



COVID-19 environmental and operational impact for public transport in Kuwait

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Abstract

The corona virus disease pandemic (COVID-19) is one of the recent issues that spread in the world, which disrupted life, impacted the economy, and led to heavy losses, whether for government sectors or private companies. This paper focuses on the Kuwait public transport company KPTC and Kuwait Airways' experience during the pandemic, since they incurred major losses due to the decline of their users. Public transport is a place to catch COVID-19, as it is subjected to the use of a large number of passengers daily within a small closed environment. The causes that led to the spread of the virus among public transport users and develop solutions to limit its spread and preserve public transport pioneer's safety were discussed in the paper. Additionally, the environmental impact resulting from the reduction of public transportation using was also addressed. Data was obtained from the KPTC, Kuwait Airways office, the Ministry of Health (MOH) database, and the Environment Public Authority (EPA) database. A questionnaire was distributed to public transport users to determine the reasons for the decline in its user's number and their aspirations to reconsider their use and ensure their satisfaction. For airplane data, the risk of importation of COVID-19 was calculated. For KPTC data, COVID-19 impact on the emissions generated per passenger-km was computed where the emissions were estimated by MOVES. The survey responses were statically analyzed using the chi-square test on the SPSS program, and they were compared to numerical analysis results. The results showed the impact of COVID-19 on people's willingness to use public transportation which was associated with the increase in the number of buses to implement social distancing has negatively affected the environment. Thus, a comprehensive strategy solution was presented consisting of three basic approaches: providing a healthy, risk-free environment for public transportation users, achieving social distancing at a low cost to offset the losses, and ensuring a healthy environment.

Keywords COVID-19 · Public transportation · Airplanes · Buses · Environmental impact · Corona pandemic · Database

Introduction

The impact of COVID-19 is noticeable all over the world in all aspects of life. Life as we know it has come to a standstill ever since the World Health Organization declared the disease's spread as a pandemic on the 11th of March 2020. Worldwide, the pandemic posed a significant challenge for public transportation and air travel, resulting in a decline in demand and revenues generated. A survey conducted by

Molloy et al. (2020) showed that public transportation took the hardest blow worldwide, either because of government measures such as restricting travel or by individual choices where people refrained from using public transportation to reduce the probability of their exposure to the virus. Figure 1 shows the variation in the use of public transportation in different countries of the world.

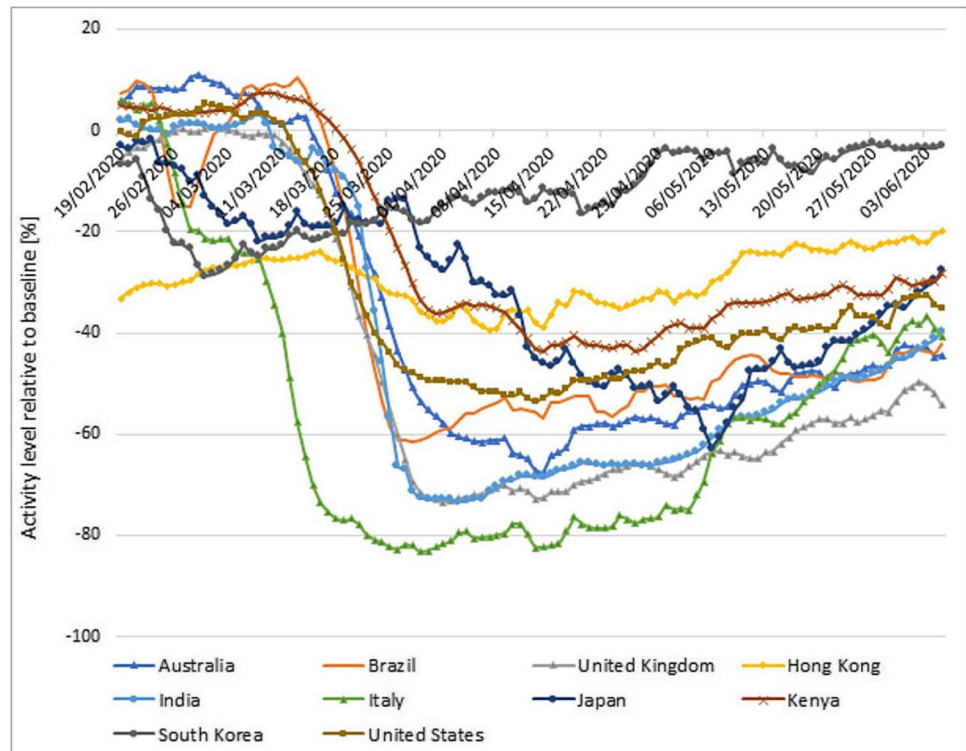
As the spread of the virus started reaching more and more countries throughout the world, governments started implementing different regulations in order to slow the spread of the virus and flatten the curve of the total number of active positive corona virus cases. On the 13th of March, the state of Kuwait announced its first measures in combating the virus. The country suspended all commercial flights from and to Kuwait International Airport and restricted repatriation flights to Kuwaiti travellers and their first-degree relatives as well as cargo flights. In addition, the government

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Fig. 1 Change in the use of public transportation (“Molloy et al.”2020)



gave employees a 2-week holiday until the 26th of March and banned gatherings, health clubs, cafes, and the use of public transportation, including buses and taxis.

The ban on buses remained in effect until the 18th of August for a period of 158 days. With no public transportation, businesses that were allowed to operate during the total lockdown period struggled to maintain business operations as their employees did not have a means of transportation. Flights started to resume to and from Kuwait Airport on the 1st of August with an airport capacity of only 30% for the first phase-out of a three-phase plan that will see the airport return to 100% capacity in August 2021. The Directorate General of Civil Aviation Safety Department pronounced that the opening would involve a maximum of 100 flights and 10,000 passengers a day.

Main focus of the study

As mentioned earlier, the COVID-19 pandemic stopped public transportation for more than 3 months for the first time in the history of mankind. Mainly, this study focuses on COVID-19 impact on public transportation in Kuwait. There is no doubt that this study is a new one in the field, and it will continue to involve more aspects the pandemic is not over yet. In this paper, the data obtained from authorities pertaining to the number of repatriation flights, number of citizens evacuated, and flights before and during the pandemic will be analyzed. The impact of the pandemic on Kuwait's aviation sector will be examined. Similarly, data related to bus ridership

during and before the pandemic is analyzed to examine the pandemic's impact on public transportation in the country.

Literature review

As of the fall season of 2020, research on the effects of COVID-19 on the use of public transport was still limited. Nevertheless, there are a handful of studies that so far give an insight into these effects around the world. First and foremost, it is important to understand the reasons behind considering public transport vehicles and stations a high-risk environment for transferring COVID-19. The International Association of Public Transport Authorities (UITP) mentioned three main reasons, which are (UITP 2020):

1. Buses and trains are closed places with limited space, and the spread of COVID-19 virus increases with the increase in the number of passengers, whether in stations or on buses. It also made it difficult to travel on buses and trains, which can be crowded and increase the risk of infection.
2. It is difficult to identify which passengers or workers have the infection, because sometimes some people with active covid virus show no symptoms.
3. The presence of public surfaces used by everyone that are a source of transferring germs and viruses, such as seats, handrails, doors, and ticket vending machines.

4. It should be noted, however, last reason is no longer considered a serious source of risk for COVID-19 (Kampf et al 2021).

Transportation

Buses

The COVID-19 pandemic had a strong impact on the global mobility. Public transport has been negatively affected since some people considered it unsafe, so they avoided it. A study conducted in Switzerland aimed to study the impact of COVID-19 on the travel behavior of public transport users and focused on the route choice and recurrent trips. By following 48 users for months, very same were already followed before the pandemic so the comparison would be accurate. The results showed that the main observed differences in travel behavior were regarding the costs of transfers and travel duration in trains. So, users have no specific preferred route for a recurrent trip. However, they choose different routes (Marra et al, 2022). Emmanuel Mogaji (2020) theoretically studied the present and long-term impact of COVID-19 on transportation in Lagos State, Nigeria. The majority (52.3%) of the surveyed population for that study used public transport as their primary means of travel, consisting mainly of buses and minibuses. Due to the government-issued public transport guidelines to limit the spread of COVID-19, buses, and minibuses were expected to operate at low capacities to keep a minimum safe distance between passengers. Due to a relatively small fleet, this led to an increase in public transport fares as the demand became greater than the supply, which has added to the cost of living, causing a decrease in ridership (Mogaji 2020). Contrary to the surprising result found in Nigeria's Lagos, ridership in a first-world country like Sweden decreased differently, yet the logical reasons, out of fear of contracting the virus from public transport sharing (Jenelius and Cebecauer 2020). The results were obtained by analyzing ticket sales, ticket validation, and passenger counting data in three regions of Sweden, Skåne, Västra Götaland, and Stockholm., Stockholm had the most cases of COVID-19 between March and May 2020. The analysis showed that Stockholm had the most significant decrease in public transport ridership, with almost 60% less ridership than those before COVID-19. Västra Götaland meanwhile experienced the lowest decrease in ridership at approximately 40%. It is essential to mention that during the analysis period, the government of Sweden did not apply strict regulations or lockdown rules, and unlike other countries, they did not force curfews (Jenelius and Cebecauer 2020).

Air travel

Due to the COVID-19 outbreak, air transport has also declined. The airlines began to adjust their network. For

example, daily flights in South America decreased by 90% in March 2020 because COVID-19 affected the first quarter of 2020 for airlines (IATA 2020). Pereira and Soares de Mello study the efficiency of the three major airlines in Brazil (Azul, Gol, and Latam) by analyzing the multi-standard data envelope in the first months of 2020 compared to the first months of 2019. The Data Envelopment Analysis (DEA) is a nonparametric mathematical programming problem (Charnes et al. 1978) that calculates the efficiencies of Decision-Making Units (DMUs), considering their resources (inputs) and products (outputs). The DMU data took from the airline as variables of the number of take-off times, cargo load, the ton available, and spent fuel. Every DMU's efficiency (GLO-2019/1, AZU-2020/1, TAM-2020/1) seeks to investigate best practices for the fleet. However, the restrictions imposed by the government due to COVID-19 dropped the demand in March 2020 while a minimum flight attendance was determined by authorities. The efficiency of operating flights is not appropriate and directly affects the financial results. The allowance for cargo flights has helped companies to reduce revenue losses. They used the TRIMAP software, developed by Clímaco and Antunes (1989), to solve the MCDEA (Multicriteria Data Envelopment Analysis model) model. (Pereira and Soares de Mello 2021). Another study by Maneenop and Kotcharin selected samples in April 2020, including 103 firms in air transportation around the world. Countries with at least four firms were chosen. So, the final sample included 52 listed firms. The main methodology applied in this research is by Fama et al. (1969) which is common in the finance literature and economic to realization the influence of new information. The approach to studying the event begins with lower stock returns on market returns. Actual inventory returns and expected returns are estimated among them as an abnormal yield difference. If the market is semi-strong, the yield must be zero abnormal, which means that market prices are the same as fair value. These events have had negative effects on stock prices in the global aviation industry. The results provided a greater understanding of how airline stock prices deteriorated during the crisis as investors interpreted information. For example, a reduction in the aircraft fuel tax on domestic flights could be implemented to reduce operating costs due to low passenger numbers. The administration should allow the airlines to be able to operate with irregular flight schedules that reflect market demand (Maneenop and Kotcharin 2020).

Cases and health requirements

The COVID-19 pandemic resulted in negative impacts on travelers' mode choice behavior since they sometimes avoid riding a bus fearing of getting infectious with the corona virus. Zafri et al. (2022) conducted a study in Bangladesh to estimate mode-wise perceived risk of viral transmission and highlight the factors that impacted the perceived risk

in the country. The results showed that people perceived a very high risk of transmitting the virus in public transport such as buses. While they had perceived a moderate risk in shared transportation modes such as rickshaw and ridesharing. And as expected, they had perceived very low risk in private modes including private cars, motorcycle, walking, and cycling. The high-risk perception of transmitting the virus in public transport modes resulted in a shift to private modes which caused a reduction in public transport users and led to worsening urban transport problems (Zafri et al. 2022). Several studies confirm that COVID-19 cases are related to the spread of the virus in society and not to the rates of public transport commuters, and here are some studies for areas that have confirmed that. In Hartford, Connecticut, cases of COVID-19 have decreased, while the number of passengers on public transport was constant. On the other hand, in San Francisco, California; Salt Lake City, Utah; Columbus, Ohio; and Austin, Texas, the rate of public transport passengers was also stable, but the number of COVID-19 cases increased. In New York, in the period from June 1 to August 18, the rate of positive COVID-19 cases decreased by 70%, from 3.3% to 1.1%, with 150 million trips by subway trains and buses during the same period. (“Day-by-day ridership numbers,” 2021). The reason is that transportation passengers usually talk little to each other, and the time a person spends affects the likelihood of infection since bus trips are usually short (Sam Schwartz 2021). Although scientific background about COVID-19 is limited since it is considered a new virus, some regulations were imposed for passengers while riding public transportation to protect themselves, as means of transport have little or no role for transmitting the virus when applying the health requirements recommended by public health experts. Social distancing is one of the recommendations CDC (Centers for Disease Control and Prevention) (Milne et al. 2020). It was also recommended to maintain a social distancing of at least 6 feet between passengers, as this scale was determined prior to authorization to wear the mask (“COVID-19 and Your Health”, 2021). On the other hand, the World Health Organization recommended only one meter or 3 feet. In a study on physical distancing, it was found that the transmission of COVID-19 is less with distances of 3 feet or more (Chu et al. 2020). Masks have played an effective role in several previous studies of infectious diseases, and in the COVID-19 pandemic, their role has emerged in limiting the spread of the virus, which helps preventing infectious particles from exhaling, coughing, or sneezing to transmit from one person to another, which maintains the safety for all passengers (Milton et al. 2013). Evidence proved the importance of covering the face to prevent infectious particles’ inhalation, especially in indoor places such as public transport (Anfinrud et al. 2020). In Nanjing, China, they studied several patients infected with the new Coronavirus.

This study shows the possibility of infection without symptoms and the possibility of transmission of the COVID-19 virus carriers without symptoms. The contagious period can reach 3 weeks. This illustrates to the importance of wearing masks in public places (Hu et al. 2020). Liu and Zhang studied the effect of putting on masks on limiting the spread of the COVID-19 virus. They used an analysis of the typical case of an infected person from Chongqing, China boarded a bus of 39 passengers for a 2-h trip. The infected passenger was not wearing a mask. Also, many passengers did not wear masks. After the examination, five other passengers on the same trip got the infection. Still, one of them who was wearing a mask boarded another bus of 14 passengers for a 50-min trip. The 14 passengers were examined and followed up medically for 14 days. The results showed that none of them was infected with COVID-19. Thus, face masks can reduce drastically the transmission of COVID-19 (Liu and Zhang 2021). Moreover, Wei Lyu and George L. Wehby studied the effect of wearing a mask in public places in some states of the USA by examining the daily changes in the growth rates of COVID-19 cases after implementing the use of a face mask in public places. It was found that the decrease in positive COVID-19 cases was associated with the imposition of face masks. With that decision, more than 200,000 cases of COVID-19 were avoided, which highlights the significance of wearing masks on reducing the spread of COVID-19 (Lyu and Wehby 2020). Cleaning and sterilizing buses and utilities were initially thought to be essential during the pandemic since respiratory droplets may land on surfaces. It is potential for a person to be infected with COVID-19 by touching these surfaces and then touching his mouth, nose, or eyes since high concentrations of coronaviruses could survive infectious on non-living surfaces for a period of 9 days. Disinfecting surfaces with 0.1% sodium hypochlorite or 62–71% ethanol greatly reduces viability of coronavirus on surfaces within 1 min of exposure time. So, researchers expect that its effect against transferring the virus will be similar (Kampf et al. 2020). The possibility of contracting the virus by surface contact is extremely slight compared to person-to-person spread. In one of the published articles, they studied the possibility of corona virus spreading through contact surfaces, and it turned out to be a tiny percentage that is almost negligible (Goldman 2020, 2021). Despite that, disinfection and cleaning are considered by some as essential measures for public waste companies to gain the confidence of passengers and assure everyone’s safety. Rutgers University has studied the effectiveness of ultraviolet light to disinfect buses, as UVC rays have proven to be effective in disinfecting water and surfaces and may also help lessen the risk of infection with corona virus (Medina 2021).

The current COVID-19 outbreak is an extraordinary event in air transportation. This has contributed to global aviation

in the spread of a pandemic at the level of the planet, which has spread to more than two hundred countries. As of August 23, 2020, the number of infected cases has reportedly exceeded 23 million, with more than 800,000 deaths worldwide (Sun et al. 2020). However, it was found that infection with COVID-19 during an air fly trip is considered low due to the presence of air filtration systems in the plane which is considered highly technical and used by all major airlines and contributes greatly to the elimination of the virus, as it can remove up to 99.99 of the portable particles (2021 et al. 2021). Researchers from Harvard University have shown that HEPA systems which are high-efficiency air filters in airplanes can change the cabin air twenty to thirty times per hour. Another study focused on the flow of virus particles in the plane showed that the possibility of disease transmission from an infected person to another in the plane is 3:1000 if both passengers were wearing a mask. The report also indicated that airlines are applying strict cleaning protocols, oblige passengers to wear a mask, and social distancing measures. In addition to the fact that the shorter the flight, the lower the risk of infection. (Ianzito 2021).

Environment

After studying the impact of COVID-19 pandemic on the environment, it was noticed that the whole world is suffering from an increase in air pollution rates that are represented by nitrogen dioxide, sulfur dioxide, carbon dioxide and particulate matter. This increase was mainly caused by Power stations, the transport sector and the industrial sector. Due to the lockdown, the imposed restrictions on the transport sector, that led to the suspension of movement of vehicles, planes, and people and the suspension of industrial activities. Which resulted in an improve in air quality and a reduction in environmental pollution since carbon dioxide levels, black carbon, greenhouse gases, and nitrogen dioxide were reduced (Zambrano-Monserrate et al. 2020). Air Quality Index (AQI) can be defined as a measure used worldwide by environmental agencies and public bodies to measure the air's cleanliness. The lower the indicator, the better the air quality, and vice versa. The European Space Agency collected data with the Sentinel-5P satellite using a troposphere monitor (TROPOMI) in collaboration with NASA that collected data via its AURA satellite using Ozone Monitoring Instruments (OMI). These data indicated an improvement in the AQI and the environment, as well as a decrease in nitrogen dioxide emissions by up to 30% (Muhammad et al. 2020). During the lockdown in the Spanish city of Barcelona, the air pollution rates decreased by 50%, as well as a 45 to 51% decrease in nitrogen dioxide (NO₂) and black carbon (BC) levels (Tobías et al. 2020). China's carbon emissions have decreased by nearly 1 million tons which is 25% less than the same period last year before COVID-19

(Wang and Su 2020). Particulate matter (PM_{2.5}) in Malaysia also decreased by 58.4% during lockdown (Abdullah et al. 2020). In Venice, which is located in Italy, water canals have become more transparent and fresher during lockdown due to the reduction in water pollution. Restricting traffic in America has reduced carbon emissions by 40% (Mousazadeh 2021). As a result of COVID-19, transportation has been restricted by 90% which led to a 30% decrease in air pollution (Muhammad et al. 2020). A recent study showed that the earth's vibrations resulting from traffic and industrial work fell by half globally during the lockdown due to COVID-19, according to Daily Mail. Social distancing, less vehicles on the roads, and a the decrease in tourism and transport have resulted in the "longest and most pronounced quiet period" of Seismic noise that has been documented in history. A study was conducted in Dublin, Ireland aimed to measure noise pollution before and during lockdown by analyzing data collected from 12 noise monitoring stations. The average hourly noise obtained from 12 noise monitoring stations for the pre-shutdown period January 1, 2020, to March 24, 2020, was compared with the average hourly noise during the shutdown from March 25, 2020. Due to the changes in traffic conditions and their differences during the day, and the effect of this on the noise pattern, the 24-h period was divided into three time divisions, night (11 PM to 7 AM), day (7 AM to 7 PM), and evening time (7 PM to 11 PM). In each station, two box plots were prepared representing the pre-shutdown and during shutdown periods based on hourly average, hourly maximum, and minimum hourly noise data. It was shown that there was a significant decrease in noise levels at all stations during the closure period due to the restriction of road and air traffic The detailed report indicated that seven stations witnessed a sudden decrease in noise between 14 and 17 March 2020. The other five stations experienced a sharp drop in noise near the start of the lockdown. While stations located within the city and closer to the city center show an early reduction in noise. However, the stations with lower noise levels were located near the city limits and close to the M50 motorway (Basu et al. 2021).

Impact of COVID-19 in Kuwait

The first case of "COVID-19" was recorded in Kuwait on February 24, 2020, according to the Kuwaiti Ministry of Health statistics. After that, the number of cases has rapidly multiplied. Therefore, the Kuwaiti government began to follow the developments of the spread of the disease and implement regulations to limit its spread. On February 26, schools and universities were closed. Additionally, the Kuwaiti government imposed a curfew starting on March 22, and the authorities also imposed total isolation of the areas of Mahboula and Jleeb Al-Shuyoukh on April 6 due to the

spread of the epidemic in them, and mosques and places of worship were closed on May 13. As of January 20, 2021, the Ministry of Health in Kuwait had recorded 158,000 cases of COVID-19 and 948 deaths. The impact of Corona in Kuwait extended to the transport and aviation sector.

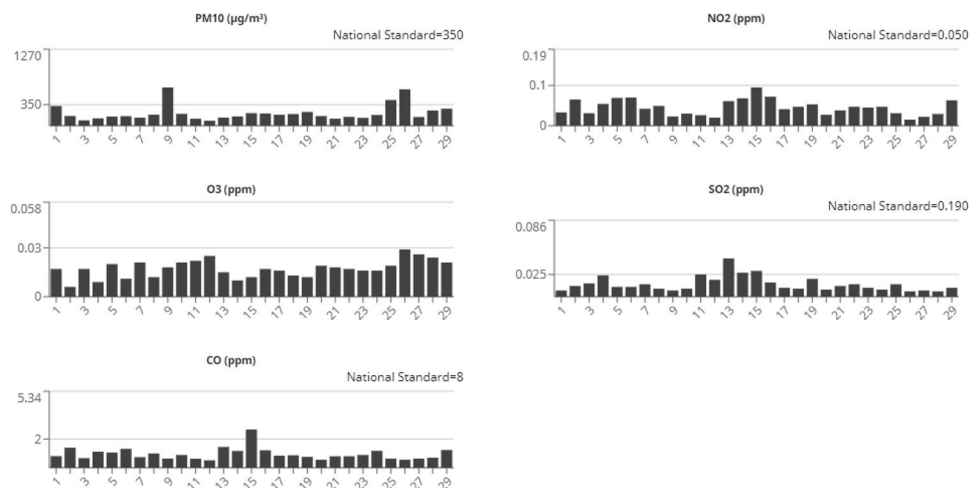
The turnout after the opening of public transport was minimal, as the buses worked with lower capacities and they were not full of passengers due to several reasons including the low population density, in addition to the return of many expatriates to their countries who were the most used category of buses. In addition to the social distancing that was applied furthermore, which made buses carrying only seated passengers without stopping as before. There is no doubt that the public transport company suffered significant losses like other companies during the COVID-19 pandemic.

Kuwait national airways company was keen on the safety of the individuals by imposing restrictions where individuals must commit to wearing a mask throughout the traveling stages and sterilization continuity. Additionally, they have to follow the instructions for physical distancing and contactless as much as possible. Departing passengers must follow the travel requirements for the destination country, such as a virus-free check. It is not allowed to have carry-on bags on the plane, except for medicine bags, personal belongings, and children's belongings. For arriving passengers, they must sign in to the Shlonik application, and random PCR testing will be performed on 10% of the total arrivals. They also must have a negative PCR test and submit it to the airline before being accepted to fly. All arrivals will be subjected to 14 day-home quarantine. With the outbreak of COVID-19, Kuwait developed a plan to evacuate Kuwaitis return from all parts of the world by reviewing the data and numbers related to citizens desiring to return according to the countries in which Kuwaitis reside and their health and

social conditions. The outbreak of the new coronavirus has led to a collapse in demand for flights, and the decline in demand has reduced revenues and even losses for the first time in years.

To examine the impact of COVID-19 on the Kuwait environment, a comparison was made between pollutants caused by buses and airplanes. The Shuwaikh area was chosen as a study area, where the air quality was clarified for the following 3 months: February 2020, which is the period before the pandemic (Fig. 2); May 2020, where the full curfew was (Fig. 3) and January 2021, after the curfew and the start of returning to life (Fig. 4). The study included periodic analysis over the 3 months of five parameters that contribute to air pollution which are: PM₁₀, NO₂, O₃, SO₂, and CO₂. Figures 2, 3, and 4 contain the temporal variation of each parameter in a separated chart over the study period. Where the X-axis presents the days of each month (29 days in February and 31 days in both May and January) while the Y-axis shows the recorded values of each parameter. Regarding PM₁₀, it exceeded the national standard value for almost 3 days during February while it was much lower in May during the lockdown. In January 2021, it reached almost zero levels from the 21st to the 30th of the month. Regarding O₃, the lowest recorded values were during the lock down while the values after returning to life were a bit higher than those before and during the pandemic. NO₂ values were the highest before the pandemic exceeding the national standards, they decreased during the full curfew and reached the lowest values below the standard in January 2021 after returning to normal life. For SO₂, the recorded values in February were much higher than those in May and January indicating a reduction in their existence in the atmosphere. Additionally, carbon dioxide (CO₂) reached the lowest values in January 2021 compared to February and May 2020. Overall, the positive impact on emission reduction was recognizable and significant during the lockdown.

Fig. 2 Pollutant chart variation in February 2021 (Air Quality Status 2021)



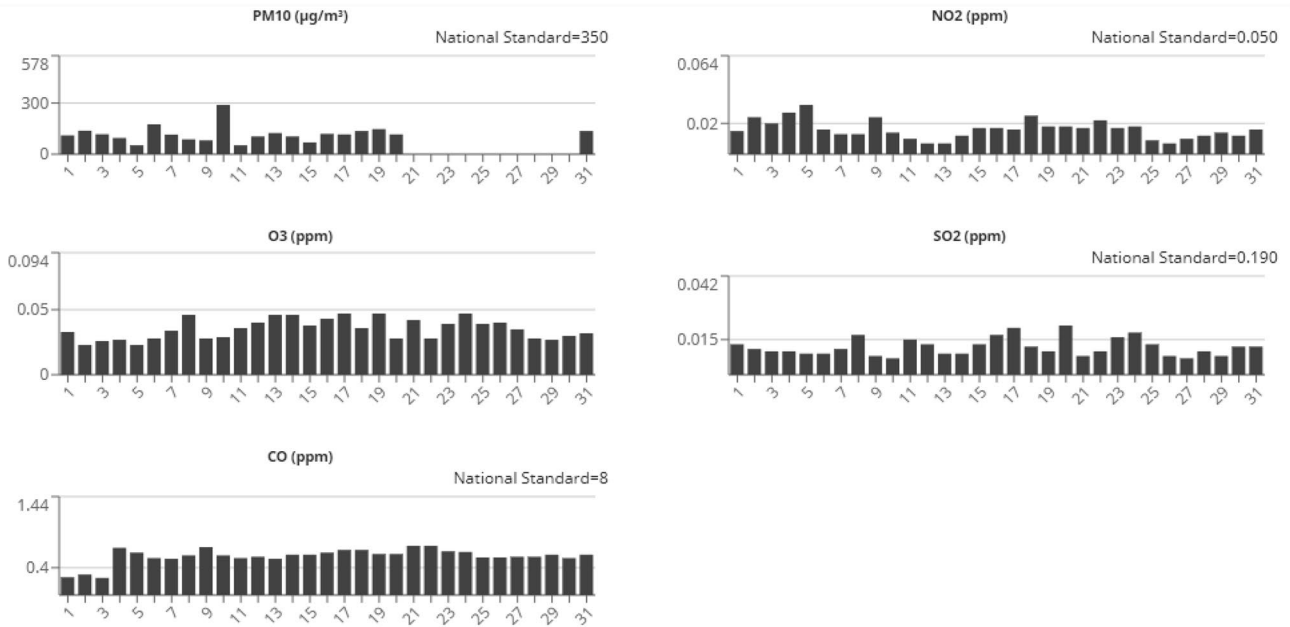
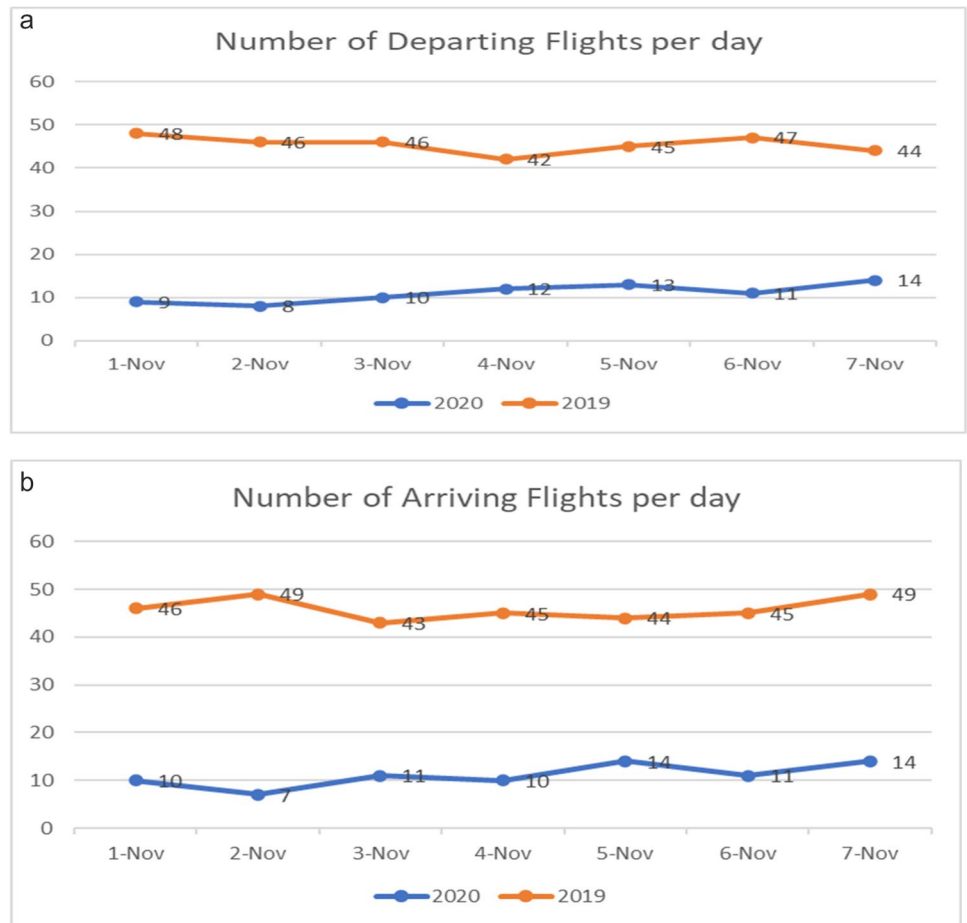


Fig. 3 Pollutant chart variation in May (Ait Quality Status 2021)

Fig. 4 Pollutant chart variation in January 2021 (Ait Quality Status 2021)



Methodology

This chapter discusses the approaches followed to study the impact of COVID-19 on bus ridership and airport ridership in Kuwait. The analysis is carried out by comparing bus ridership on key lines in the weeks before the beginning of lockdown on March 13 and after lifting lockdown and allowing businesses to operate in August 2020. A survey was conducted to compare the results of the numerical analysis to the results obtained from surveys and further validate the impact of COVID-19 on people even after lockdown has been finished.

Impact of COVID-19 on flights

The data used in this study was obtained from the Kuwait Airways office, including a summary of the number of flights operated by Kuwait Airways in November 2019 and November 2020. The data includes the total number of passengers per flight and the type of flight, whether normal service flight or cargo flight. Additionally, data regarding the number of evacuation flights and evacuated citizens is also provided, as well as the number of COVID-19 cases that arrived from these evacuation flights which were between the 19th of April and 25th of April 2020. Analysis of flight ridership will be carried out by comparing the number of inbound and outbound passengers in November 2020 to those a year earlier in November 2019.

Calculating risks of spreading COVID-19 through flight activity

It is possible to calculate the risk of importation of COVID-19 by following the method applied by Nakamura and Managi (2020). Where the risk was calculated based on origin–destination annual air flows. Their methodology was done based on Gilbert et al. (2020) where the risk is calculated by the following equation:

$$\gamma_{OD} = \frac{e_o n_o A_{od}}{\sum_j e_j n_j} \quad (1)$$

where n_o is the travel flow from the origin (o), and the cumulative incidence e_o is equal to the total number of confirmed cases per municipality where airports are located, divided by the municipal population. A_{od} is the probability of traveling from the origin (o) to destination (d). The importation risk to destination (d) from any origin:

$$R_d = \sum_i \gamma_{OD} \quad (2)$$

where the relative risk is normalized to 1.

Impact of COVID-19 on public bus transport

The used data was obtained from the Kuwait Public Transport Company (KPTC) from two bus-routes, which are Route 18 and Route 507, before and after the lockdown that was enforced from the 13th of March to the 17th of August 2020. This lockdown period costed the public transport company a total loss of 959,469 Kuwaiti Dinars, the equivalent of 3.17 million US dollars. The data included the number of passengers per route and the number of buses operating for each route. Moreover, the data also included the timetables that were operating before the 13th of March and those that are operating since the 18th of August.

Emission changes per kilometer person before and after lockdown

The collected data from the KPTC gave us the opportunity to further analyze the impact of COVID-19 on the emissions generated per km. CO₂ emissions from bus route 18 can be estimated by calculating the number of kilometers traveled by each bus on that route and multiplying it by the emissions per km for each bus. In order to get a more accurate model, the approach adopted by Sui et al. (2020) was followed, where they introduced an emissions model that allowed them to estimate CO₂ emissions of 2056 buses from 278 routes covering 1.5 million ridership in Qingdao, China.

In this study, CO₂ emissions are estimated by the MOVES (Motor Vehicle Emission Simulator) model developed by EPA (United States Environment Protection Agency). Road vehicles are generally classified into four categories: passenger cars, light commercial vehicles, heavy-duty vehicles and buses, mopeds, and motorcycles. According to the MOVES model, each vehicle category has different emissions as emission is a variable dependent on the weight of the vehicle, the type of fuel, and the type and technology of the vehicle motor. Moreover, emission factors in the MOVES model are divided further by the area, highway, rural or urban. In the MOVES model, emissions are defined as a function of speed and vehicle-specific power (VSP) for light-duty vehicles, and speed and scaled-tractive power (STP) for heavy-duty vehicles and buses. VSP or STP is measured by the engine power output per vehicle unit mass. Second-by-second VSP/STP (KW/ton) are calculated using Eq. (3):

$$VSP(STP) = \frac{A}{M} \cdot v + \frac{B}{M} \cdot v^2 + \frac{C}{M} \cdot v^3 + \frac{m + n \times w}{M} (a + g \sin \theta) \cdot v \quad (3)$$

where A is the rolling resistance coefficient (KW·s/m), B is the rotational resistance coefficient (KW·s²/m²), C is the aerodynamic drag coefficient (KW·s²/m²), m is vehicle mass (tons), M is fixed mass factor (tons), n is the number of passengers and w is the average passenger mass, which is

Table 1 Parameters for VSP/STP

	A	B	C	M	M
VSP	0.156461	0.002002	0.000493	1.4788	1.4788
STP	1.0944	0	0.003587	17.1	16.556

default to be 60 kg per person as most of the passengers are adults, v is instantaneous vehicle speed (m/s), a is instantaneous acceleration (m/s^2), g is gravitational acceleration with a value $9.8 m/s^2$, θ is the fractional road grade. In our case, θ is set to be 0 since Kuwait is flat and road grade is negligible if present. Table 1 shows the parameters of VSP and STP.

The total link-based CO₂ emissions of the bus are estimated using the following formula:

$$TE = \sum_{i=1}^I TSTP_i \times ER_i \tag{4}$$

where $i = VSP/STP$ mode index, $1, 2, \dots, I$; ER_i is CO₂ emission rate for VSP/STP mode i (g/s); $TSTP_i$ is time spent in VSP/STP mode i (s); and TE is the total link-based CO₂ emissions (g). Per-kilometer-person CO₂ emissions are calculated by Eq. (5)

$$E_{km-per} = TE / (L \times n) \tag{5}$$

where L is the length of the link and n is the number of in-vehicle persons including the driver.

Survey

Two separated questionnaires were conducted and spread to have a better visualization of the impact of COVID-19 on public transport in Kuwait. The first one included questions regarding flight use and the risk associated with taking a flight and using the airport grounds, among other questions. The second one was about buses, it included questions related to the frequency of usage of buses and fears associated with usage among other questions. A sample of the questionnaire questions about airports and buses is shown in Table 2 and Table 3 in Appendix 1, respectively.

Referring to Table 2 in the Appendix, the first two questions are related to demographic factors to study the individual differences including age and nationality of the participants. These general questions provide a base for studies in order to understand if there is a significant correlation between these factors and their willingness to use public transport during the pandemic. Additionally, more questions were presented to provide a full image of the participants' perspectives regarding traveling during the pandemic, and whether they will still be cautious even after leisure travel opens again. Moreover, the participant's current awareness and precaution levels are tested

Table 2 Cumulative incidence per origin

Origin city	Cumulative incidence
Amman	3.38%
Bahrain	6.45%
Dhaka	3.52%
Doha	5.44%
Dubai	3.50%
Istanbul	3.06%
Lahore	0.54%
London	7.31%
Riyadh	1.03%

by asking if they have followed any specific actions to avoid getting infected. The questionnaire also included questions about the levels to which a respondent would be concerned about contracting COVID-19 in the future after the pandemic has subsided. These questions about current and future concerns, help the team in testing the significance of the correlation between the current behavior of participants and how they would act in the future regarding COVID-19. The participants were also asked if they knew anyone who had caught COVID-19 because of traveling recently, in order to study examine the correlation between that response and other responses to know if it affects the levels of concern regarding the virus.

Following Table 3 in the Appendix, the questions were structured to understand whether or not the participants were affected by the impact of COVID-19 on public transportation, namely bus transport. This was mainly added to study how those who do use public transport were affected by COVID-19. While for those who do not use it, the study team at least aims to understand how the participants perceive public transport in Kuwait and their perspective on buses which might improve the overall bus experience. Studying the variation of ridership number after the pandemic and compare it to that before, would also be important and take part in the study.

Survey analysis

The results obtained from both questionnaires were analyzed to examine the relations and dependency of the question responses. For example, it would be analyzed if nationality would have a significant impact on bus ridership, or if age has an impact on risk taking when it comes to travelling once airports are operational. In order to conduct such an analysis, the chi-square test was performed using the software SPSS. The chi-square is commonly used to examine the significance of the correlation between two or more categorical variables.

Results

This chapter includes the results of the comparison between airport data before and after lockdown as well as the calculation of the risk regarding the spread of COVID-19 through traveling internationally. Additionally, the analysis of bus ridership before and after lockdown, in addition to the corresponding environmental impact this change in ridership and new occupancy rules are causing. The results of the survey are also discussed in detail.

COVID-19 impact on air travel

The results related to the impact of COVID-19 on air travel are divided into three subsections. The first is related to the

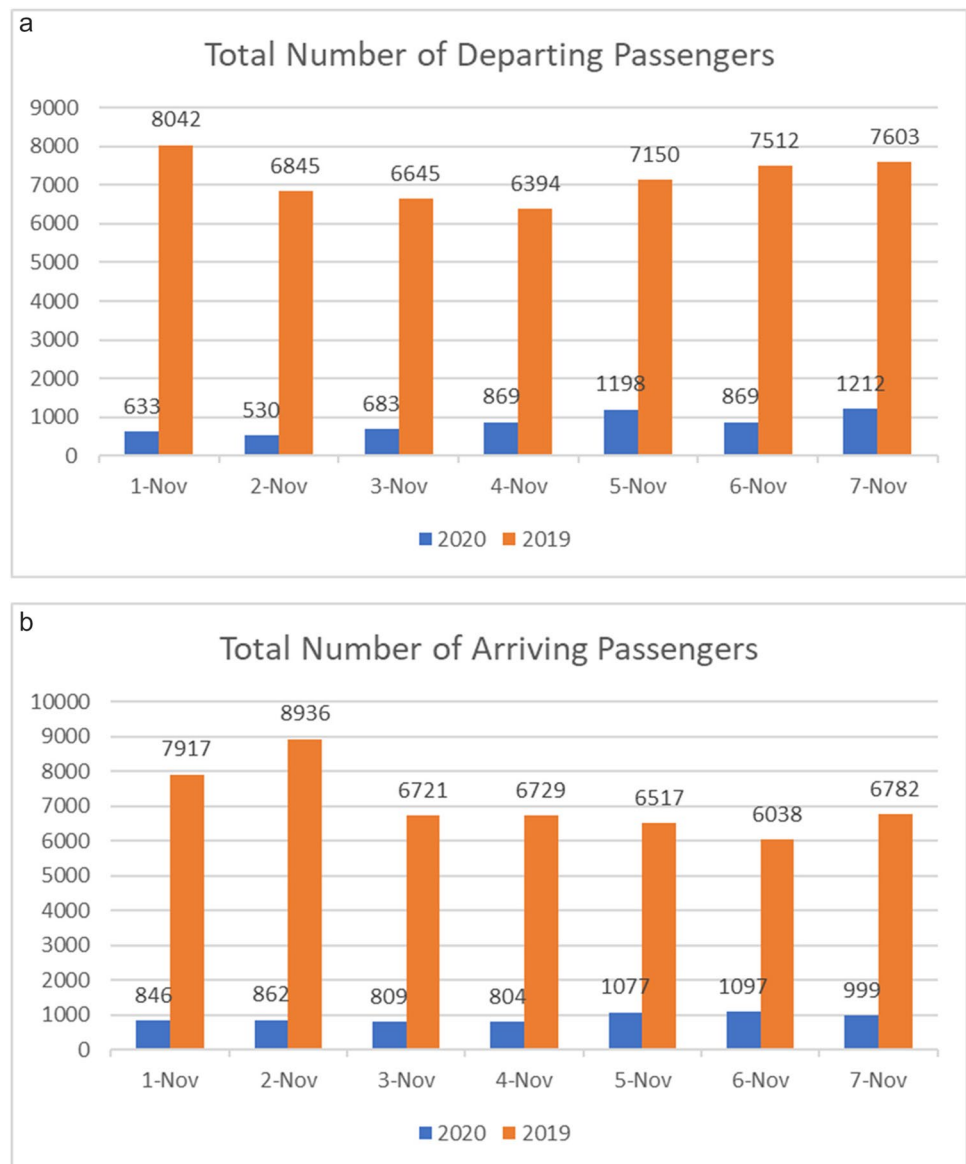
impact on the number of flights and passengers, which is done by comparing data recorded in 2020 to that in 2019. The second one presents data about evacuation flights while the last one is regarding the risks associated with spreading COVID-19 through air travel.

Impact on the number of flights and passengers

Figure 5a compares the number of departing flights per day for the first week of November 2020 with those in 2019 while Fig. 5b presents the number of arriving flights for the same periods.

Similarly, the total number of passengers during those two periods is displayed in Fig. 6a and Fig. 6b for departing and arriving flights, respectively. Referring to Fig. 6a, it is shown that number of departing passengers in the first week

Fig. 5 a Number of daily departing flights. b Number of daily arriving flights



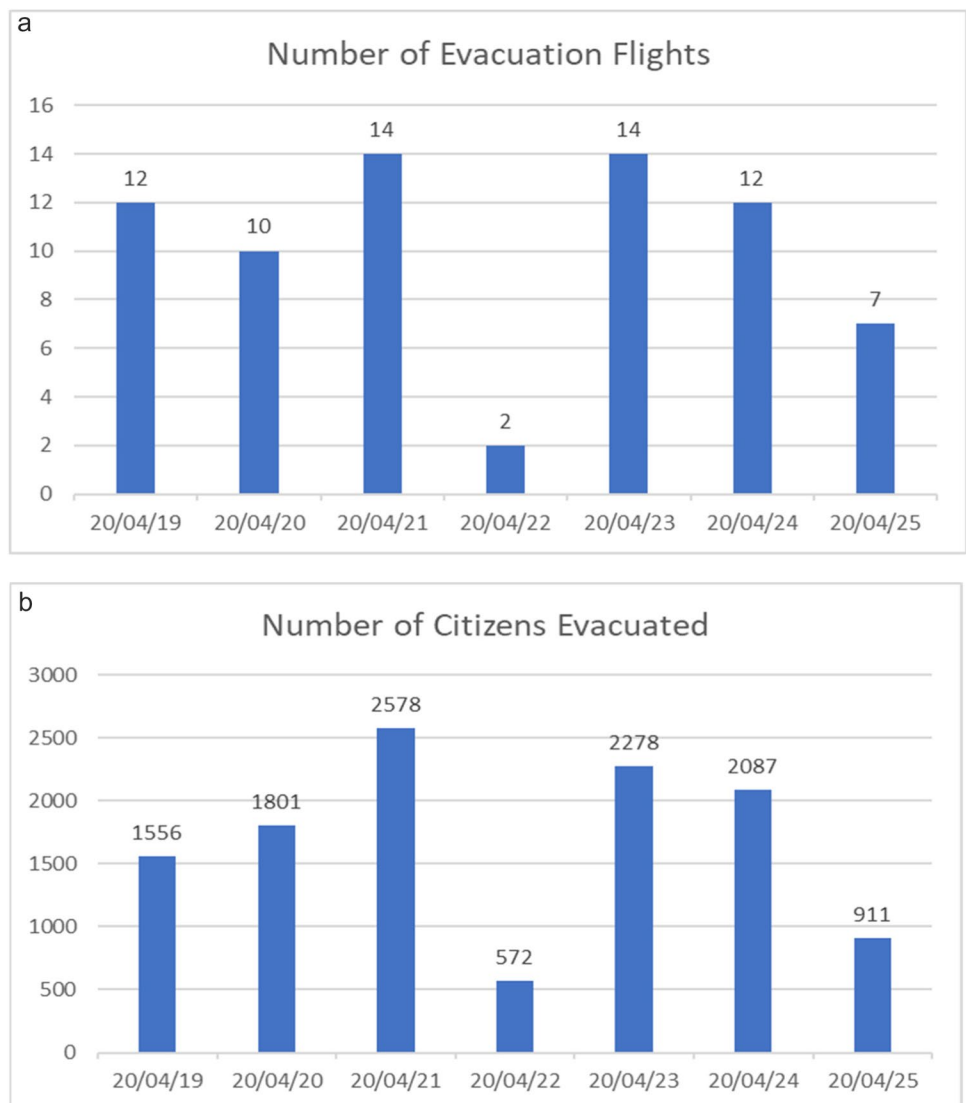
of November year 2019 reached its highest number on the 1st of November with 8042 passengers, while its lowest was on the 4th of November with 6394 passengers. Meanwhile, the highest number of departing passengers in the first week of November year 2020 was on the 7th of November with only 1212 passengers, and while the lowest was on the 2nd of November with only 530 passengers. In Fig. 6b, a relatively similar situation can be observed for the arriving passengers, whereby the highest number of arriving passengers in that same week in 2019 was 8936 on the 2nd of November and the lowest was on the 6th of November with 6038 passengers. In comparison with 2020 arriving/departing passengers, the highest number of arriving passengers was 1097 passengers on the 6th of November which is almost 12% of the highest number in 2019, and the lowest on the 4th of November with 804 passengers.

The data displayed in the figures are provided in Table A4 and Table 5 in the Appendix including the corresponding

average daily number of flights and passengers in 2019 and 2020, respectively. It can be noticed that the average total number of departing passengers per day fell from 7170 in week 1 of November 2019 to 856 on average per day during the same week in 2020. This corresponds to a reduction of 88% in the number of people travelling per day. Additionally, there was a huge drop in the number of flights per day with the average daily departing and arriving flights during that week dropping from around 45 flights per day to 11 flights per day, which corresponds to a 76% drop in the number of daily flights. Likewise, the average number of daily arriving passengers in that week was 7091 in 2019 and dropped to 928 in 2020, indicating a decrease of about 87%.

Another significant impact caused by COVID-19 was the evacuation flights that were occurring worldwide at the beginning of the pandemic when most countries were enforcing strict lockdowns and restricting air travel to evacuation flights only. Kuwait rapidly took action and evacuate

Fig. 6 a Total number of departing passengers per day. b Total number of arriving passengers per day



its residents from around the globe and the data about the number of evacuation flights and corresponding passengers is represented and analyzed in the study, along with the number of arriving passengers who were infected with the virus.

Evacuation flights

Evacuation flights occurred during April 2020 and successfully 11,783 residents of Kuwait were evacuated during a week from the 19th till the 25th of April. The number of daily evacuation flights and the number of daily evacuated citizens respectively are shown in Figs. 7a and b, respectively.

From Fig. 7a, it can be noticed that number of evacuation flights varied throughout the week with the highest operating flights of 14 flights on the 21st and 23rd of April 2020. On the other hand, the lowest number of flights was with 2 flights in the middle of that week.

From Fig. 7b which presents the number of citizens evacuated during the pandemic, it is noticeable that these flights were able to transport and safely evacuate about 11,783 citizens from different countries. The highest number of citizens evacuated was 2578 on the 21st of April while the least was 572 on the 22nd of April.

Some of the evacuated citizens were carrying the virus, whether asymptomatic or not, and the government was able to isolate those cases before they were able to transmit the virus as people arriving during that week were all forced to quarantine at designated locations. Figure 8 shows the origin countries with the highest number of arriving passengers who had positive COVID-19. It is obvious that flights arriving from the UK had the highest number of COVID-19 infected people, with a total of 216, which is more than

half of the total number of infected cases arrived. Followed by Iran were 90 passengers who arrived to Kuwait and the infection. The third highest number of COVID-19 cases was 24 passengers who arrived from GCC which is almost equal to those from France with 23 positive COVID-19.

Figure 9 shows the inbound COVID-19 cases from different countries over the study period. It was noticed that the temporal distribution of the cases differs from one country to another. For example, the infections from Iran were dominant at the beginning of the pandemic from the end of February till the mid of March while the infections from the UK peaked towards the end of the study period by the end of April.

Risk of importation of COVID-19

The risk of importation of COVID-19 was estimated based on the data provided by Kuwait Airways regarding origin–destination air flights which include data on different types of flights. Only passenger flights are used for the risk estimation since the risk presented by cargo flights is negligible. The data includes flight traffic from the 1st of November 2020 until the 7th of November 2020. It was assumed that the weekly scheduled flights will be the same as the first week of November and the number of passengers per flight to be equal to that during the first week in order to extrapolate the presented data into the end of November. Since no further information on air travel during that month was provided and no major holidays fell during that month that will increase the demand for air travel, it is safe to assume that similar traffic flow was observed during the following weeks of November

Fig. 7 **a** Number of daily operated evacuation flights between the 19th and the 25th of April 2020. **b** Number of citizens evacuated from the 19th till the 25th of April

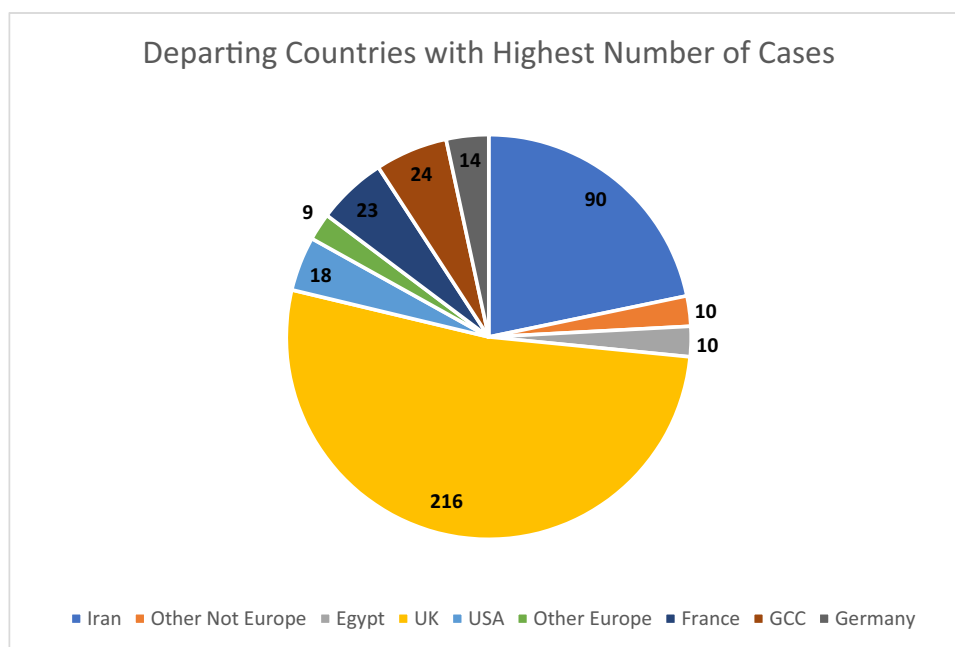


Fig. 8 The number of COVID-19 struck cases arriving from countries

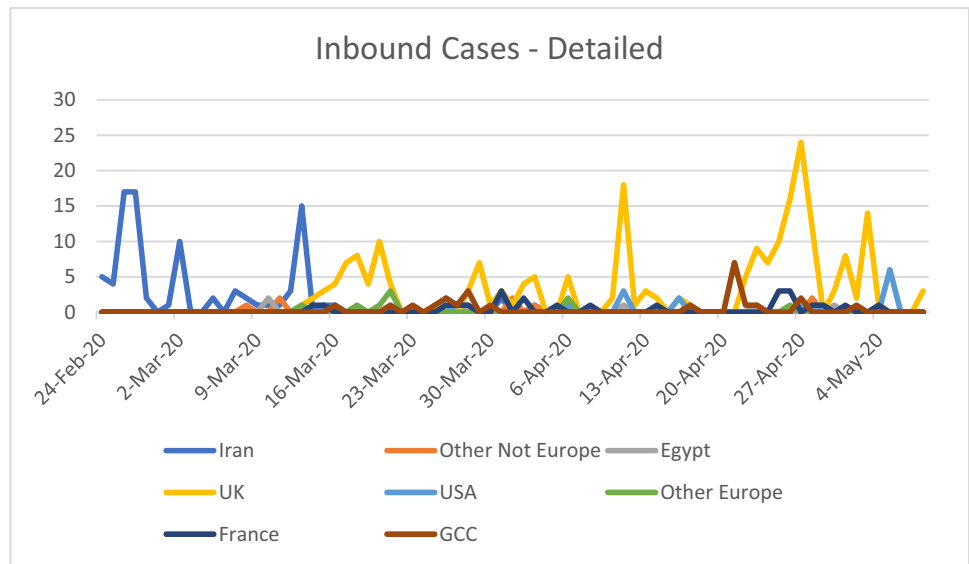
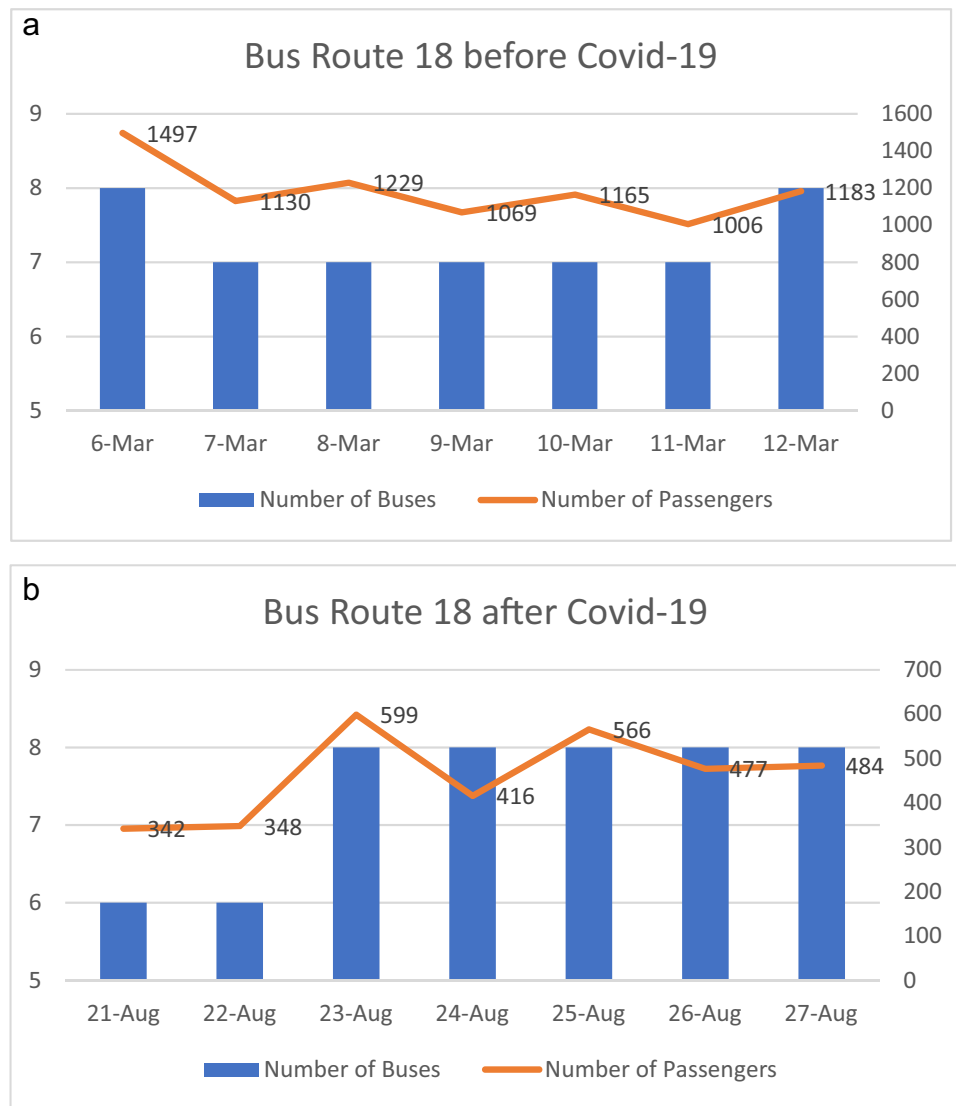


Fig. 9 Inbound cases—detailed over the study period



2020. Moreover, besides the data regarding air travel and number of passengers arriving and departing to and from Kuwait International Airport, the equation applied by Nakamura and Managi (2020) was used in the study to calculate the risk associated with traveling from that origin. To do so, data was collected regarding COVID-19 cases per month per origin country. Before the risks can be calculated, the arriving and departing flights are separated and the corresponding number of flights per week to or from an airport are summarized. These are provided in Table 7 in the Appendix. It was recognized that some of the flights were almost empty, such as those from Bangalore, Chennai, and Mumbai, where only 4 passengers were recorded per flight. Moreover, some flights averaged a low number of travelers per week that would normally be more occupied. Flights from Beirut, Lebanon, averaged only 13 passengers per flight, while those from Cochin, India averaged only 15 passengers. Therefore, flights with a low number of passengers were excluded from this study, and only flights with an average occupancy of 50 passengers or more were taken into consideration.

The number of confirmed COVID-19 cases recorded from flights arriving from each municipality until the 13th of February 2021 was included in analyzing the risk of importation of COVID-19. However, detailed data about the total number of COVID-19 cases per municipality was not available for Dubai and Istanbul, and therefore, for these two cities, the number of COVID-19 cases used is that of the entire country. Furthermore, the most recent population stats for the corresponding municipalities/countries were used to calculate the cumulative incidence e_o in Eq. (1), which is mentioned earlier. Also, since no flights are arriving from Abu Dhabi International Airport it is safe to assume for our risk calculation that people who want to travel to Kuwait from Abu Dhabi are most likely going to come to Kuwait through Dubai.

The sum of all cumulative incidences e_j and all corresponding passenger inflows n_j are calculated such that the total is considered to be that of the flights until the 13th of February 2021. Therefore, the cumulative incidence is first calculated for all the mentioned origins.

$$e_o = \frac{\text{Confirmed cases}}{\text{Population}}$$

The resulting values for the cumulative incidence for each origin are shown in Table 2. The results show that London is the location with the highest cumulative incidence, where 7.31% of the population were confirmed cases of COVID-19. Bahrain is the second highest with 6.45% and Lahore is the lowest with 0.54%. Riyadh also had low levels of 1.03% only.

The total number of inflowing passengers n_j and the total incidence e_j based on the values in Table 8 in the Appendix are per year:

$$\sum_j e_j n_j = 11153$$

A_{od} is the probability of traveling from the origin (o) to destination (d), which is determined by the flight frequency from the origin cities. The highest being Dubai and Istanbul with 14 flights per week. The risk flow γ_{OD} per origin is accordingly calculated according to Eq. (2) and the results are shown in Table 3, in addition to the importation risk from each origin. It is shown that due to the difference in the number of weekly flights and the average number of travelers per flight between the different origin airports, the results of the risk flow and importation risks were different than the results for the cumulative incidence. This means that although London and Bahrain had the highest cumulative incidence, the origin cities with the highest risk were Dubai and Istanbul since Dubai had a risk of 9.04% and Istanbul a risk of 7.64%, compared to 0.92% and 0.99% for London and Bahrain respectively.

Impact of COVID-19 on public transport

The results in this section are divided into two subsections. The first one analyzes the impact of COVID-19 on bus ridership in Kuwait, by examining the before-lockdown and after-lockdown ridership numbers for two main bus lines operated by KPTC. while the second subsection shows the results of the environmental impact of COVID-19 on one of those bus routes, whereby the emissions are calculated per kilometer person.

Impact on bus ridership

Figures 10a and b represent the number of buses and number of passengers for the week before lockdown and the week after lockdown for bus route 18 respectively. Referring to Fig. 10a, it was noticed that shows that the number of buses

Table 3 Importation risk

Origin city	γ_{OD}	R_d
Amman	6.67E-06	0.06%
Bahrain	5.14E-05	0.99%
Dhaka	3.66E-06	0.02%
Doha	5.33E-05	1.79%
Dubai	1.34E-04	9.04%
Istanbul	1.14E-04	7.64%
Lahore	2.87E-06	0.03%
London	4.77E-05	0.92%
Riyadh	2.98E-06	0.03%

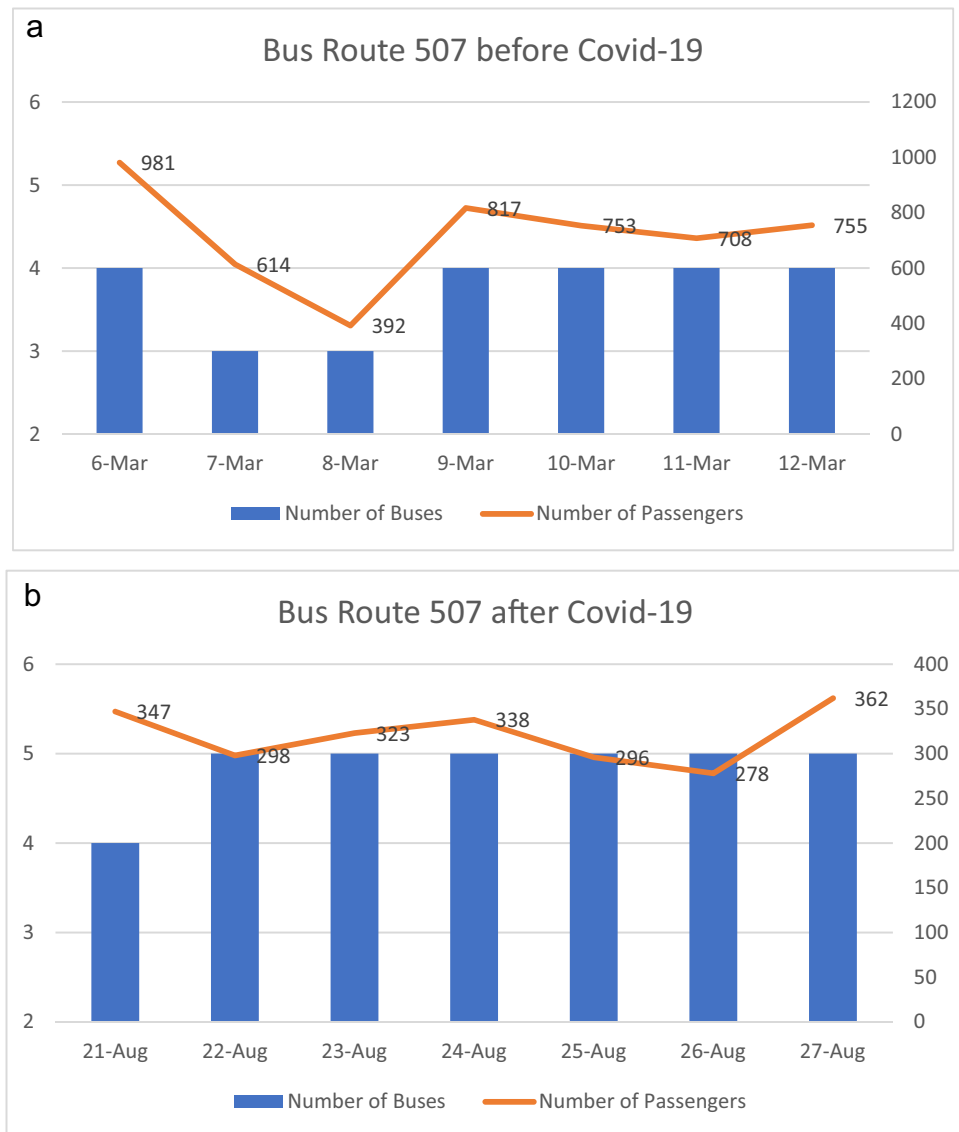
operating daily on bus route 18 in the week before the lockdown was mostly 7, with the exception of 2 days where the number of buses was 8. The extra bus was added to accommodate for the extra number of passengers on the weekend as the 6th and 12th of March represent a Friday and a Thursday, respectively. And about the number of passengers per day, it can be seen that the lowest number was on the 11th of March with a total of 1006 passengers, while highest on the 6th of March with a total of 1497 passengers.

Meanwhile, in Fig. 10b representing the data obtained from the same bus route in the week after withdrawing the lockdown restrictions, it was recognized that the number of buses was low on the weekend with 6 buses operating daily during the weekend, unlike that in Fig. 10a where the number of Buses was higher during the weekend than during the week. However, the daily number of buses operating during the weekdays was higher after the lockdown, where 8 buses

were operating daily versus 7 before lockdown. Although the number of buses operating per day increased during the weekdays after COVID-19, the number of passengers per day dropped significantly, whereby the highest number of passengers per day was recorded on the 23rd of August with only 599 passengers, and the lowest was recorded during the weekend on the 21st of August with 342 daily passengers.

The results show that the strict regulations enforced by the government for the operation of buses have been taken seriously by the operators, more specifically in this case by KPTC, as the number of passengers dropped significantly to less than 50% on average per day. By taking into consideration that not only the number of daily passengers has dropped, but also the number of buses in operation has increased by 1 per weekday, one can assume that bus use in Kuwait is indeed safe, and the rules enforced are helping to keep the number of infections at very low rates.

Fig. 10 a Bus route 18 during the week before lockdown. **b** Bus route 18 during the week after lockdown



from 5 before to 8 after lockdown. It is important to mention that KPTC’s management was able to do that by decreasing the number of lines in operation from a total of 28 to 21 lines, thereby increasing the number of buses per operational line post lockdown. The route followed by the buses pre-lockdown and post-lockdown was the same with the buses stopping at the following 10 stations per direction, in their longest route, which is equivalent to approximately 32 km. Bus route 18 stations: Mirqab Station – Dirwaza Station – Mubarak AL Kabir Station – Cairo St Station – Hawally Station – 4th R.R. / Tunis Station – Airport Station—Shuwaikh Station – Sabah Hospital Station – UN Station.

Environmental impact of buses due to COVID-19

From Fig. 12 which presents data regarding route 18 (Fig. 12), it is obvious that there is a drop in the total number

of daily passengers before and after lockdown from 1183 passengers per day with 5 buses before the lockdown to 462 passengers with 8 buses after the lockdown. Dividing the average number of daily passengers by the number of buses operating gives an insight into how much of a drop in occupancy occurred before and after lockdown. Before lockdown, that number would be 237 passengers per bus, while after lockdown, it is just 58 passengers per bus. The number dropped by almost 4 times. It is important to mention that this number is just for a rough approximation of the impact on occupancy and not the actual occupancy per bus as this is taken on a total per day basis and not per bus per trip basis which would be the accurate way to do it, and this was done to calculate the emissions per kilometer per person. According to the time-of-day data before lockdown for route 18, a driver can complete about 8 trips per shift with a total number of 18 per day, producing 124 complete trips

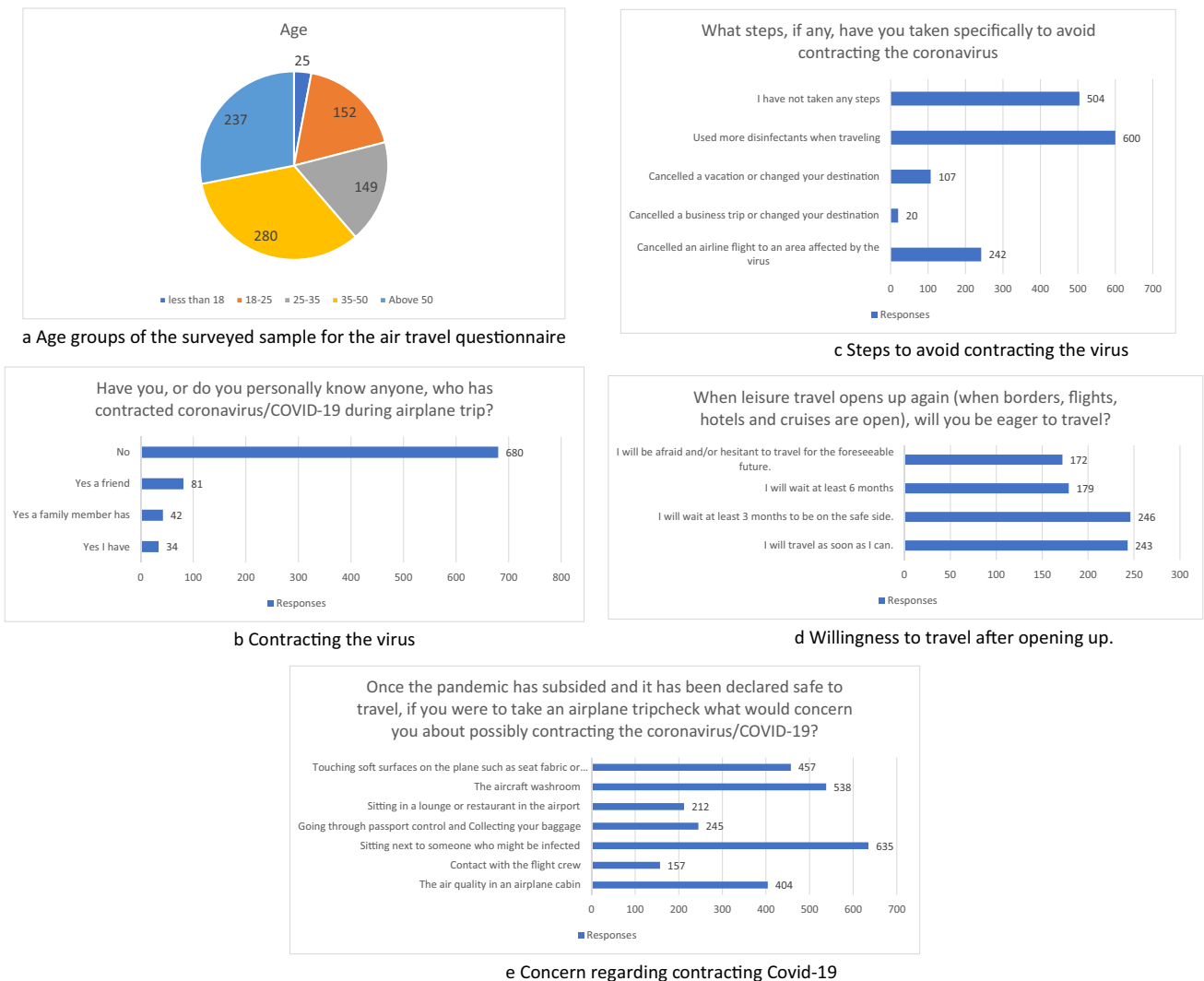


Fig. 12 Bus route 18

in a single direction. Knowing that the total length of that route is approximately 32 km, the resulting total travelled distance covered by all the daily trips amounts to 3968 km. By applying the same method to the time-of-day data for route 18 after lockdown, the total number of trips is 112, with a total km covered of 3584 km. Which is 384 km less than those covered before lockdown. As mentioned previously, the number of operating buses on route 18 before lockdown was 5 indicating that on average each bus covered a distance of 793.6 km daily, while after the lockdown when 8 buses were put into operation, the average distance covered by each one dropped to 448 km daily. By dividing the average daily distance covered by a single bus by the average number of passengers per bus, we would get a notion of how many km are driven per person before and after lockdown (this is not to be confused with km-per). The calculation is shown below:

$$\begin{aligned} &\text{distance traveled per passenger before lockdown} \\ &= \frac{\text{Average distance traveled by a single bus}}{\text{Average no. of passengers per bus per day}} = \frac{793.6}{237} = 3.35\text{km/per} \\ &\text{distance traveled per passenger after lockdown} = \frac{448}{58} = 7.72\text{km/per} \end{aligned}$$

The results show that the distance traveled by a bus per a single passenger more than doubled after lockdown, thereby the efficiency was immensely reduced, and more emissions per person were generated. To calculate that the STP value needs to be estimated. Therefore, it was assumed that the bus weight is the one supplied by MOVES for STPs, which is 16.56 tons. However, since the speed and acceleration information are not available on a per second basis. The average speed and average acceleration are calculated based on the time-of-day data which showed that the time to complete the 32 km route is 70 min. Thus, the average speed v_{avg} is:

$$v_{avg} = \frac{32 \times 1000}{70 \times 60} = 7.62\text{m/s}$$

The corresponding average acceleration a_{avg} can be calculated from the displacement of the bus, which is the distance traveled d , with 0 initial velocity v_0 .

$$\begin{aligned} d &= v_0t + \frac{1}{2}a_{avg}t^2, \text{ then} \\ a_{avg} &= \frac{2d}{t^2} = 0.03628\text{m/s}^2 \end{aligned}$$

In order to calculate VSP, it is necessary to know the number of passengers per bus per trip, or at least in this case the average number of passengers per trip. By dividing the total number of passengers per day by the number of trips per day, the average number of passengers per trip before lockdown and after lockdown can be calculated as shown below:

$$\begin{aligned} n_{\text{before}} &= \frac{\text{Average number of daily passengers}}{\text{Number of trips per day}} + 1(\text{driver}) = \frac{1183}{124} + 1 = 10.54 \approx 11\text{people} \\ n_{\text{after}} &= \frac{\text{Average number of daily passengers}}{\text{Number of trips per day}} + 1(\text{driver}) = \frac{462}{112} + 1 = 5.125 \approx 5\text{people} \end{aligned}$$

It is noticed that the number of passengers per trip is relatively small even before lockdown. This is because buses work around the clock to provide transport means even when there are very few passengers outside the rush hour periods. The number of people in a bus on average throughout the day before lockdown was 11 including the driver and it became 5 after lockdown.

$$\begin{aligned} VSP(STP) &= \frac{A}{M} \cdot v + \frac{B}{M} \cdot v^2 + \frac{C}{M} \cdot v^3 + \frac{m+n \times w}{M}(a + g \sin \theta) \cdot v \\ VSP_{\text{before}} &= 0.859\text{KW/ton} \\ VSP_{\text{after}} &= 0.853\text{KW/ton} \end{aligned} \tag{6}$$

According to the MOVES-Matrix conceptual flow, a VSP ratio between 0 and 1 KW/ton and a speed between 0 and 25 mph (7.62 m/s corresponds to 17 mph) produces an emission rate of about 2 CO₂ g/s (Liu et al. 2019).

The total link-based CO₂ emissions of bus are estimated, however since the per instant data is not provided and since the average speed over the entire period is assumed, then the value of TE at the average speed is multiplied by the total time needed to complete the route, which is 4200 s.

$$\begin{aligned} TE &= \sum_{i=1}^I TSTP_i \times ER_i \\ TE_{\text{before}} &= 4200 \times 0.859 \times 2 = 7215.6\text{g} \\ TE_{\text{after}} &= 4200 \times 0.853 \times 2 = 7165.2\text{g} \end{aligned} \tag{7}$$

While the emissions per km-person discussed in Eq. (5) will become as follows:

$$\begin{aligned} \text{Before lockdown} : E_{\text{km-per}} &= \frac{TE}{L \times n} = \frac{7215.6}{32 \times 11} = 20.50\text{g/km-per} \\ \text{After lockdown} : E_{\text{km-per}} &= \frac{TE}{L \times n} = \frac{7165.2}{32 \times 5} = 44.78\text{g/km-per} \end{aligned}$$

It can be noticed that although the total CO₂ emissions on the link before and after lockdown were relatively the same, whereby the decrease was less than 1% of the total CO₂ emitted, the emission per km person is what is interesting since the values became more than twice after lockdown. Before lockdown, on average 11 people were on a bus at any given moment on route 18, while after lockdown and the introduction of new occupancy rules and 3 additional buses, this number dropped to be only 5 people per bus. This resulted in an increase in emissions per km person from 20.5 g/km-per to 44.78 g/km-per, corresponding to an increase of 118%. The reason for the increase in emissions per person after lockdown is due to the decrease in the capacity of buses, increase in the number of buses, and the decrease in the number of people using public transportation due to the pandemic. Therefore, the efficiency of the public transit system has decreased in terms of emissions per kilometer per person. That means the impact of COVID-19 pandemic on public transportation is negative.

Survey results

This section shows the results of the conducted questionnaires and the applied statistical tests.

Air travel questionnaire

The air travel questionnaire was filled out by 832 respondents, of which 751 were Kuwaiti nationals and 81 were non-Kuwaiti. The age groups of the participants are presented in Fig. 13a. The majority of participants (33.65%) were in the age group between 35 and 50 years with 280 participants. The second largest age group was those above 50 age group with 237 respondents, followed by the age group 18 to 25 years with 152 respondents almost equivalent to the number of participants in the age between 25 and 35 years of age with 149 participants. The age group least represented in this sample is the youngest age group with only 25 people less than 18 years old.

Out of the 832 participants in the survey, 726 did not travel during the past 6 months, while only 113 did. Additionally, 680 participants did not contract or know anyone who has contracted the virus during airplane travel, while 81 had friends that contracted the virus, and 42 had family members that did while 34 of the participants have contracted the virus as shown in Fig. 13b.

Figure 13c presents the results of the question regarding the steps the participants have taken to avoid contracting the coronavirus; the steps taken in order of frequency are as follows: using more disinfectant (600), cancelling a flight (242) changing flight destination for vacation purposes (107), cancelling a business trip (20), while there were 504 responses where participants said they did not take any steps.

Figure 13d presents the responses on whether participants would be eager to travel one leisure travel opens up again. It was shown that 243 answered that they would travel as soon as they can. While the remaining participants chose to be more careful, with 246 saying that they would wait at least 3 months. 179 participants were willing to wait at least 6 months, and 172 would not travel for the foreseeable future.

The participants were asked what would concern them regarding traveling and contracting COVID-19. The results are shown in Fig. 13e. The majority of participants (635) were afraid to sit next to someone who might be infected, followed by fear of contracting the virus in the aircraft washroom (538), touching soft surfaces in the plane such as the seat or blankets (457), the air quality in the airplane cabin (404). And regarding the fear of contracting the virus in the airport, 245 participants were worried about the passport control and baggage claim area while 212 were afraid of sitting in a lounge or an airport restaurant.

Correlation test The results of the conducted chi-square test are shown in the table below, showing the correlation between age and nationality with the other factors (willingness to travel, contracting virus, comfort flying driving staying home).

The summary of conducted correlation tests for the air travel survey is presented in Table 4, whereby it is clear that the nationality of the participant had no correlation with eagerness to travel when leisure trips open, not even with previous exposure to people who contracted COVID-19 due to air travel. Nationality also played no significant role in the comfort level of participants to travel when it is deemed safe to. Therefore, it was concluded that including the nationality of the participant in the examination doesn't provide any insight into what the outcome of other questions in the survey might be since all factors are independent of participants' nationality.

On the other hand, age had a significant role and unlike nationality, since there was a strong correlation between age and eagerness to travel because after statically examining the correlation of each age group with eagerness to travel, it was revealed that 75 participants aged from 18 to 25 had the willingness to travel as soon as it is accessible for them, while 20 of participants from the same age group were afraid to travel even in the foreseeable future. Additionally, age factor had also a significant correlation with having been exposed to COVID-19 through air travel or known someone who had contracted the virus through air travel. Moreover, there was a correlation between the age of participants and their comfort level to fly after it has been declared safe to travel. In order to have an accurate examination, the replies of each age group on each question have been analyzed. The results showed a significant relationship between age and the COVID-19 consequences on public transport. It was noticed that the older the participant, the more afraid they were from taking risks that might cause him or her to contract the virus. For instance, the question regarding travel eagerness when leisure travel opens up showed that 114 participants out of 172 who were afraid of traveling, were above 35 years while only 22 were younger than 25 years. Moreover, out of the 243 participants who were willing to travel as soon as possible, 75 were between 18 and 25 years compared to 51 who were above 50 years old. The results also showed that the older the participants the more likely they would wait and see what happens rather than jumping on the first plane and perhaps risking contracting the virus, where 104 participants aged above 35 chose to wait for at least 6 months before traveling, and only 65 participants younger than 35 years old would wait that long. Similarly, in the question regarding comfort level to travel



Fig. 13 a Age groups of the surveyed sample for the air travel questionnaire. b Contracting the virus during an airplane trip. c Steps to avoid contracting the virus. d Willingness to travel after opening up. e Concern regarding contracting COVID-19

in airplane versus driving or staying at home, the older the participant, the more likely that they would stay home. For instance, out of the 393 participants who preferred to stay

at home for the foreseeable future, 254 of them were above 35 years old while 64 were younger than 25 years of age. Meanwhile those numbers dropped for the older age group

Table 4 Correlation matrix and two-tailed probabilities

	Code	1	2	3	4	5
1	Nationality	1	-			
2	Age	-	1			
3	Eagerness to travel	0.953	0.000	1		
4	Exposure to COVID-19	0.216	0.002	-	1	
5	Comfort to travel	0.108	0.013	-	0.000	1

when choosing to fly without a problem, as 227 had no problem with traveling while there was an increase in the younger age group where 104 did not have a problem with traveling in an airplane compared to 64 who chose to stay at home. In order to have a more detailed analysis and to understand the participants' behavior regarding COVID-19 and public transport, the responses to the eagerness to travel were compared to the those regarding comfort to travel using airplanes when leisure trips are considered safe. Based on the results, it was concluded that there was a correlation between the responses and that the participants who expressed fear of traveling immediately after leisure travel opens up are mostly the same ones who expressed fear of using airplanes to travel and rather preferred staying at home for the foreseeable future. For instance, 157 out of the 170 who preferred to stay at home when asked about their eagerness to travel when leisure travel opens up again, also chose to stay at home when asked about their comfort flying for leisure when it is deemed safe to travel. Moreover, about 70% of those who chose to wait 6 months before traveling, chose to stay at home for the foreseeable future when asked about their comfort in using airplanes to travel or even driving to their destination. This indicates that people who were worried and more cautious regarding contracting COVID-19 are mostly older people fearing for their health. Additionally, for those who were younger and afraid of contracting the virus, they were also hesitant to take airplane trips for leisure purposes before making sure that it is very safe for them and their families, and until then they would rather stay at home and not even drive to a leisure destination.

Public transportation questionnaire

Regarding public transport questionnaire, a total of 513 participants filled it out. 88% of them own a car or have access to it, while 12% of them did not. regarding the participants' nationality, the majority of the participants were Kuwaiti (69%). From Fig. 14a, it can be noticed that most of the participants were aged between 18 and 25 (44%), followed by participants between 35 and 50 (21%). The participants between 25 and 35 (16%) were almost equal to those over 50 (15%). However, only 4% were less than 18.

The opinion of participants regarding the public transportation in Kuwait took place in the questionnaire, the results presented in Fig. 14b show that only 53 participants rated public transportation in Kuwait as very good and 109 rated it as good while 113 rated it as fair. However, 95 believed that it is very poor and 129 said that it is poor.

And about participant experience on riding a bus in Kuwait, the majority (785%) of them did not ride the bus in Kuwait, while only 25% did. Regarding riding a bus frequency by those who ride a bus, 24 participants rode it daily, 11 rode it weekly, 21 rode it monthly, while 23 used the bus several times a week, and 35 used it several times a month.

The participants that did not use the bus were asked to list one or more reasons why they do not, the reasons and responses of participants are shown in Fig. 14c. It can be noticed that the majority cited crowdedness in buses as the main reason for not riding a bus, followed by waiting or standing for a long time. Owning a car was also a significant reason for not riding a bus since 122 participants justified not riding a bus due to owning a car. Long walking distances to and from bus stations prevented 113 participants from having the willingness to ride a bus, and this can be related to the hot climate that makes walking for a long distance a non-preferrable activity, especially during summer. Additionally, problems with getting on and off the bus were chosen by 55 participants as a reason for avoiding riding a bus.

In order to enhance the quality of public transportation in Kuwait, participants were asked to mention the suggestion improvements that can be added to the public transportation system in Kuwait to encourage people to use it more often. All suggested recommendations are shown in Fig. 14d, it is visible that the majority (321) mentioned that they would like to improve bus stops in addition to the services provided such as comfortability, seats, and timetables. Two hundred fifty responders prefer to induce bus priority lanes which would reduce delays. Two hundred participants agree with having more timetable reliability, 174 wanted direct bus routes with no stops, while 153 wanted basic information on catching the bus the last three suggestions help in saving passengers' time.

Participants were asked to choose the most used transportation mode of three modes during the public transportation shut down as presented in Fig. 14e. The majority used

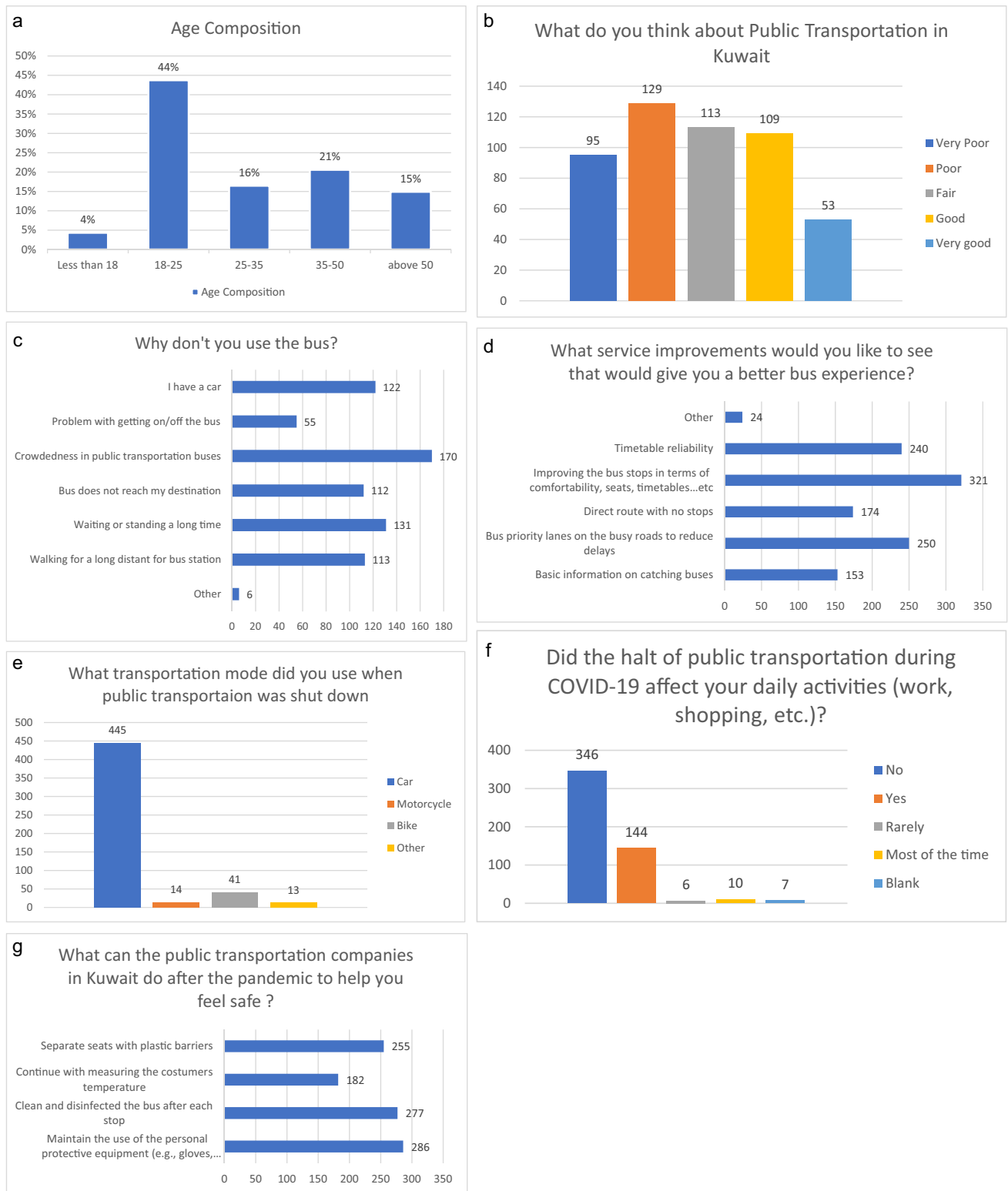


Fig. 14 **a** Age composition. **b** Public transportation rating. **c** Reason for not using the bus. **d** Improving bus transport. **e** Transportation mode during public transportation halt. **f** Effect of public transportation halt on daily activities. **g** Steps that would help customers to feel safer

private cars (445) followed by bicycles (41), and motorcycles (14). Other answers included staying at home and carpooling.

Figure 14f provided a summary of the responses regarding the effect of the halt of public transportation during the pandemic on participants’ daily activities. A total of 346 experienced no change in their daily activities while 144 did. Ten participants were affected most of the time, while 6 were rarely affected.

It is also significant to study people’s willingness of using the bus system after the pandemic, 78% of participants were not willing to use the buses anymore while only 22% would use it, which indicates that few people are willing to use the bus service after the pandemic than the ones that used it before.

Since many people are not willing to ride public buses again, it is required for public transportation companies to provide some steps that help riders to feel safe while they are on a bus. Figure 14g provides the steps that could improve the safety of buses after the pandemic. According to the results, it can be concluded that most participants prefer maintaining the use of personal protective equipment, cleaning and disinfecting the bus after each stop, and separating seats with plastic barriers. Moreover, 182 participants suggested the continuation of measuring customer temperatures.

Correlation test For the public transport questionnaire, the participants were asked to rate public transport in Kuwait belongs to the Likert’s 5-point scale, and in this case the rating starts with very poor as the first response and ends with very good as the opposing 5th response. Table 5 shows the correlation matrix of the public transport questionnaire. It can be recognized that Nationality has a major impact on bus ridership, whereby there was a significant correlation (0.0). Non-Kuwaitis made up the majority of those who ride the bus, where 95 participants out of 125 who rode the bus were Non-Kuwaiti while only 30 were Kuwaiti. Similarly, the majority of those that are willing to use the public transportation system after the end of the pandemic are non-Kuwaiti making up to 65% of the participants. However, nationality had an effect on public transportation rating. Furthermore, bus ridership is dependent on car ownership,

whereby the majority of those who own a car does not ride the bus since they use their own car as a transport mode. A total of 362 out of 443 of car owners or those who have access to a car do not ride the bus, while only 81 of those who do have access to a car ride the bus. However, 17 out of the 61 participants who have no access to a car, do not ride the bus, while 44 do. In addition, car ownership had a direct impact on the effect of public transport halt on daily activities, since 97% of those who experienced no impact on their daily activities during the halt of PT already had access to a vehicle, while only 3% of those who had no impact did not have access to a vehicle.

Conclusions

From the beginning of considering COVID-19 as a pandemic, Kuwait announced strict lockdown regulations that banned public transport completely and suspended all commercial flights from and to Kuwait International Airport, and restricted travel to evacuation flights for residents of Kuwait and cargo flights in order to stop the spread of the virus. Flights and buses started to resume in August. For buses, new regulations were imposed including a reduction in the occupancy to a maximum of 50% per bus, adding a plastic barrier for the driver, testing temperature for drivers and passengers, as well as placement of hand sanitizers throughout the buses.

This study aims to analyze public transport ridership data in Kuwait before and after the lockdown period, estimate the environmental impact of public transport due to COVID-19, study COVID-19’s impact on air travel, and evaluate the risk of importation from different Airports flying to Kuwait International Airport as per the most recent data until February 2021. This paper studies the impact of COVID-19 during the first phases of the pandemic.

Regarding air travel data analysis, it was recorded that number of passengers per day fell from 7170 departing in the first week of November 2019 to 856 departing in that same week in 2020. Moreover, a significant drop in the number of departing and arriving flights per day from 45 flights to 11 was observed during the same week, which

Table 5 Correlation matrix

Code	1	2	3	4	5	6	7
1 Nationality	1	-					
2 Age	-	1					
3 Car ownership	-	-	1				
4 Bus Ridership	0.000	-	0.000	1			
5 PT rating	0.229	0.094	0.101		1		
6 Effect of PT halt on daily activities	-	-	0.000	-	-	1	
7 Using PT after pandemic	0.000	-	-	-	-	-	1

corresponds to a 76% drop in the number of daily flights. Likewise, the average number of daily arriving passengers in that week in 2020 was dropped by 87% of that in 2019. Evacuation flights occurred in April 2020 and successfully evacuated 11,783 residents of Kuwait during a week from the 19th till the 25th of that month. The arriving citizens were put in quarantine to prevent the spread of the virus. Most of the COVID-19 cases from the evacuated passengers were from London Heathrow with 216 followed by Iran with 90 cases. According to the risk flow analysis results, it was proved that the highest importation risks were from Dubai and Istanbul. Although the number of infected people in those areas was not the highest, but the high number of weekly flights increased those risks to 9.04% for Dubai and 7.64% for Istanbul.

Regarding bus ridership, the daily number of passengers for KPTC before the lockdown in 2020 was 22,662 with 151 buses. The daily number of passengers after lockdown between the 18 of August 2020 and the 25 of December 2020 was 15,819 with 174 buses. After studying the environmental impact of the drop in passenger count and the increase in bus count, it was revealed that the per km person CO₂ emissions on bus route 18 increased from 20.5 to 44.78 g/km-per, corresponding to an increase of 118%.

To hear the public voice and understand their perspective regarding COVID-19 impact on public transport, two independent questionnaires were conducted, one about air travel during the pandemic and the other about using public transport during the pandemic. The first one was filled out by 832 participants, where 751 of them were Kuwaiti nationals and the majority aged between 35 and 50 years with 280 respondents followed by 237 who were above 50 years old.

Based on statistical test results, it was shown that age was a significant factor, but nationality was not. Since the age factor had two strong correlations with eagerness to travel, participants' comfort level to fly after it has been declared safe to travel. Additionally, the correlations pointed out that the older the participant, the more worried they seemed from contracting the virus, and the less willing they were to travel.

About the second questionnaire regarding public transport, 513 participated, and 69% of them were Kuwaiti, and 44% were between 18 and 25 years of age. The correlation test results showed that nationality had a major impact on bus ridership, whereby out of the 125 participants who rode the bus, 95 were non-Kuwaiti. This number dropped to 109 for those willing to take the bus after the pandemic is over, and similarly, the majority (65%) were non-Kuwaitis. It was also observed that bus ridership is correlated with car ownership, as the majority of those who use public transport were non-car owners.

In order to improve air flights and buses, several solutions were recommended to increase safety such as far-UVC light to kill viruses and germs, improving the ventilation system in buses, using COVID-19 robots, as well as adopting

contactless passenger management and payment. In conclusion, it is recommended to study the further impact of COVID-19 on public transport and air travel in Kuwait over a longer period to have a detailed and accurate knowledge of the long term of the pandemic and to assess the effectiveness of the adopted 3 stage plan to return full commercial flight operation by August 2021.

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Author contribution Sharaf AlKheder: conceptualization, manuscript writing.

Data availability All data used in this work are presented in the published article.

Declarations

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