexico, Canada, Chile and Germany.

Year	Cities	PM2.5		PM10		SO2		CO		NO2		O3	
		Rg.	Av.	Rg.	Av.	Rg.	Av.	Rg.	Av.	Rg.	Av.	Rg.	Av.
2020	Washington	9–67	37.37	4–43	16.76	1–2	1.02	1–5	1.9	1–13	5.26	11–44	31.21
	Los Angeles	12–73	35.96	10–31	22.43	–	–	1–4	1.55	1–12	5.1	16–79	42.48
	Sao Paulo	19–101	51.33	–	–	–	–	–	–	–	–	12–56	30.01
	Ciudad de Mexico	46–128	78.78	23–63	41.34	1–22	4.15	8–17	10.83	11–36	21.85	18–101	68.23
	Guadalajara	–	–	15–48	30.37	–	–	1–4	2.19	6–22	13.62	19–78	45.25
	Toronto	13–61	33.56	–	–	–	–	1–3	1.33	4–28	12.11	21–49	31.33
	Montreal	8–53	24.94	–	–	5–12	5.73	–	–	3–16	6.85	16–37	24.51
	Santiago	5–150	68.35	39–96	68.14	–	–	1–25	7.08	6–36	18.72	5–53	29.91
	Berlin	–	–	8–60	27.01	–	–	–	–	5–33	18.71	20–55	33.45
	Munich	–	–	8–62	22.79	1–2	1.42	–	–	2–43	21.66	20–59	38.15
2019	Washington	9–65	28.28	2–36	15.02	1–2	1.05	1–8	2.69	–	–	8–45	34.4
	Los Angeles	13–70	38.95	10–39	21.57	–	–	1–5	2.72	1–15	6.71	27–59	42.43
	Sao Paulo	22–101	56.81	–	–	–	–	–	–	–	–	5–70	27.56
	Ciudad de Mexico	38–161	89.39	7–80	49.46	1–24	7	4–12	7.33	12–45	28.53	4–113	69.94
	Guadalajara	–	–	20–57	34.89	–	–	1–23	3.73	8–45	18.49	20–70	45.11
	Toronto	12–79	32.32	–	–	1–3	1.86	1–4	2.24	4–28	12.49	22–40	31.85
	Montreal	7–58	27.95	–	–	5–30	7.03	6–7	6.01	4–21	9.63	–	–
	Santiago	5–150	81.6	19–138	74.8	–	–	1–31	10.55	16–85	35.7	3–51	21.56
	Berlin	–	–	9–62	26.2	–	–	–	–	12–33	22.35	11–54	32.92
	Munich	–	–	8–45	23	3–41	29.01	–	–	12–43	25.71	20–52	35.83

Note: Rg. = Ranges, Av. = Average.

highest indicatory air pollutant was PM2.5 = 13-70 (μg m^{-3}) with averaged 39.0 (μg m^{-3}). Depending on this analysis, during lockdown 2020 the averages of NO_2, CO and PM2.5 declined by 24%, 43%, and 8%, respectively.

In Sao Paulo, Brazil, the maximum concentrations were estimated for PM2.5 = 19-101 (μg m^{-3}) during lockdown 2020 and averaged 51.3 (μg m^{-3}). In 2019, it was found that PM2.5 = 22-101 (μg m^{-3}) and averaged 56.8 (μg m^{-3}). During the lockdown, the average PM2.5 decreased by 10%.

In Ciudad de Mexico, the maximum indicatory air pollutant during lockdown was related to the PM2.5 which was ranged and averaged 46-128 (μg m^{-3}) and 78.8 (μg m^{-3}), respectively. The said concentration in 2019 was in the range of 38–161 (μg m-3) and averaged 89.4 (μg m-3). According to this analysis, during lockdown 2020, all concentrations except CO decreased by 12% for PM2.5, 16% for PM10, 41% for SO_2, 24% for NO_2, and 3% for O_3. During lockdown in Guadalajara, Mexico, the maximum indicatory air pollutant was related to the O_3 which was ranged from 19 to 78 (ppb) and averaged 45.3 (ppb). This concentration in 2019 was in the ranged of O3 = 20-70 (ppb) and averaged 45.1 (ppb). Accordingly, during the lockdown, the average CO and NO_2 decreased by 42% and 26%, respectively.

In Toronto, Canada, the maximum indicatory air pollutant was associated with the PM2.5 = 13-61 (μg m^{-3}) during the lockdown and averaged 33.6 (μg m^{-3}). In 2019, it was detected that PM2.5 = 12-79 (μg m^{-3}) and averaged 32.3 (μg m^{-3}). Accordingly, during the lockdown, the averages of CO, NO_2, and O_3 reduced by 41%, 4%, and 2%, respectively. In Montreal, the maximum indicatory air pollutant was associated with the PM2.5 = 8-53 (μg m^{-3}) and averaged 24.9 (μg m^{-3}). In 2019, it was detected that PM2.5 = 7-58 (μg m^{-3}) and averaged 28.0 (μg m^{-3}). In general, the averages of NO_2, SO_2, and PM2.5 during lockdown decreased by 29%, 19%, and 11%, respectively.

In Santiago, Chile, the PM2.5 as the highest indicatory air pollutant, during the lockdown, was ranged from 5 to 150 (μg m^{-3}) and averaged 68.4 (μg m^{-3}). The said concentration in 2019 was in the ranges of 5–150 (μg m^{-3}) and averaged 82.0 (μg m^{-3}). In general, during the lockdown, the averages of PM10, PM2.5, NO_2, and CO reduced by 9%, 17%, 48%, and 33%, respectively.

In Berlin, Germany, the maximum indicatory air pollutant, during the lockdown, was associated with the PM10 = 8-60 (μg m^{-3}) and averaged 27.0 (μg m^{-3}). The mentioned concentration in 2019 was in the ranges of 9–62 (μg m^{-3}) and averaged 26.2 (μg m^{-3}). Depending on this analysis, during the lockdown, the average of NO_2 decreased by 17%. In Munich, the highest indicatory air pollutant, throughout lockdown, was associated with the PM10 ranged 8-62 (μg m^{-3}) and averaged 23.0 (μg m^{-3}). The mentioned concentration in 2019 was in the ranges of 8–45 (μg m^{-3}) and averaged 23.0 (μg m^{-3}). In general, during the lockdown, the averages of PM10, SO_2, and NO_2 decreased by 1%, 95%, and 16%, respectively.

Table 8 shows the values of averages and ranges of indicatory air pollutants during lockdown 2020 and one year before in 2019 for Spain, France, UK, Italy, Turkey, and Sweden. During lockdown 2020 in Barcelona, Spain, the maximum indicatory air pollutant was related to the O3 ranged 17-44 (ppb) and averaged 32.3 (ppb). The said concentration in 2019 was in the range of 18–52 (ppb) and averaged 31.0 (ppb). Accordingly, during the lockdown, the averages of PM10 and NO2 decreased by 20% and 54%, respectively. During lockdown in Madrid, the maximum indicatory air pollutant was related to the PM2.5 ranged 24-109 (μg m^{-3}) and averaged 50.0 (μg m^{-3}). The said concentration in 2019 was in the range of 17–89 (μg m^{-3}) and averaged 39.0 (μg m^{-3}). In general, during the lockdown, the averages of O_3, NO_2, and SO_2 reduced by 15%, 58% and 53%, respectively.

In Paris, France, the highest indicatory air pollutant, during the lockdown, was associated with the PM2.5 ranged 22-128 (μg m^{-3}) and averaged 57.2 (μg m^{-3}). The mentioned concentration in 2019 was in the range of 36–113 (μg m^{-3}) and averaged 70.0 (μg m^{-3}). Accordingly, during the lockdown, the averages of NO_2, PM10, and PM2.5 decreased by 45%, 40%, and 18%, respectively. Throughout lockdown in Marseille, the highest indicatory air pollutant was associated with the PM2.5 ranged 8-79 (μg m^{-3}) and averaged 41.2 (μg m^{-3}). The mentioned concentration in 2019 was in the range of 10–84 (μg m^{-3}) and averaged 33.2 (μg m^{-3}). In general, throughout lockdown, the averages of O_3 and NO_2 were reduced by 4% and 50%.

During lockdown in London, the UK, the maximum indicatory air pollutant was related to the PM2.5 range 26–115 (μg m^{-3}) and averaged 51.0 (μg m^{-3}). The said concentration in 2019 was in the range of 26–133 (μg m^{-3}) and averaged 59.0 (μg m^{-3}). Accordingly, during the lockdown, the averages of CO, PM10, PM2.5, and NO_2, reduced by 59%, 13%, 14%, and 42%, respectively. During lockdown in West Midlands, the PM2.5 ranged from 11 to 97 (μg m^{-3}) and averaged 39.0 (μg m^{-3}). The said level in 2019 was in the range of 15–125 (μg m^{-3}) and averaged 46.0 (μg m^{-3}). In general, during the lockdown, the averages of NO_2, PM10, PM2.5, and O_3 decreased by 50%, 16%, 15%, and 9%, respectively.

In Roma, Italy, the highest indicatory air pollutant, during the

Table 8
Indicatory air pollutants values for Spain, France, UK, Italy, Turkey and Sweden.

Year	Cities	PM2.5		PM10		SO2		CO		NO2		O3	
		Rg.	Av.	Rg.	Av.	Rg.	Av.	Rg.	Av.	Rg.	Av.	Rg.	Av.
2020	Barcelona	–	–	6–34	17.88	–	–	–	–	4–24	10.13	17–44	32.33
	Madrid	24–109	50.01	8–45	17.56	1–3	1.87	–	–	2–17	9.17	22–51	33.73
	Paris	22–128	57.17	14–58	27.77	–	–	–	–	6–44	23.07	16–55	36.54
	Marseille	8–79	41.19	5–31	15.37	–	–	–	–	1–13	5.41	17–54	37.07
	London	26–115	50.47	12–54	24.23	1–11	4.2	2–7	3.08	6–32	18.23	21–49	34.11
	Birmingham	11–97	38.94	5–42	15.29	–	–	–	–	1–12	4.08	23–49	33.61
	Roma	9–74	36.13	6–58	21.47	–	–	–	–	1–17	8.08	10–30	21.36
	Milan	17–114	57.22	9–67	24.07	–	–	–	–	8–49	22.07	–	–
	Ankara	15–76	50.1	14–51	28.37	1–6	2.87	1–13	4.17	7–33	19.7	9–29	16.61
	Istanbul	16–99	62.37	11–120	31.91	1–6	1.89	1–4	1.8	4–52	20.78	5–23	13.66
	Stockholm	7–60	18.52	3–47	17.14	–	–	–	–	2–13	6.72	–	–
2019	Barcelona	–	–	10–35	22.4	1–2	1.12	–	–	9–39	22.13	18–52	30.69
	Madrid	17–89	38.58	7–40	16.34	2–6	3.98	–	–	7–45	21.87	24–59	39.59
	Paris	36–113	69.77	19–110	46.42	–	–	–	–	26–63	41.61	18–52	32.54
	Marseille	10–84	33.22	5–52	15.03	1–2	1.05	–	–	2–25	10.75	27–52	38.66
	London	26–133	58.59	12–57	27.89	1–9	2.09	3–12	7.44	13–52	31.62	16–61	31.4
	Birmingham	15–125	45.49	6–53	18.29	–	–	–	–	1–18	7.41	21–77	36.77
	Roma	17–89	42.49	6–70	19.02	–	–	–	–	8–26	16.87	10–30	20.1
	Milan	21–114	52.57	10–53	22.87	–	–	–	–	7–50	21.26	–	–
	Ankara	23–104	56.53	13–190	39.26	1–21	2.89	4–12	8.11	6–23	10.71	1–5	1.94
	Istanbul	17–299	60.36	20–167	46.98	3–24	8.31	7–35	22.49	11–58	27.44	4–51	31.29
	Stockholm	10–93	34.56	3–83	31.01	–	–	–	–	4–24	11.24	–	–

Note: Rg. = Ranges, Av. = Average.

lockdown, was associated with the PM2.5 range 9–74 (μg m^{-3}) and averaged 36.1 (μg m^{-3}). The mentioned concentration in 2019 was in the range of 17–89 (μg m^{-3}) and averaged 42.5 (μg m^{-3}). Accordingly, during the lockdown, the averages of NO2 and PM2.5 reduced by 52% and 15%, respectively. Throughout lockdown in Milan, the PM2.5 ranged from 17 to 114 (μg m^{-3}) and averaged 57.2 (μg m^{-3}). The mentioned concentration in 2019 was in the range of 21–114 (μg m^{-3}) and averaged 53.0 (μg m^{-3}). In general, during the lockdown, the averages of NO2, PM10, and PM2.5 raised slowly by 3%, 5%, and 8%, respectively.

In Ankara, Turkey, the maximum indicatory air pollutant, during the lockdown, was related to the PM2.5 range 15–76 (μg m^{-3}) and averaged 50.1 (μg m^{-3}). The said concentration in 2019 was in the range of 23–104 (μg m^{-3}) and averaged 57.0 (μg m^{-3}). Accordingly, during the lockdown, the averages of PM2.5, SO_2, PM10, and CO decreased by 11%, 1%, 28%, and 49%, respectively. During lockdown in Istanbul, the maximum indicatory air pollutant was related to the PM10 range 11–120 (μg m^{-3}) and averaged 32.0 (μg m^{-3}). The said concentration in 2019 was in the range of 20–167 (μg m^{-3}) and averaged 47.0 (μg m^{-3}). In general, during the lockdown, the averages of CO, SO_2, PM10, NO_2, and O_3 decreased by 92%, 77%, 32%, 24%, and 56%, respectively.

From the first death due to coronavirus in Stockholm, Sweden, the highest indicatory air pollutant was associated with PM2.5 ranged 7-60 (μg m^{-3}) and averaged 18.5 (μg m^{-3}). In 2019, it was detected that PM2.5 = 10-93 (μg m^{-3}) and averaged 35.0 (μg m^{-3}). In general, during the lockdown, the averages of NO_2, PM10, and PM2.5 decreased by 40%, 45%, and 46%, respectively.

3.3. Comparison between current and similar research

In a research conducted by Xu et al. (2020) investigated, assessed, and compared the effect of the coronavirus on AQI in China during lockdown as well as 2017 to 2019. The outcomes revealed that throughout February 2020, the average indicatory air pollutant of PM10, PM2.5, NO_2, CO, and SO_2 were lower than those in a similar month from 2017 until 2019. According to the distribution of the combined AQIs during the lockdown, the overall amounts of classes I and II raised to 41%, whereas the combined amounts of classes IV, V, and VI decreased up to 14.0%. It is obvious that throughout the lockdown, the AQI around central China enhanced considerably.

Gautam (2020) reported that the main negative impact on the surrounding environment and public has been revealed because of coronavirus, nevertheless, a positive impact has also been discovered regarding AQI. Supplementary outcomes have been obtained through the National Aeronautics and Space Administration (NASA), showing a substantial decrease, around 50%, in the AQI of the Indian area. This specific perspective illustrates the impact of the restricted regulation because of coronavirus on aerosol optical thickness, particularly in India. Yongjian et al. (2020) discovered that there is a substantial connection between AQI and coronavirus infection, which could moderately describe the impact of lockdown and offer implications for the management and avoidance of this particular new infectious disease.

In the current research, results demonstrated that the average values of AQI in the 12 countries within lockdown 2020 for classes I, II, and III increased by 12%, 9%, and 13% while for classes IV, V, and VI decreased by 10%, 27%, and 3% in comparison with the identical time throughout 2019. The results also indicate that throughout lockdown 2020, in the 12 countries, the percentages of indicatory air pollutants of PM2.5, PM10, SO_2, CO, and NO_2 decreased by 16%, 21%, 41%, 48%, and 35% in comparison with 2019.

Aloi et al. (2020) evaluated the effect of quarantine enforced in Spain on metropolitan mobility. The evaluation pointed out a general mobility drop of 76%, becoming less essential regarding the personal vehicle. Public transport usage decreased by approximately 93%, indicatory air pollutants of NO_2 decreased by around 60%, and traffic incidents decreased by approximately 67% in relative conditions. Zheng et al. (2020) discovered a substantial and positive relationship between the volume of buses, trains, and flights from Wuhan and the daily as well as the cumulative quantities of coronavirus conditions in other urban centers with gradually raised correlations for buses and trains.

The results and comparisons in the current research demonstrated that the lockdowns of 12 countries led to dramatically decreased human movements and public transit usage up to −90% until the end of March and it had no major changes until the end of May. In general, mechanism analysis and comparisons highlighted that the lockdowns of 12 countries led to decreased human mobility and improvement in the AQI around the world.

4. Conclusion

This study seeks to consider the impact of coronavirus lockdown on the public transportation usage and ambient air quality i.e. both AQI and indicatory air pollutants in 12 countries. In order to consider how quantities of public transit usage have decreased in various urban areas globally during the lockdown, appropriate statistic data are extracted from the Moovit platform. Regarding ambient air quality, the daily air quality index is generally computed depending upon the whole day average levels for SO_2, CO, NO_2, PM10, PM2.5 as well as the daily average value of 8-h highest level for O3. To assess AQI status for selected countries during the lockdown 2020 and one year before, during the same period, data were collected manually from World's Air Pollution. The results show that the public transit usage during the lockdown in comparison with one year before estimated almost −87% for Madrid, −78% for Barcelona, −86% for Paris and Marseille, −80% for London, −72% for West Midland, −89% for Milan and Roma, −65% for Stockholm, −81% for Ankara and Istanbul. In addition, the public transit usage during lockdown evaluated nearly −76% for Berlin and Munich, −75% for Washington and Los Angeles, −79% for Toronto and Montreal, −63% for Sao Paulo, −77% for Ciudad de Mexico, −68% for Guadalajara and −80% for Santiago.

In the case of AQI classes during the lockdown, the values of AQI did not change in Barcelona but for Madrid, the percentage of AQI improved 23% for class III. In Paris, the percentage of classes II and III increased by around 7% and 11%, while in Marseille, class II increased by around 8%. In London, the percentage of classes II and III increased by around 3% and 18% while in the West Midlands, the percentage of class I increased by 1.5% followed by class II = 6%. In Roma, the percentage values for class I improved by around 6% and class II = 15%. In Stockholm, the percentage of AQI for class I shows a huge improvement which was around 30%. The percentage of AQI in Ankara improved where class II increased by 12%. In Istanbul AQI significantly improved where classes I, II, III, and IV increased by nearly 7%, 14%, 25%, and 50%, respectively. In Munich, the values of AQI improved where the percentage of class I increased by nearly 25%. In Los Angeles, the values of AQI improved where the percentage of classes I and II increased by nearly 21% and 5%, respectively. In Canada, although the values of AQI in Toronto did not change significantly, it has improved in Montreal where the percentages of class II increased by 25%. In Brazil, the percentage of classes I, II, and III increased by 9%, 7%, and 3%, respectively, which means AQI improved. In Mexico, the percentage of classes II and III in Ciudad de Mexico increased by 3% and 8%, while in Guadalajara, AQI improvement took place where the percentage of class I increased by 11%. In Chile, there was a major change for AQI where it was around 1.5% for class I, 5% for class II, and 3.9% for class III.

In the case of indicatory air pollutants during the lockdown, in Barcelona, the averages of PM10 and NO2 decreased by 20% and 54% while in Madrid, the averages of SO_2, NO_2, and O_3 decreased by 53%, 58%, and 15%, respectively. In Paris and Marseille, the averages of PM10, PM2.5, NO_2, and O_3 decreased by 40%, 18% 48%, and 4% respectively. In London and West Midlands, the averages value for PM10, PM2.5, NO_2, decreased by 15%, 14%, 46%, respectively. In Roma, the averages of NO_2 and PM2.5 were reduced by 52% and 15%. In Stockholm, the averages of NO_2, PM10 and PM2.5 reduced by 40%, 45% and 46%, respectively. In Ankara, the averages of PM2.5, PM10, SO_2 and CO decreased by 11%, 28%, 1% and 49%, while in Istanbul, the averages of PM10, SO_2, CO, NO_2 decreased by 32%, 77%, 92%, and 24%, respectively. In Berlin, the average of NO_2 decreased by 17%, while in Munich, the averages of NO_2, SO_2 and PM10 reduced by 1%, 95% and 16%, respectively. In Washington, although the averages of SO_2, CO and O_3 decreased by 3%, 30% and 10%, in Los Angeles, the averages of PM2.5, CO and NO_2 decreased by 8%, 43% and 24%, respectively. In Toronto, the averages of CO, NO_2 and O_3 decreased by 41%, 4% and 2%, while in Montreal, the averages of NO_2, SO_2 and PM2.5 reduced by 29%, 19% and 11%. In Ciudad de Mexico, PM2.5, PM10, SO_2, NO_2 decreased by 12%, 16%, 41% and 24%. In Guadalajara, the averages of CO and NO_2 decreased by 42% and 26%, respectively. In Santiago, the averages for PM10, PM2.5, NO_2, and CO were reduced by 9%, 17%, 48%, and 33%, respectively.

The government in countries, as provided in this research, except Sweden considered increasing precautionary actions such as a ban on private vehicles during the lockdown in cities to decrease the distribution of the COVID-19. Although these restriction rules were announced, they encouraged people to walk, cycle, and utilize public transportation for the necessary situation based on the social contact rules, wear a face covering, and hand sanitization. Since the results of this research showed that the lockdowns have led to dramatically decreased human movements and public transit usage up to −90% until the end of May, it demonstrated that there is a relationship between public transit usage and improving air quality in the mentioned countries during the lockdown.

In general, these kinds of outcomes reveal that there is a substantial association between COVID-19 with public transit usage and ambient air quality, which might partly clarify the influence of the country's lockdown action and offer benefits regarding the management and also avoidance of the mentioned particular new illness. As for upcoming research, more cities in the mentioned countries can be considered for the robust estimation of the effect of COVID-19 lockdown on public transportation and AQI.

Authorship statement

Mohammad Ali Sahraei: Conception and design of study, Acquisition of data, Analysis and/or interpretation of data, Drafting the manuscript, Revising the manuscript critically for important intellectual content, Approval of the version of the manuscript to be published. Emre Kuşkapan: Conception and design of study, Acquisition of data, Analysis and/or interpretation of data, Drafting the manuscript, Revising the manuscript critically for important intellectual content, Approval of the version of the manuscript to be published. Muhammed Yasin Çodur: Conception and design of study, Acquisition of data, Analysis and/or interpretation of data, Drafting the manuscript, Revising the manuscript critically for important intellectual content, Approval of the version of the manuscript to be published.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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