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Urban Transportation Measures and Vaccination Impact on The Number of COVID-19 Infections: A Before and After Study

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ABSTRACT: Prior research on COVID-19 focused primarily on travel behavior changes before, during, and after the pandemic, with the aim of analyzing the significant variables. However, this research aims to study and compare the effects of traffic and transportation measures, specific events, and vaccination rates on the COVID-19 infection rate in Tehran, Iran. A correlation analysis is employed to investigate the degree of relationship between the number of infected individuals on each day and the implementation time of measures, events, and the vaccination rate. Over a 14-day period, the majority (67%) of measures and events had a significant impact on either decreasing or increasing the number of infections at a significant level of 1%. Results indicate that congestion pricing suspension has the most effect on decreasing the virus spread (correlation coefficient between -0.75 and -0.94). As another traffic-related measure, intercity travel bans also contributed to a decrease in infections. Additionally, certain holidays/events and their related movements and gatherings are linked to an increase in cases (correlation coefficient between 0.71 and 0.96). The ongoing decrease in infection rate could be attributed to the increasing vaccination rate, showing a negative correlation with a coefficient of -0.771.

KEYWORDS: Pandemic control; Transportation measure; Traffic management; Response effectiveness; Correlation analysis

1. INTRODUCTION

The outbreak of the COVID-19 virus as a serious threat to global public health was first recognized in December 2019 with the emergence of the initial cases in Wuhan, China. The high infection rate, the lack of vaccination, and the unpreparedness to combat this virus led to its rapid spread in other countries globally in a very short time (WHO, 2020). Approximately, 8,000 people were infected in only two months, prompting the World Health Organization to declare this virus as another global pandemic (Hatamzadeh et al., 2020). In response to these extraordinary conditions, governments implemented various measures to control the virus's spread, including quarantine, social distancing, and restrictions on business activities. For instance, in China, measures such as quarantining infected people, travel restrictions, the closure of recreational facilities, and the prohibition of public gatherings were executed as preventative measures against the virus. The decrease in the transmission period and changes in the growth rate of new cases indicated the effectiveness of these measures in controlling the virus's spread (N. Zhang et al., 2021).

Transportation system could also be considered as one item that can either accelerate or decelerate the virus's transmission. The demand for various transportation modes is also influenced by the virus's spread (Márquez et al., 2019), the restrictive measures imposed by governments, and individuals' perception about their own safety (Bhaduri et al., 2020). For instance, individuals' attitudes and mindsets can affect travel patterns and users' choices (Hatamzadeh et al., 2020, 2021; Khalilikhah et al., 2016). Given the uncertainty about the infections means of this virus, people's reactions and choices, have had a direct impact on transportation mode choice and travel behavior; one of the most notable outcomes has been the decline in public transportation ridership (Tiikkaja & Viri, 2021).

It is very important to note, in contrast to previous research that correlated travel behavior change to socioeconomic variables (e.g., age, gender, and income), more specific factors need to be included such as personal attitudes (e.g., health concern and fear) as well as government policies and legal measures (Elias & Zatmeh-Kanj, 2021; Qi et al., 2021). In early 2020, cases were officially reported in Iran, a government committee was established to make decisions on controlling the virus's spread, announcing them as measures of the National Task Force Against Coronavirus. These measures include various measures such as social distancing, school closures, and the cancellation of cordon pricing in the cities (The National Task Force Against Coronavirus in Iran, 2021). Considering the initiation of vaccination in February 2021, it can be argued that these measures could have been considered a major obstacle to decreasing the number of COVID-19 cases in Iran.

While there is a considerable amount of research conducted in this area, most studies focus on mode choice before, during, and after COVID-19. They aim to investigate the factors related to these choices or conduct behavioural analyses of their decisions and try to investigate the effect of socioeconomic variables on people's travel behaviour. Hence, still, there is a considerable gap between the effect of government policies and personal travel attitudes during pandemics like COVID-19. Therefore, our study aims to analyze the impact of measures imposed by the Iranian government, as well as specific events, on the spread of COVID-19 in Tehran, Iran. The examined measures in this study encompass restrictions on business activities and traffic prohibitions. Their impacts on the number of patients are compared with vaccination, which was implemented at a later stage.

This research will commence with a review of prior studies, an explanation of the research methodology, details on

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the selection of measures and dates under scrutiny, an assessment of the effects of these measures and events during specified time intervals, and a discussion of the findings. In the final phase, we will draw conclusions from the study and provide recommendations for future research.

2. LITERATURE REVIEW

With the rising rate of the COVID-19 virus in urban communities, researchers from various fields have delved into examining the impact of the virus on human lives, including assessing its influence on the urban transportation systems. For instance, understanding modal shifts during the COVID-19 pandemic is important for assessing the impacts on various transportation modes, infrastructure planning, and policy-making (J. Zhang et al., 2021). Besides, some research used the stringency index based on nine response indicators (workplace closures, school closures, closures of public transportation, restrictions on internal movements, international travel controls, cancellation of public events, restrictions on public gatherings, stay-at-home requirements, and public information campaigns to analyze the impact of COVID-19 on transportation sectors (Li et al., 2024; Sekadakis et al., 2023).

A worldwide survey conducted by the WCTRS COVID-19 Taskforce revealed a significant global modal shift from public transportation to other modes. Cars claimed the largest share, followed by walking, cycling, and motorcycles, with geographical variations indicating diverse changes in transportation behavior (J. Zhang et al., 2021). The emergence of COVID-19 led to decreased mobility in the United States (Warren & Skillman, 2020) and a study in India by (Bhaduri et al., 2020) showed a propensity to shift towards remote work and online shopping, with a preference for private modes of transportation. Similarly, Abdullah et al. (2020) found a significant shift from public transportation to personal and non-motorized modes, particularly for shopping purposes. Sahraei et al. (Sahraei et al., 2021), observed a 90% decrease in public transportation use across 12 countries from January to March 2020, accompanied by improved air quality. Arellana et al. (Arellana et al., 2020), studied the impact of COVID-19 regulations in Colombia, revealing decreased use of all transportation modes. Aaditya and Rahul (Aaditya & Rahul, 2021), emphasized significant shifts in mode choice behavior during the pandemic, influenced by increased disease awareness and safety concerns. Policymakers should consider these psychological impacts to provide safe and reliable transportation options post-lockdown.

The COVID-19 pandemic induced a shift in travel behavior as individuals actively avoided public spaces due to virus-related concerns, resulting in significant travel decrease (Atombo et al., 2023). Studies in China emphasized the role of holiday travel as a major contributor to mobility changes and virus spread compared to impending travel restrictions (Gibbs et al., 2020). In India, research on travelers' perceptions during and after the lockdown phase revealed substantial changes in travel behavior, with a prevailing belief in the safety of private cars over other transportation modes, particularly among older and higher-income individuals (Rankavat et al., 2022). Similar findings in India by Das et al. (Das et al., 2021), linked changes in travel mode to socioeconomic variables, including age, gender, and income. Borkowski et al. (Borkowski et al., 2021), highlighted an inverse relationship between travel times and the fear of contracting COVID-19 due to quarantine measures. In Iran, Shaer et al. (Shaer et al., 2021), explored the relationship between active travel modes and built environment variables in Shiraz, noting increased walking and cycling times in the central business district compared to other areas. Another study (J. Zhang et al., 2021), investigated travel behavior changes across age groups in Hong Kong, revealing decreases in intracity travel for adults, children, students, and the elderly from the virus outbreak to March 2021 in China (42%, 86%, 73%, and 48%, respectively).

Ongoing studies on the impact of the COVID-19 pandemic on travel patterns reveal sustained changes. Italy, the first European country to enforce a lockdown, witnessed a significant decrease in road traffic, notably in public transportation demand during the initial pandemic phase (Costa et al., 2022). In Lisbon's 2022 lockdown, socioeconomic activity and mobility patterns shifted. Post-lockdown, cycling increased for recreational purposes, while work and school trips decreased (Costa et al., 2022). Another study on paratransit operators during the pandemic highlighted safe but 60% more expensive transportation services, impacting users based on travel purposes and demographics (Nie et al., 2022). Californian e-commerce and shopping patterns were affected by the pandemic, leading to changes in car miles driven and trips taken. Notably, 30% maintained pre-pandemic habits, 54% increased e-commerce dependence, and 16% decreased reliance (Luo et al., 2023). In Massachusetts, societal disruption prompted increased reliance on cars for commuting, while on-site work likelihood rose for those who bought cars during the pandemic (Zheng et al., 2023). Another study in Pasig, Philippines, explored how proximity to green spaces influenced active travel behavior, highlighting significant contributions to walking and cycling. Green spaces were shown to promote well-being and active lifestyles during stressful times (Barquilla et al., 2023).

Developed nations have established policy frameworks to address various macroeconomic shocks, while developing countries, vulnerable to the devastating COVID-19 pandemic, respond on different scales due to institutional impediments (Mogaji et al., 2022). The transportation sector, not significantly affected globally, raises concerns for countries grappling with limited options, high private automobile ownership, air pollution, and car accident-related fatalities (Khadem Sameni et al., 2021). Atahan and Alhelo's study in Istanbul analyzed human mobility changes throughout one year of the COVID-19 pandemic, emphasizing its substantial impact on mobility patterns. They found a trend towards using personal automobiles for daily excursions, highlighting the importance of effective measures like staggered work hours and decreased transit capacity for sustainable transportation solutions (Atahan & Alhelo, 2022). In Indonesia, another study evaluated the government's transportation policy during the COVID-19 outbreak, revealing a decrease in effectiveness over time. The greater costs associated with maintaining social distancing measures and the diminishing strictness of imposed mobility limitations may have a more significant impact on rising countries with large informal sectors, such as Indonesia (Khoirunurrofik et al., 2022). Another study's investigation into the impact of the pandemic on Bangladeshi citizens' travel choices revealed significant changes in travel mode preferences. Men, working and shopping outside, faced greater risk, with recreational trips decreased while work trips remained unaffected. Online work, education, and shopping grew in popularity, primarily in urban areas, with buses being the preferred mode of transportation for both short- and long-distance recreation and market visits during the pandemic (Anwari et al., 2021). Since, the pandemic caused a significant decrease in global travel demand, with preferences shifting toward private vehicles, bicycles, walking, telecommuting, and online activities, some researchers tried to investigate the effect of telecommuting on COVID-19, and vice versa (Brůhová Foltýnová & Brůha, 2024; Javadinasr et al., 2022; Kogus et al., 2022; Ton et al., 2022).

Other authors explored the impact of travel demand management policies during the COVID-19 pandemic in Tehran, Iran, revealing shifts in travel behavior, mode choices, meas-

ures, and infrastructure planning. They found that fear of virus exposure led to decreased public transportation use and increased reliance on private cars, potentially causing long-term declines in public transportation trips and changes in trip frequencies. To ensure a more sustainable transportation future, adaptable measures and strategies are crucial (Baghestani et al., 2023). In a study by Lak et al., analyzing 43,000 COVID-19 patients in Tehran during the first five months of the pandemic, spatiotemporal modeling and regression analysis investigated variables related to the pattern of COVID-19 infection across 22 districts. Population density, neighborhood scatter, pharmacies, stores, and factors linked to healthcare facilities and public transportation, such as bus stations, emerged as significant variables influencing the increased infection rate (Lak et al., 2021).

This study addresses a significant gap in the literature by investigating the effect of urban transportation policies, governmental measures, and vaccination rates on COVID-19 infection rates, a topic that has been largely neglected in prior studies. Whereas previous research has generally related changes in travel behaviour to socioeconomic issues, our analysis investigates the direct effects of specific transportation policy and public health measures on pandemic dynamics. Our findings, which correlate traffic measures, events, and vaccination progress with infection trends in Tehran, Iran, provide new insights into the potential for targeted transportation policies and vaccine initiatives to affect pandemic outcomes. This study emphasizes the significance of combining urban transportation planning with public health measures, offering significant recommendations to policymakers and urban planners in pandemic management.

3. METHODOLOGY

In this study, the correlation between the COVID-19 infection rate and the various measures or events influencing it is explored in Tehran, Iran. The daily infection rate data have been published officially for each city of Iran (Ministry of Health and Medical Education, 2021). In the rest of this section, the details of the measures and events under study are introduced, and the analytical approach of this research is also presented.

3.1 Measures, Events, and Vaccination Rate

As mentioned, one set of the investigated data comprises measures and some events. Since the movements can boost the infection rate of COVID-19 (Ahmadi et al., 2020), the governments have tried to limit people's movements to decrease the infection rates.

It should be noted that other factors can also influence the outbreak of COVID-19. However, in line with the purpose of this research, which aims to investigate the impact of transportation-related factors and vaccination rates on the daily infection rate of COVID-19, we have examined three groups of measures, specific events, and vaccination rates that influence the volume of people's movements (Figure 1).

3.1.1 Executive orders on work activities

As mentioned above, the first group of measures is "Executive orders on work activities," which determine the type of activity in organizations and departments in the form of on-site or teleworking during the COVID-19 outbreak (Ministry of Health and Medical Education, 2021). The aforementioned measures align with the teleworking policy that decreased movements.

3.1.2 Traffic measures

The second category of measures affecting the number of patients under evaluation includes traffic-related measures, which include two main groups. The first one is related to the cordon pricing of Tehran city's Central Business District (CBD), which has been implemented for private cars to address traffic congestion (Habibian & Rezaei, 2017). For this aim, before the emergence of COVID-19, the cordon pricing policy was implemented in an area of 96 square kilometres within the CBD. According to this policy executed in Tehran, the people must pay entrance tolls to enter the CBD zone (Fowri & Seyedabrishami, 2020). However, during the COVID-19 era, this policy has been intermittently suspended and reapplied multiple times as a measure to control the spread.

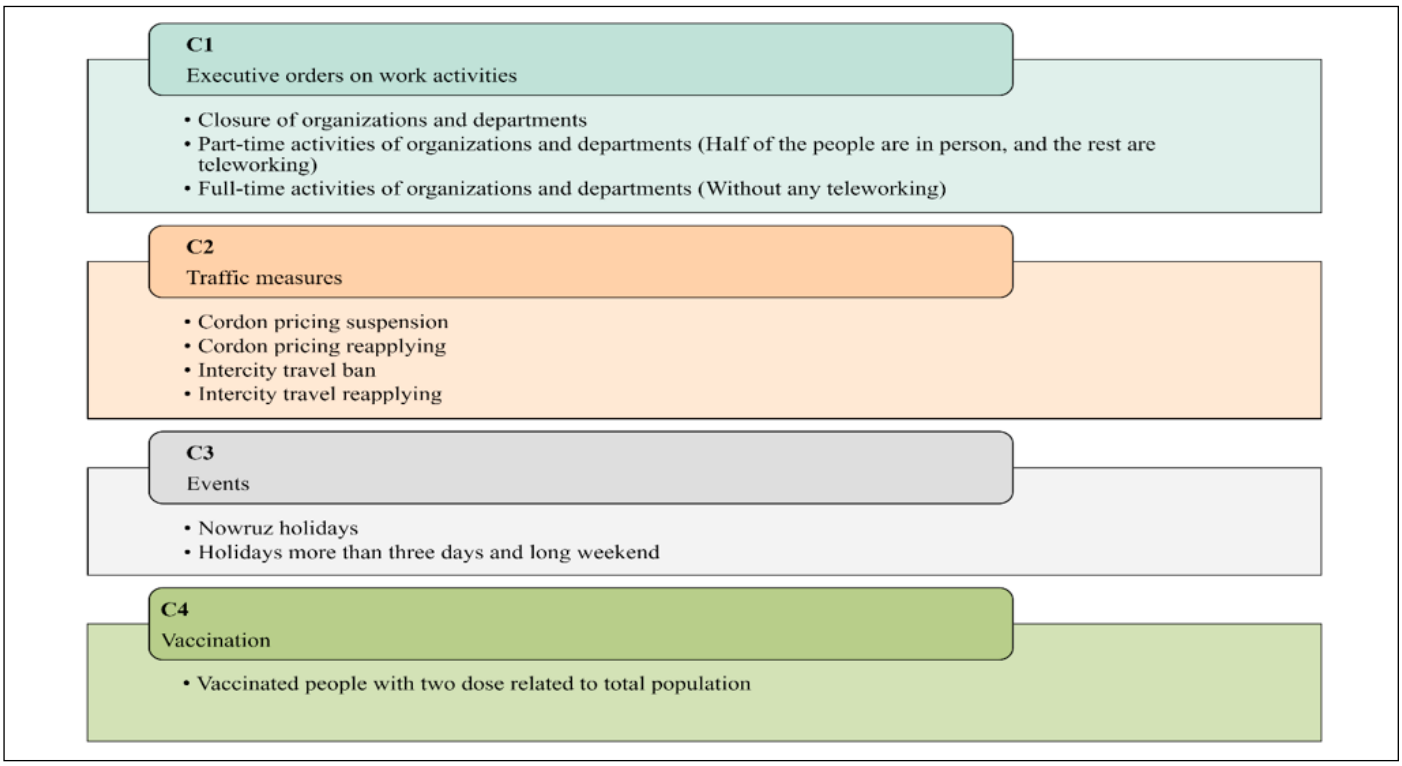

Figure 1. Classification of measures/special events/vaccination rate affecting the infection of COVID-19

3.1.3 Events

In this research, in addition to the aforementioned factors, the effect of some historical events, e.g., the Nowruz[1] holidays and holidays over three days, as well as long weekends, has been investigated. It must be mentioned that those holidays usually resulted in more movements which could affect the number of COVID-19 patients.

3.1.4 Vaccination

The final category explores the effect of the vaccination rate of people who received two doses of the vaccine on the number of COVID-19 patients. The vaccination process in Iran started with a delay compared to other countries. The first dose of the vaccine was administered to medical staff in February 2021, and after a time gap, the injection process for the entire population commenced. By October 2021, the vaccination rate had reached 30% of the population.

3.2 Correlation analysis

The correlation analysis is usually used to investigate the degree of correlation between two sets of variables. The linear correlation coefficient (r or R) is a measure that provides information on the extent to which two variables have a very close association (Senthilnathan, 2019). Fundamentally, the coefficient of correlation "R" will range between -1 and +1, i.e., $-1 \leq R \leq +1$. According to (Gogtay & Thatte, 2017) by measure, the correlation coefficient can be interpreted based on its value. The positive value of R, i.e., $(0 < R \leq +1)$, shows a positive correlation, and the negative value of R, i.e., $(-1 \leq R < 0)$, shows a negative correlation. It must be noted that the closer the correlation is to the absolute value of 1, the stronger the correlations between the two variables.

In this study, the correlation between the number of infected individuals (i.e., daily confirmed new infection case) and the implementation time of measures by 'The National Task Force Against Coronavirus in Iran,' specific events, and the vaccination rate has been evaluated at a significance level of 1%. It is important to note that, in accordance with previous studies and guidelines in the field of controlling and containing the spread of COVID-19, a 14-day duration following the implementation of measures and events has been considered for studying the correlation (The Centers for Disease Control and Prevention, 2021). In this way, during the implementation of each of the measures, the occurrence of events, or reaching a certain percentage of vaccination, the correlation between two categories of variables has been investigated. The first category, which represents the time frame, is an ascending 14-day period containing 14 record set of data from 1 to 14. The second category, which can be ascending, descending, or a combination of the two, is the number of people infected with COVID-19 according to the mentioned period from day 1 (implementation of measures, events, or vaccination) to day 14. It is on this basis that the relationship between the number of COVID-19 infections and the implementation of each of the actions and events is measured. The subsequent section will provide detailed information on the mentioned variables.

3.3 Overlook

Figure 2 shows the daily infection rate of COVID-19 in Tehran from the beginning of the COVID-19 outbreak to the end of 2021. In the mentioned time in Tehran, there are five peaks of COVID-19, which are marked in red boxes. It is obvious that various factors can cause these peaks of COVID-19 infection, and measures, events, and vaccination processes are a significant part of these factors. In this study, 23 measures of the National Task Force Against Coronavirus, events, holidays, and vaccination have been evaluated for their effectiveness, and the implementation time is illustrated in Figure 2. The approach of this study is to investigate the effectiveness of the mentioned factors that are effective in the infection rate with the COVID-19 virus, which will be analyzed in five time periods, and the results will be presented in the following parts. In some periods, to clarify the changes, the traffic statistics extracted from the analysis of the information of Tehran's Automatic number-plate recognition (ANPR camera) have also been used (Consortium of Amirkabir University of Technology and Tarbiat Modarres University, 2021). This information is taken from the output of Tehran traffic camera records, based on which, the changes in modes between the dates of the measures of the cordon pricing (during the outbreak of COVID-19) and one year before (days without COVID-19) have been compared.

4. RESULTS

This section analyses the period studied from the beginning of the virus outbreak to the end of 2021 in five shorter periods. Also, in the first two periods, the traffic statistics of modes within the scope of cordon pricing of Tehran are used to evaluate the effect of traffic measures on the rate of infections.

4.1 Time period 02/19/2020 to 06/20/2020

In examining the trend of changes in the number of infected people, the period from the beginning of the virus outbreak to the end of June 2020 in Tehran is analysed (Figure 3). The outbreak process exhibited fluctuations during this period, marked by two peaks. Through correlation, Table 1 analyses the effect of the mentioned items numerically. It is important to note that the effect period of each measure or event is considered two weeks, as indicated by green and red arrows in the figure.

Due to the unknown characteristics of the virus, and the lack of accurate information on how to manage it, the virus has developed rapidly at the beginning of its outbreak. To control the spread of the virus during the Nowruz holiday of 2020, the relevant authorities banned intercity travel. Consequently, the number of people infected with the virus decreased by 50% two weeks after the peak period. Another reason contributing to the decrease in infection rates was the suspension of cordon pricing in the middle of April 2020. The number of virus-infected people has dropped from 356 to 213 after the cordon pricing suspension. Table 1 also shows the significance of the decreasing trend that these two measures have caused.

Businesses gradually started working after passing through the first peak period, and the intercity travel ban was lifted simultaneously. These measures gradually prepared the conditions for the second peak period. According to Figure 3, the number of infected people has increased by over 60% in less than 20 days since implementing the above measures in the third week of April 2020. Nevertheless, a correlation analysis over a 14-day interval did not show a significant increase in infected. During May 2020, a multi-day holiday allowed citizens to travel to other cities, contributing to increased COVID-19 infections. This event, as well as the reapplying of cordon pricing and the full-time activities of organizations and departments, have also contributed to the upward trend in the number of infected in less than 10 days.

Traffic statistics confirm the effects of traffic measures on the number of infected with COVID-19. Table 2 shows the share of different vehicles in the cordon pricing rings of Tehran city before and after the implementation of traffic measures. Due to the suspension of cordon pricing, the share of non-private vehicles (public transportation and taxis) has decreased by 4.8%. In contrast, the share of these vehicles increased by 2.8% after cordon pricing was reestablished.

1 Nowruz is the Iranian (Persian) New Year starting usually on March 21st.

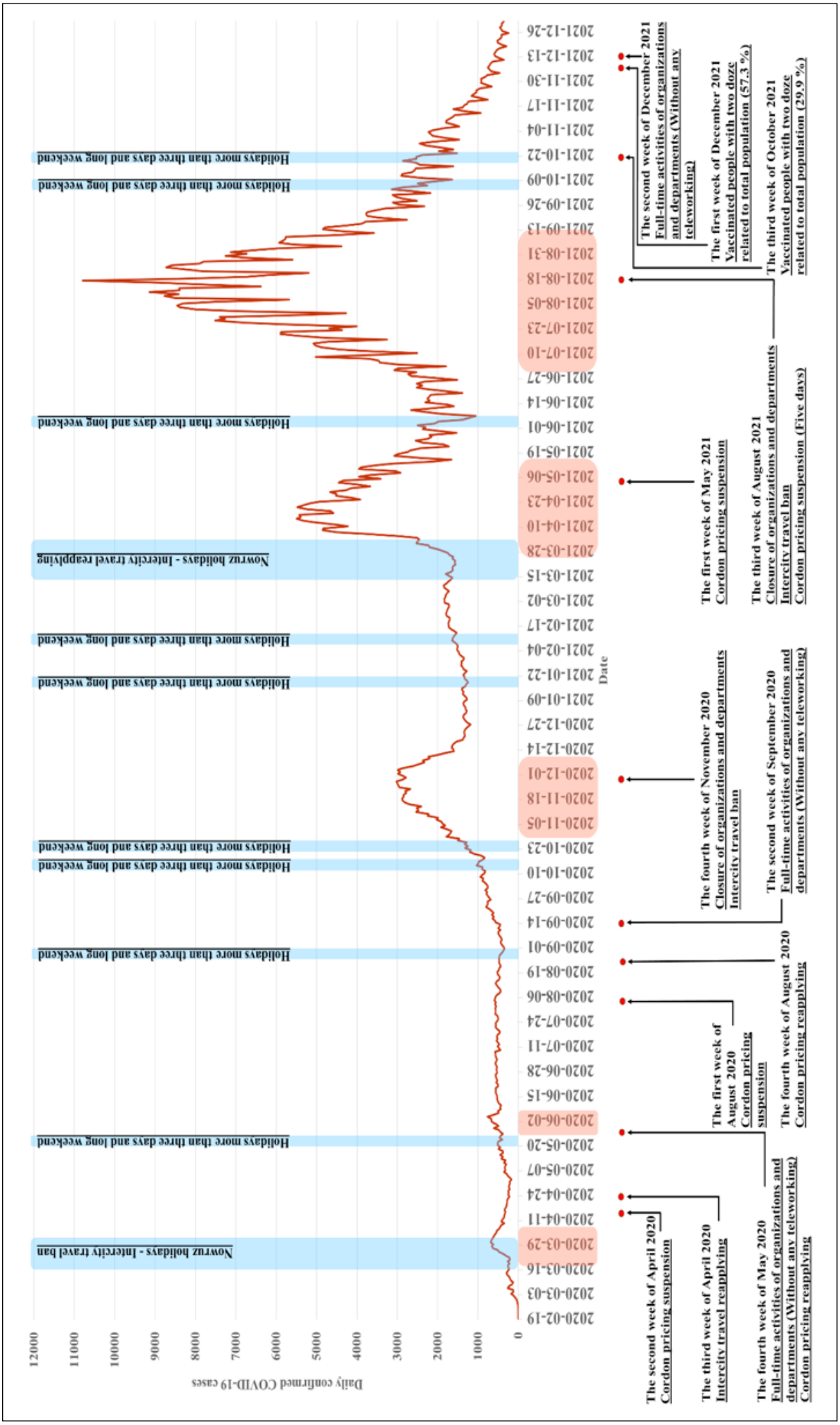

Figure 2. Daily statistics of Tehran's COVID-19 infection with influence of measures, events, and vaccinationResults

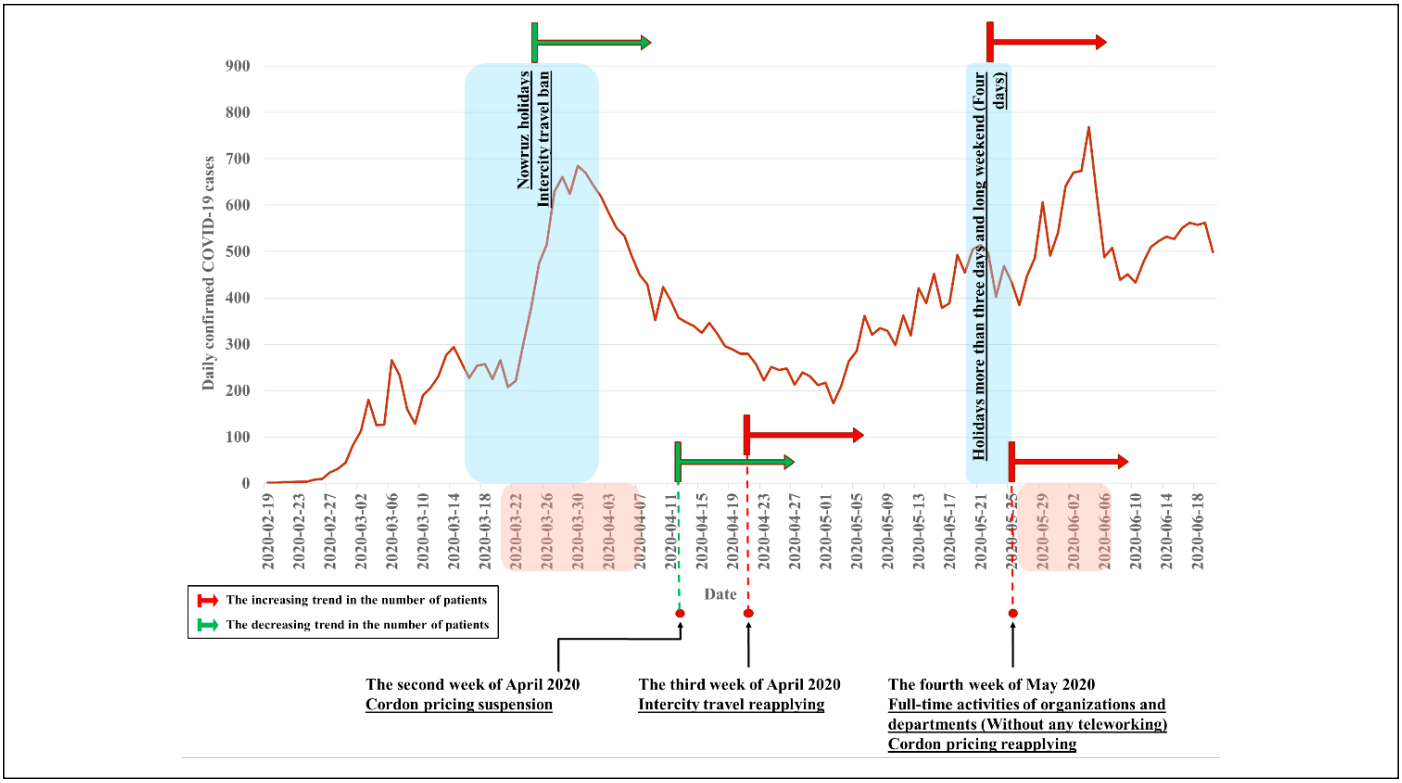

Figure 3. Daily statistics of Tehran's COVID-19 infection from 02/19/2020 to 06/20/2020

Item	Class	Measures/ Events	Date	Correlation analysis	
				Correlation coefficient	Significance level
1	C2, C3	Intercity travel ban, Nowruz holidays	The fourth week of March 2020	-0.908	0.000
2	C2	Cordon pricing suspension	The second week of April 2020	-0.940	0.000
3	C2	Intercity travel reapplying	The third week of April 2020	-0.534	0.049
4	C3	Holidays more than three days and long weekend	The fourth week of May 2020	0.881	0.000
5	C1, C2	Full-time activities of organizations and departments (Without any teleworking), Cordon pricing reapplying	The fourth week of May 2020	-0.530	0.051

Table 1. Correlation analysis between measures/events and the number of infected people (02/19/2020 to 06/20/2020)

Measures	Date	Share of private car (%)		Share of taxi (%)		Share of public transportation (%)		Changes in the share of non-private vehicles
		BI*	AI**	BI*	AI**	BI*	AI**	
Cordon pricing suspension	The second week of April 2020	85.2	90	12.3	8	2.5	2	-4.8
Intercity travel reapplying	The fourth week of May 2020	88.4	80.2	9.2	17	2.4	2.8	8.2

*BI: Before Implementation
**AI: After Implementation

Table 2. Share of different vehicles before and after implementation of traffic measures from 02/19/2020 to 06/20/2020

According to Table 2, it can be concluded that if cordon pricing is canceled, more people will use their private cars for trips. A decrease in the accumulation of people in other vehicles, which serve as centers for transmitting the virus from one person to another, has been observed. However, with the reapplication of cordon pricing, this pattern changes, and the gathering of people in public transportation and taxis increases, becoming a contributing factor to the long-term increase in the number of patients (Gkiotsalitis & Cats, 2021; Rahimi et al., 2021).

4.2 Time period 06/21/2020 to 10/06/2020

Some measures and events have caused changes in the number of people infected with COVID-19 between the second and third peak periods of the virus. Figure 4 shows these changes from June 2020 to the first week of October. During the first week of August 2020, cordon pricing was again suspended, resulting in an 18% decrease in infected people. After this measure, in the fourth week of August, the authorities decided to reapply the cordon pricing, which resulted in increasing the number of infected by 6%. Traffic

measures in this period had no significant impact on infection rates, as indicated by Table 3. During this period, the four-day holiday at the end of August led to an increase in the number of infected people from 377 to 460 in two weeks, and the correlation analysis in Table 3 demonstrates that the trend is significant. All departments and organizations began operating at total capacity starting in the second week of September, contributing to the increase of 306 infected individuals in just two weeks.

In this period, changes in the share of different vehicles in the cordon pricing rings have occurred due to the implementation of traffic measures. According to Table 4, after the suspension of cordon pricing in the first week of August 2020, the share of non-private vehicles decreased by 6.1%, and with the reapplying of this plan in the fourth week of August, the share of these vehicles has increased by 2.6%.

4.3 Time period 10/07/2020 to 01/31/2021

Figure 5 shows the statistics of virus infections in Tehran from October to the end of January 2021. The figure indicates that the appropriate measures were not implemented before COVID-19 reached its third peak. In addition, two holidays in the last weeks of October have helped to aggravate the unfavourable conditions. As a result, the number of infected people increased two weeks after the second holiday from 1249 to 2031 (63%). Table 5 also shows a strong correlation between the mentioned holidays and infection rates. The number of infected people reached its peak in November 2020 as a result of the virus spreading during this time. This is why, for a week in November, the authorities shut down Tehran completely and teleworked all businesses. Within two weeks of this measure, the number of infected people decreased by 44%. With the decrease in the spread of the virus at this

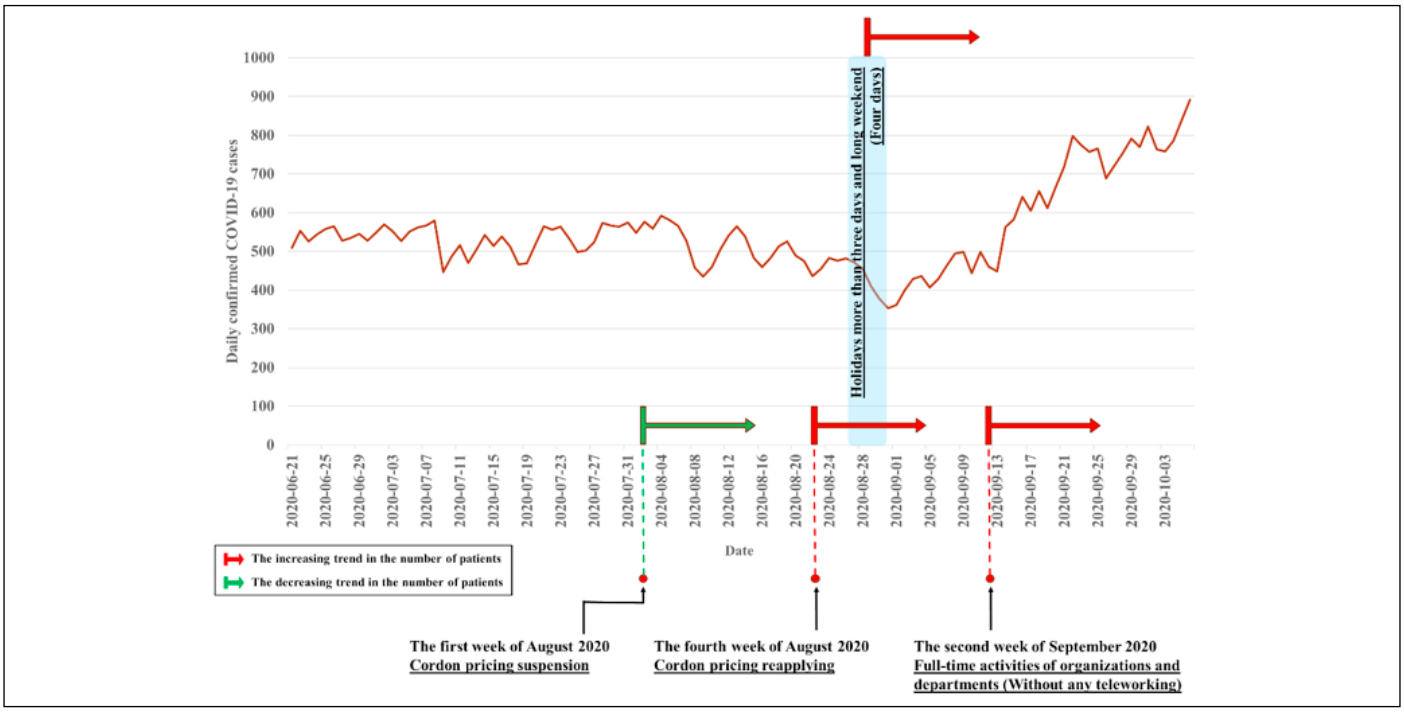

Figure 4. Daily statistics of Tehran's COVID-19 infection from 06/21/2020 to 10/06/2020

Item	Class	Measures/ Events	Date	Correlation analysis	
				Correlation coefficient	Significance level
1	C2	Cordon pricing suspension	The first week of August 2020	-0.453	0.104
2	C2	Cordon pricing reapplying	The fourth week of August 2020	-0.625	0.017
3	C3	Holidays more than three days and long weekend	The fourth week of August 2020	0.862	0.000
4	C1	Full-time activities of organizations and departments (Without any teleworking)	The second week of September 2020	0.801	0.001

Table 3. Correlation analysis between measures/events and the number of infected people (06/21/2020 to 10/06/2020)

Measures	Date	Share of private car (%)		Share of taxi (%)		Share of public transportation (%)		Changes in the share of non-private vehicles
		BI*	AI**	BI*	AI**	BI*	AI**	
Cordon pricing suspension	The first week of August 2020	83.6	89.7	13.5	8.3	2.9	2	-6.1
Intercity travel reapplying	The fourth week of August 2020	87.8	85.2	9.7	12.1	2.5	2.7	2.6

*BI: Before Implementation
**AI: After Implementation

Table 4. Share of different vehicles before and after implementation of traffic measures from 06/21/2020 to 10/06/2020

peak and at the same time as a holiday in January 2021, the ban on intercity travel has been cancelled, and travel during this holiday has been another factor in the increase in the number of infected people.

4.4 Time period 02/01/2021 to 05/19/2021

Statistics show an increase in virus infections in the winter of 2021 (Figure 6). Like previous multi-day holidays, February holidays have led to a significant increase in the number of infected people during two weeks, which can be seen in Table 6. Tehran shows its fourth peak of COVID-19 due to a series of factors at the end of March 2021 and the start of the Nowruz holiday. We can mention lifting the intercity travel ban in Tehran, which led to many trips from or to Tehran. At the same time as this holiday, the English variant of COVID-19, known as Alpha, entered Iran and spread quickly. In Figure 6, it is seen that two weeks after the last day of the holiday, the highest infection rate since the beginning of the outbreak, 5497 people per day, has been recorded, showing a growth of 120% in two weeks. To control the virus in the fourth peak of COVID-19, in the first week of May 2021, cordon pricing was suspended in the city of Tehran, which resulted in a 55% decrease in infection cases after two weeks.

4.5 Time period 05/20/2021 to 12/31/2021

This period from May to December 2021 includes the fifth and last peak of COVID-19 (Delta), which was investigated in this study. It is worth noting that only in this period the vaccination of people with the COVID-19 vaccine has reached an acceptable level, and its positive effect has been shown (Figure 7). At the beginning of this period (the first week of June 2021), a four-day holiday, like other previous holidays, increased the number of patients by 57% within two weeks. However, this issue is not significant according to the results of the correlation analysis in Table 7. At the same time as this holiday, the dangerous variant of Delta has arrived in Tehran, which has prepared the conditions for entering the fifth peak of COVID-19. With the intensification of the spread of COVID-19 and reaching the highest infection rate in Tehran (11,000 people per day) to control the virus, it was decided to completely close all businesses, including offices, organizations, and guilds, for 5 days. During this period, intercity travel was also prohibited, and the suspension of cordon pricing was implemented in Tehran. These approvals have shown their positive effects in the next two weeks in such a way that the number of infections has decreased by about 40% (about 4000 people). The high coefficient value of -0.804, as shown in Table 7, indicates a significant nega-

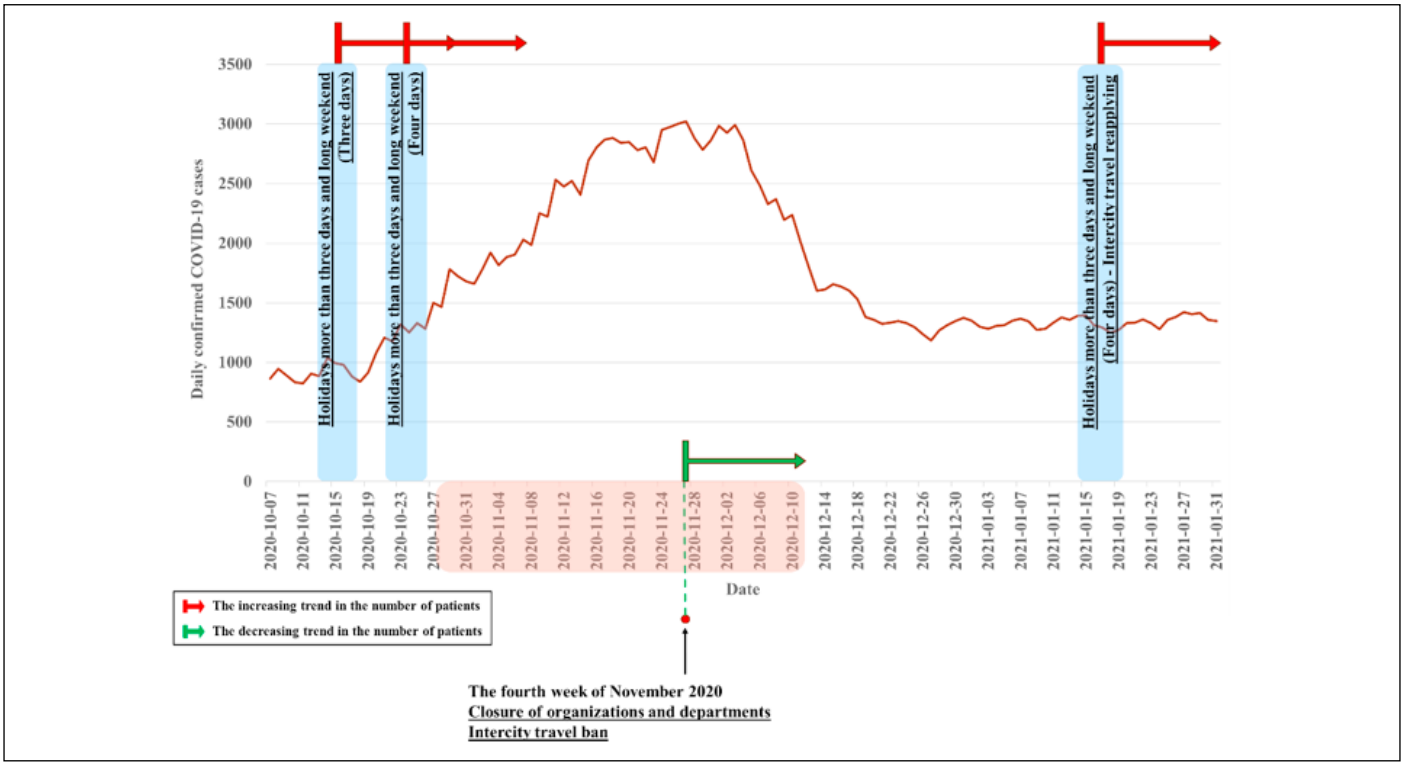

Figure 5. Daily statistics of Tehran's COVID-19 infection from 10/07/2020 to 01/31/2021

Item	Class	Measures/ Events	Date	Correlation analysis	
				Correlation coefficient	Significance
1	C3	Holidays more than three days and long weekend	The third week of October 2020	0.957	0.000
2	C3	Holidays more than three days and long weekend	The fourth week of October 2020	0.921	0.000
3	C1, C2	Closure of organizations and departments, Intercity travel ban	The fourth week of November 2020	-0.925	0.000
4	C2, C3	Intercity travel reapplying, Holidays more than three days and long weekend	The third week of January 2021	0.706	0.005

Table 5. Correlation analysis between measures/events and the number of infected people (10/07/2020 to 01/31/2021)

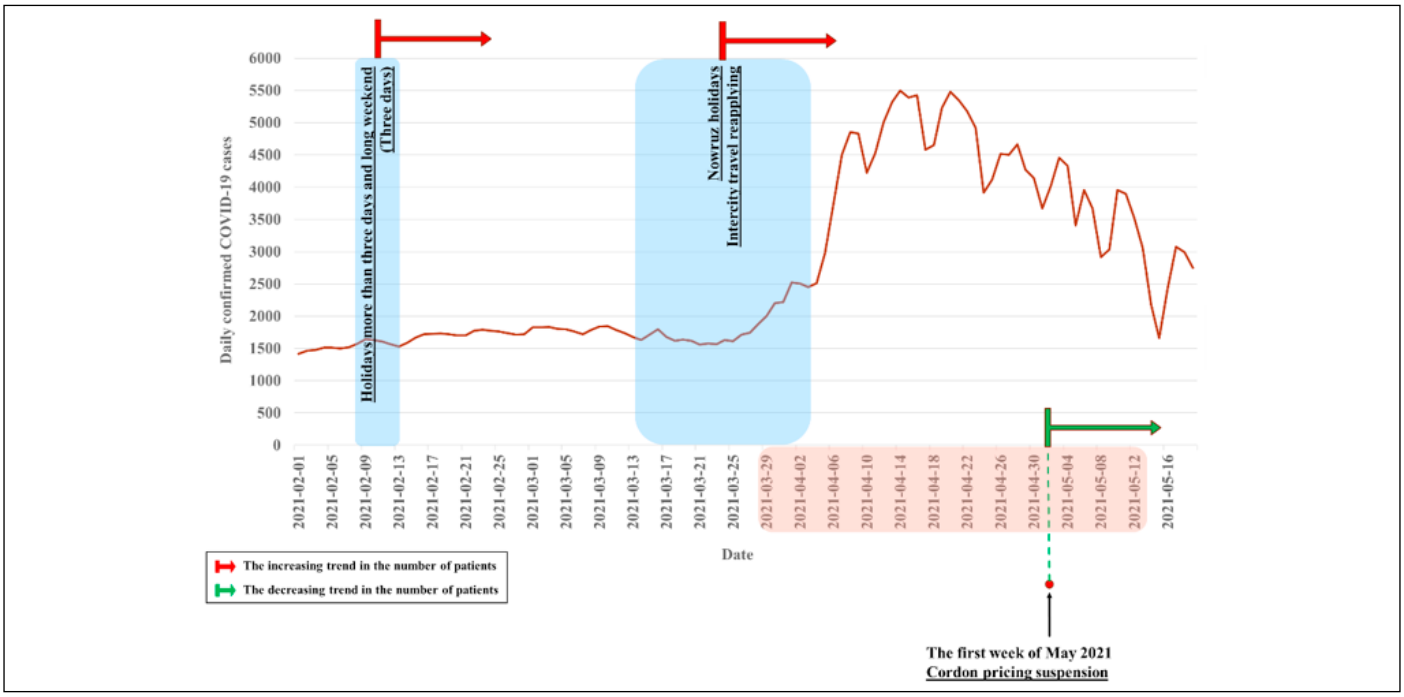

Figure 6. Daily statistics of Tehran's COVID-19 infection from 02/01/2021 to 05/19/2021

Item	Class	Measures/ Events	Date	Correlation analysis	
				Correlation coefficient	Significance
1	C3	Holidays more than three days and long weekend	The second week of February 2021	0.875	0.000
2	C2, C3	Intercity travel reapplying, Nowruz holidays	The fourth week of March 2021	0.901	0.000
3	C2	Cordon pricing suspension	The first week of May 2021	-0.755	0.002

Table 6. Correlation analysis between measures/events and the number of infected people (02/01/2021 to 05/19/2021)

tive correlation between this measure and the infection rate, confirming the effectiveness of the implemented measures in decreasing infections.

With the decline of the fifth peak of COVID-19 and reaching stable conditions in October 2021, two multi-day holidays at the beginning and end of this month could lead to an increase in the number of patients, but this did not happen, and the results of Table 7 show that this trend is not significant. One of the main reasons for these conditions is the achievement of a suitable level of vaccination for people with the COVID-19 vaccine. The vaccination process, which had started months ago, intensified at the same time as the number of infections dropped to the fifth peak in Tehran. About 30% of the city's people were vaccinated in the third week of October. This vaccination rate of people helped to prevent the increase in the number of infections and the beginning of a new peak. It should be noted that the significance of decreasing infection statistics through 30% vaccination is not significant at the 99% confidence level but at the 95% confidence level.

With the increase in the vaccination rate of people, the improvement of the conditions of COVID-19 and the decrease of people infected with this virus have continued during November 2021. About 45 days have passed since the vaccination of 30% of people; in the first week of December 2021, the rate of vaccinated people has reached more than 57% (almost doubled). This vaccination rate, which is correlated with a coefficient of -0.771, is one of the reasons why the trend of contracting the virus continues to decline, although the activity of all businesses resumes with 100% attendance of employees at work in the second week of December.

Correlation analysis results for significant cases are presented in Table 8, ranging from the highest decrease impact to the highest increase impact. The cordon pricing suspension has highest impact on decreasing the infection rate (with correlation coefficient equal to -0.940), and holidays more than three days and long weekend has highest impact on increasing the infection rate (with the correlation coefficient equal to 0.957).

5. CONCLUSIONS

With the emergence and spread of COVID-19 around the world, human societies have undergone fundamental changes in lifestyle. The change in travel patterns is one of the most significant examples of such changes. In order to minimize the spread of the virus and enhance community health, authorities and decision-makers have been compelled to approve and implement new regulations, such as social distancing and quarantine. Despite existing studies, the impact of transportation measures on the number of infections has been less considered. The aim of this study is to investigate this impact and associate it with vaccination records through correlation analysis. The evaluation of transportation measures over a 14-day period reveals that, at a significance level of 1%, the majority (67%) of these measures had an impact on the number of infections (either increasing or decreasing).

Based on results, traffic-related measures (Class C2) have had the greatest impact on decreasing the trend of infections. Cordon pricing suspension, combined with an increase in preference for personal vehicles, led to a decrease in infections as a result of decreasing crowding among non-personal vehicles. This conclusion is evident in the correlation coefficients associated with these measures. As another traffic-

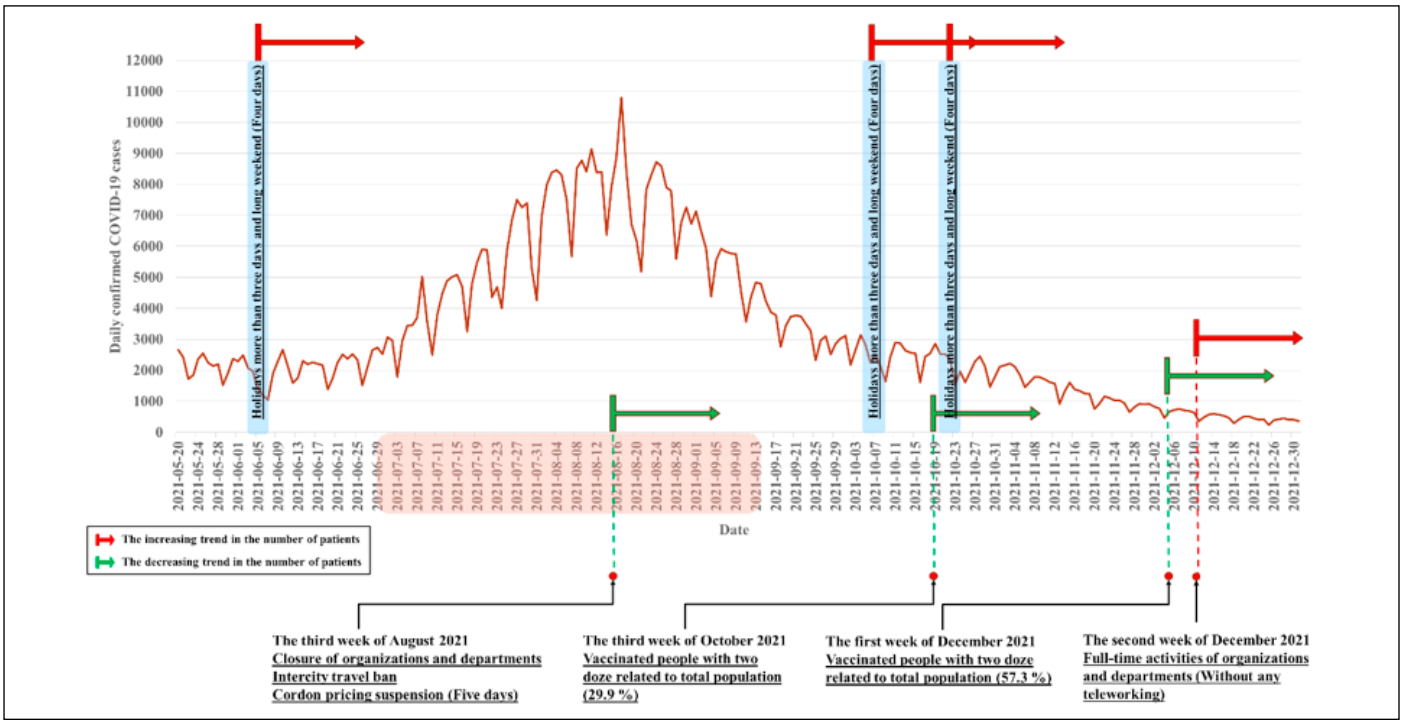

Figure 7. Daily statistics of Tehran's COVID-19 infection from 05/20/2021 to 12/31/2021

Item	Class	Measures/ Events	Date	Correlation analysis	
				Correlation coefficient	Significance
1	C3	Holidays more than three days and long weekend	The first week of June 2021	0.605	0.022
2	C1 C2	Closure of organizations and departments, Intercity travel ban, Cordon pricing suspension	The third week of August 2021	-0.804	0.000
3	C3	Holidays more than three days and long weekend	The first week of October 2021	0.257	0.374
4	C4	Vaccinated people with two doses related to total population (29.9 %)	The third week of October 2021	-0.606	0.022
5	C3	Holidays more than three days and long weekend	The fourth week of October 2021	-0.250	0.389
6	C4	Vaccinated people with two doses related to total population (57.3 %)	The first week of December 2021	-0.771	0.001
7	C1	Full-time activities of organizations and departments (Without any teleworking)	The second week of December 2021	-0.649	0.012

Table 7. Correlation analysis between measures/events and the number of infected people (05/20/2021 to 12/31/2021)

Item	Class	Measures/ Events	Date	Correlation analysis	
				Correlation coefficient	Significance
1	C2	Cordon pricing suspension	The second week of April 2020	-0.940	0.000
2	C1, C2	Closure of organizations and departments, Intercity travel ban	The fourth week of November 2020	-0.925	0.000
3	C2, C3	Intercity travel ban, Nowruz holidays	The fourth week of March 2020	-0.908	0.000
4	C1, C2	Closure of organizations and departments, Intercity travel ban, Cordon pricing suspension	The third week of August 2021	-0.804	0.000
5	C4	Vaccinated people with two doses related to total population (57.3 %)	The first week of December 2021	-0.771	0.001
6	C2	Cordon pricing suspension	The first week of May 2021	-0.755	0.002
7	C2, C3	Intercity travel reapplying, Holidays more than three days and long weekend	The third week of January 2021	0.706	0.005
8	C1	Full-time activities of organizations and departments (Without any teleworking)	The second week of September 2020	0.801	0.001
9	C3	Holidays more than three days and long weekend	The fourth week of August 2020	0.862	0.000
10	C3	Holidays more than three days and long weekend	The second week of February 2021	0.875	0.000
11	C3	Holidays more than three days and long weekend	The fourth week of May 2020	0.881	0.000
12	C2, C3	Intercity travel reapplying, Nowruz holidays	The fourth week of March 2021	0.901	0.000
13	C3	Holidays more than three days and long weekend	The fourth week of October 2020	0.921	0.000
14	C3	Holidays more than three days and long weekend	The third week of October 2020	0.957	0.000

Table 8. Significant correlation analysis between measures/events and the number of infected people within the studied period

related measure, the intercity travel bans also contributed to a decrease in infections. This measure can be strategically utilized in events such as holidays to decrease travel. Additionally, the results indicate that measures related to work activities (Class C1) did not show sufficient effectiveness compared to other categories. Among them, only the complete closure of businesses had a significant impact on decreasing the number of infections. These findings suggest that one-third and two-third work shifts did not have sufficient executive efficacy to decrease infection rates.

Holidays (Class C3) have led to the greatest increase in infection statistics of all the measures and events identified as contributing to the trend. This increase in virus infections can be attributed to several factors, including gatherings with limited physical distances and better travel conditions for Tehran residents to other cities. Another notable result of this study is that the absence of restrictions (such as intercity travel bans) during official holidays, especially during the Nowruz holiday, substantially increases infection rates, as clearly observed during the Nowruz holiday of 2021. Among work activities, only full-capacity operation of offices has led to a significant increase in infection rates.

The research was faced with some limitations, mainly due to the nature of the data and the employed analysis. Given that the adopted measures are dependent on decisions made by the National Coronavirus Headquarters and various temporal events, it is evident that, with access to more comprehensive data and the removal of data constraints, statistical models can be employed for a more accurate prediction of the trends in the changes of infection statistics. Because multiple resolutions were implemented at the same time, this study is limited by the lack of differentiation in the source of trends. Furthermore, city-level cameras for personal vehicles were used in this research. The combination of registered travel data and public transportation data can be used in future studies to conduct more in-depth analyses. Examining the relationship between events and policies (measures) and changes in travel mode can also be discussed in future studies. Employing other measures such as Stringency index can also be suggested for future similar research to include the strictness of government policies.

REFERENCES

Aaditya, B., & Rahul, T. M. (2021). Psychological impacts of COVID-19 pandemic on the mode choice behaviour: A hybrid choice modelling approach. *Transport Policy*, *108*(May), 47–58. https://doi.org/10.1016/j.tranpol.2021.05.003

Ahmadi, M., Sharifi, A., Dorosti, S., Jafarzadeh Ghoushchi, S., & Ghanbari, N. (2020). Investigation of effective climatology parameters on COVID-19 outbreak in Iran. *Science of The Total Environment*, *729*, 138705. https://doi.org/10.1016/j.scitotenv.2020.138705

Anwari, N., Tawkir Ahmed, M., Rakibul Islam, M., Hadiuzzaman, M., & Amin, S. (2021). Exploring the travel behavior changes caused by the COVID-19 crisis: A case study for a developing country. *Transportation Research Interdisciplinary Perspectives*, *9*(March). https://doi.org/10.1016/j.trip.2021.100334

Arellana, J., Márquez, L., & Cantillo, V. (2020). COVID-19 Outbreak in Colombia: An Analysis of Its Impacts on Transport Systems. Journal of Advanced Transportation , 2020, 1–16. https://doi.org/10.1155/2020/8867316

Atahan, A., & Alhelo, L. (2022). The Impact of the COVID-19 Pandemic on Mobility Behavior in Istanbul After One Year of Pandemic. In *Sustainable Civil Infrastructures* (pp. 933–949). https://doi.org/10.1007/978-3-030-79801-7_65

Atombo, C., Akple, M. S., & Fiifi Turkson, R. (2023). COVID-19 Safety Protocols: Do Commuters Prefer Public Transport after Relaxation of Safety Protocol Enforcement? *Transactions on Transport Sciences*, *14*(2), 68–80. https://doi.org/10.5507/tots.2023.008

Baghestani, A., Tayarani, M., Mamdoohi, A. R., Habibian, M., & Gao, O. (2023). Travel Demand Management Implications during the COVID-19 Pandemic: The Case Study of Tehran. *Sustainability*, 15(2), 1209. https://doi.org/10.3390/su15021209

Barquilla, C. A. M., Lee, J., & He, S. Y. (2023). The impact of greenspace proximity on stress levels and travel behavior among residents in Pasig city, Philippines during the COVID-19 pandemic. *Sustainable Cities and Society*, *97*(May), 104782. https://doi.org/10.1016/j.scs.2023.104782

Bhaduri, E., Manoj, B. S., Wadud, Z., Goswami, A. K., & Choudhury, C. F. (2020). Modelling the effects of COVID-19 on travel mode choice behaviour in India. *Transportation Research Interdisciplinary Perspectives*, *8*, 100273. https://doi.org/10.1016/j.trip.2020.100273

Borkowski, P., Jażdżewska-Gutta, M., & Szmelter-Jarosz, A. (2021). Lockdowned: Everyday mobility changes in response to COVID-19. *Journal of Transport Geography*, *90*(May 2020). https://doi.org/10.1016/j.jtrangeo.2020.102906

Brůhová Foltýnová, H., & Brůha, J. (2024). Expected long-term impacts of the COVID-19 pandemic on travel behaviour and online activities: Evidence from a Czech panel survey. *Travel Behaviour and Society*, *34*(May 2022), 1–11. https://doi.org/10.1016/j.tbs.2023.100685

Consortium of Amirkabir University of Technology and Tarbiat Modarres University. (2021). *Traffic volume changes during the covid-19 using traffic camera records, Tehran Travel Demand Management Research Studies, Final Report*.

Costa, M., Félix, R., Marques, M., & Moura, F. (2022). Impact of COVID-19 lockdown on the behavior change of cyclists in Lisbon, using multinomial logit regression analysis. *Transportation Research Interdisciplinary Perspectives*, *14*(3), 100609. https://doi.org/10.1016/j.trip.2022.100609

Das, S., Boruah, A., Banerjee, A., Raoniar, R., Nama, S., & Maurya, A. K. (2021). Impact of COVID-19: A radical modal shift from public to private transport mode. Transport Policy, 109, 1–11. https://doi.org/10.1016/j.tranpol.2021.05.005

Elias, W., & Zatmeh-Kanj, S. (2021). Extent to which COVID-19 will affect future use of the train in Israel. *Transport Policy*, *110*(May), 215–224. https://doi.org/10.1016/j.tranpol.2021.06.008

Fowri, H. R., & Seyedabrishami, S. (2020). Assessment of urban transportation pricing policies with incorporation of unobserved heterogeneity. *Transport Policy*, 99, 12–19. https://doi.org/10.1016/j.tranpol.2020.08.008

Gibbs, H., Liu, Y., Pearson, C. A. B., Jarvis, C. I., Grundy, C., Quilty, B. J., Diamond, C., Simons, D., Gimma, A., Leclerc, Q. J., Auzenbergs, M., Lowe, R., O'Reilly, K., Quaife, M., Hellewell, J., Knight, G. M., Jombart, T., Klepac, P., Procter, S. R., … Eggo, R. M. (2020). Changing travel patterns in China during the early stages of the COVID-19 pandemic. *Nature Communications*, *11*(1). https://doi.org/10.1038/s41467-020-18783-0

Gkiotsalitis, K., & Cats, O. (2021). Public transport planning adaption under the COVID-19 pandemic crisis: Literature review of research needs and directions. *Transport Reviews*, *41*(3), 374–392. https://doi.org/10.1080/01441647.2020.1857886

Gogtay, N. J., & Thatte, U. M. (2017). Principles of Correlation Analysis. *PubMed,* 65(3), 78–81. https://pubmed.ncbi.nlm.nih.gov/28462548

Habibian, M., & Rezaei, A. (2017). Accounting for systematic heterogeneity across car commuters in response to multiple TDM policies: Case study of Tehran. *Transportation,* 44(4), 681–700. https://doi.org/10.1007/s11116-015-9672-4

Hatamzadeh, Y., Habibian, M., & Khodaii, A. (2020). Measuring walking behaviour in commuting to work: Investigating the role of subjective, environmental and socioeconomic factors in a structural model. *International Journal of Urban Sciences*, *24*(2), 173–188. https://doi.org/10.1080/12265934.2019.1661273

Hatamzadeh, Y., Habibian, M., & Khodaii, A. (2021). Commuters' Preference to Walk: Developing a Structural Equation Model Considering Current Amount of Walking and Subjective and Environmental Factors. *Journal of Urban Planning and Development*, *147*(4), 04021043. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000714

Javadinasr, M., Maggasy, T., Mohammadi, M., Mohammadain, K., Rahimi, E., Salon, D., Conway, M. W., Pendyala, R., & Derrible, S. (2022). The Long-Term effects of COVID-19 on travel behavior in the United States: A panel study on work from home, mode choice, online shopping, and air travel. *Transportation Research Part F: Traffic Psychology and Behaviour*, *90*(July), 466–484. https://doi.org/10.1016/j.trf.2022.09.019

Khadem Sameni, M., Barzegar Tilenoie, A., & Dini, N. (2021). Will modal shift occur from subway to other modes of transportation in the post-corona world in developing countries? *Transport Policy*, *111*(July), 82–89. https://doi.org/10.1016/j.tranpol.2021.07.014

Khalilikhah, M., Habibian, M., & Heaslip, K. (2016). Acceptability of increasing petrol price as a TDM pricing policy: A case study in Tehran. *Transport Policy*, *45*, 136–144. https://doi.org/10.1016/j.tranpol.2015.09.014

Khoirunurrofik, K., Abdurrachman, F., & Putri, L. A. M. (2022). Half-hearted policies on mobility restrictions during COVID-19 in Indonesia: A portrait of large informal economy country. *Transportation Research Interdisciplinary Perspectives*, *13*, 100517. https://doi.org/10.1016/j.trip.2021.100517

Kogus, A., Brůhová Foltýnová, H., Gal-Tzur, A., Shiftan, Y., Vejchodská, E., & Shiftan, Y. (2022). Will COVID-19 accelerate telecommuting? A cross-country evaluation for Israel and Czechia. *Transportation Research Part A: Policy and Practice*, *164*(August), 291–309. https://doi.org/10.1016/j.tra.2022.08.011

Lak, A., Sharifi, A., Badr, S., Zali, A., Maher, A., Mostafavi, E., & Khalili, D. (2021). Spatio-temporal patterns of the COVID-19 pandemic, and place-based influential factors at the neighborhood scale in Tehran. *Sustainable Cities and Society*, *72*(May), 103034. https://doi.org/10.1016/j.scs.2021.103034

Li, M., Zheng, Q., & Ashuri, B. (2024). Quantifying the Impact of COVID-19 on the Transportation Construction Industry Using Regime Switching Models. *Construction Research Congress 2024, CRC 2024*. https://doi.org/10.1061/9780784485286.025

Luo, Q., Forscher, T., Shaheen, S., Deakin, E., & Walker, J. L. (2023). Impact of the COVID-19 pandemic and generational heterogeneity on ecommerce shopping styles – A case study of Sacramento, California. *Communications in Transportation Research*, *3*(August 2022), 100091. https://doi.org/10.1016/j.commtr.2023.100091

Márquez, L., Alfonso A, J. V., & Poveda, J. C. (2019). In-vehicle crowding: Integrating tangible attributes, attitudes, and perceptions in a choice context between BRT and metro. Transportation Research Part a Policy and Practice, 130, 452–465. https://doi.org/10.1016/j.tra.2019.09.061

Ministry of Health and Medical Education. (2021). *COVID-19 daily infection rate,* https://behdasht.gov.ir/اخبار-اخبار-علمی-آخرین-آمار-کرونا-در-ایران-و-جهان/230034.

Mogaji, E., Adekunle, I., Aririguzoh, S., & Oginni, A. (2022). Dealing with impact of COVID-19 on transportation in a developing country: Insights and policy recommendations. *Transport Policy*, *116*(December 2021), 304–314. https://doi.org/10.1016/j.tranpol.2021.12.002

Nie, Q., Qian, X., Guo, S., Jones, S., Doustmohammadi, M., & Anderson, M. D. (2022). Impact of COVID-19 on paratransit operators and riders: A case study of central Alabama. *Transportation Research Part A: Policy and Practice*, *161*(November 2021), 48–67. https://doi.org/10.1016/j.tra.2022.04.016

Qi, Y., Liu, J., Tao, T., & Zhao, Q. (2021). Impacts of COVID-19 on public transit ridership. *International Journal of Transportation Science and Technology*, 12(1), 34–45. https://doi.org/10.1016/j.ijtst.2021.11.003

Rahimi, E., Shabanpour, R., Shamshiripour, A., & (Kouros) Mohammadian, A. (2021). Perceived risk of using shared mobility services during the COVID-19 pandemic. *Transportation Research Part F: Traffic Psychology and Behaviour*, *81*(June), 271–281. https://doi.org/10.1016/j.trf.2021.06.012

Rankavat, S., Gurram, A. R., Pawar, D. S., & Kushwaha, V. (2022). Impact of COVID-19 on perception of commuters towards work and non-work trips in India. *Journal of the Eastern Asia Society for Transportation Studies*, *14*, 215–228. https://doi.org/10.11175/easts.14.215

Sahraei, M. A., Kuşkapan, E., & Çodur, M. Y. (2021). Public transit usage and air quality index during the COVID-19 lockdown. *Journal of Environmental Management*, *286*(August 2020). https://doi.org/10.1016/j.jenvman.2021.112166

Sekadakis, M., Katrakazas, C., Michelaraki, E., Ziakopoulos, A., & Yannis, G. (2023). COVID-19 and Driving Behavior: Which Were the Most Crucial Influencing Factors? *Data Science for Transportation*, *5*(3), 1–11. https://doi.org/10.1007/s42421-023-00078-7

Senthilnathan, S. (2019). Usefulness of Correlation Analysis. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3416918

Shaer, A., Rezaei, M., Moghani Rahimi, B., & Shaer, F. (2021). Examining the associations between perceived built environment and active travel, before and after the COVID-19 outbreak in Shiraz city, Iran. *Cities*, *115*(February), 103255. https://doi.org/10.1016/j.cities.2021.103255

The Centers for Disease Control and Prevention. (2021). *Quarantine and Isolation*, https://www.cdc.gov/coronavirus/2019-ncov/your-health/quarantine-isolation.html

The National Task Force Against Coronavirus in Iran. (2021). *Mosavabat setad melly Corona*, https://coronomy.ir/مصوبات-ستاد-ملی-مبارزه-با-کرونا-در-ایران.

Tiikkaja, H., & Viri, R. (2021). The effects of COVID-19 epidemic on public transport ridership and frequencies. A case study from Tampere, Finland. *Transportation Research Interdisciplinary Perspectives*, 10, 100348. https://doi.org/10.1016/j.trip.2021.100348

Ton, D., Arendsen, K., de Bruyn, M., Severens, V., van Hagen, M., van Oort, N., & Duives, D. (2022). Teleworking during COVID-19 in the Netherlands: Understanding behaviour, attitudes, and future intentions of train travellers. *Transportation Research Part a Policy and Practice*, 159, 55–73. https://doi.org/10.1016/j.tra.2022.03.019

Warren, M. S., & Skillman, S. W. (2020). Mobility changes in response to COVID-19. *arXiv Preprint arXiv:2003.14228*.

WHO. (2020). *Archived: WHO Timeline—COVID-19*. Wold Health Organization, https://www.who.int/news/item/27-04-2020-who-timeline---covid-19

Zhang, J., Hayashi, Y., & Frank, L. D. (2021). COVID-19 and transport: Findings from a world-wide expert survey. *Transport Policy*, 103, 68–85. https://doi.org/10.1016/j.tranpol.2021.01.011

Zhang, N., Jia, W., Wang, P., Dung, C. H., Zhao, P., Leung, K., Su, B., Cheng, R., & Li, Y. (2021). Changes in local travel behaviour before and during the COVID-19 pandemic in Hong Kong. *Cities*, *112*(February), 103139. https://doi.org/10.1016/j.cities.2021.103139

Zheng, Y., Caros, N. S., Aloisi, J., & Zhao, J. (2023). Examining the interactions between working from home, travel behavior and change in car ownership due to the impact of COVID-19. *Travel Behaviour and Society*, *33*(June), 100634. https://doi.org/10.1016/j.tbs.2023.100634