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Geographical Analysis of the Role of Public Transportation on the Spatial Distribution of Covid-19 Disease Outbreaks (Case Study: Sadeghieh Neighborhood of Tehran)

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ABSTRACT

Background: The study of the spatial distribution of epidemics and the investigation of their seasonal spread trend in geographical structures are done using statistical analysis to control society during the epidemics.

Objectives: The Covid-19 (SARS-CoV-2) disease, which has been prevalent since late December 2019, affected all bases and elements of urban and rural communities. For this reason, many studies were conducted to control this disease during the period. In the present study, public transportation systems were investigated as systems that transmitted the disease to new areas and increased the number of infected areas.

Methodology: In this study, by collecting data from Sadeghieh neighborhood in Tehran, an attempt was made to investigate temporally the spatial distribution trend of the number of infected people with Covid-19. The research was analytical and descriptive. Sadeghieh neighborhood in Tehran was selected as the study area.

Results: The relationship between the spatial distribution of the number of Covid-19 infected people and the transportation system in this neighborhood was investigated in a seasonal trend. For this purpose, the number of passengers entered Sadeghieh subway stations, separately for each season within 2020-2021 and the infected people with Covid-19 in this neighborhood were considered as the statistical population.

Conclusion: The results of this study showed that in spring, summer and winter, the incidence of the disease followed the same trend as the number of subway passengers. But in autumn, a sudden increase and sinusoidal fluctuations were observed in the incidence rate; and the measured variables did not follow the same trend.

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1. INTRODUCTION

This is not the first time in history that a pandemic has affected cities. Similar cases of widespread pandemics occurred before Covid-19 pandemic (Matthew and McDonald, 2006). Previous research focused more on the quality of life of the poor and marginalized, who are more vulnerable at the time of pandemics (Wade, 2020). But, during Covid-19 pandemic, tackling the pandemic and keeping cities alive are a matter of concern (Connolly et al., 2020a; Sharifi and Khavarian-Garmsir, 2020). For the earliest days of Covid-19 pandemic crisis, the scientific community sought to identify improvement programs and policies with a variety of topics, including mechanisms for the spread of the virus, its environmental, economic and social effects. Due to the high concentration of population and economic activities in cities, they are often the foci of infection with Covid-19. Accordingly, researchers tried to discover the dynamics of the pandemic in urban areas and to understand the effects of this disease on cities (Sharifi and Khavarian-Garmsir, 2020; Mousavi et al, 2025). The health of people in society is affected by the environment in which they live (Pinter-Wollman et al., 2018). Contact host demographic networks (Mossong et al., 2008), Contact patterns in the area, population density (Kraemer et al., 2015), population h
eterogeneity (Dushoff & Levin., 1995) and mobility (Merler & Ajelli., 2009) play an important role in the geographical spread of infectious diseases (Changruenngam et al., 2020). Traveling affects not only the spread of the disease, but also the speed of its spread (Ni and Weng, 2009; Dalziel et al., 2013; Changruenngam et al., 2020). In general, the role of population displacement and transportation infrastructure which increases inter-urban and inter-city connection has also been proven as a key factor in the spread of infectious diseases in the past such as Ebola (Connolly et al., 2020b; Sharifi and Khavarian-Garmsir, 2020). Travel restrictions are very effective in local and international travels in the early stages of the pandemic. In the next step, travel restrictions are reduced and behavioral changes are highlighted. Restrictions on travels delay the international spread of the disease (Muley et al., 2020). All published data showed reduced mobility was considered as an effective factor in reducing the spread of the virus and its cross-border transfer. Quarantine policies in Wuhan, China which restricted outdoor activities were a successful example (Pirouz et al., 2020; La et al., 2020; Aloi et al., 2020). These restrictions also affected peoples' travel behavior. So people preferred to use their own cars and avoid public transportation systems (Arellana et al., 2020). Public transportation, as crowded and closed places, accelerates transference of Covid-19 (Smieszek et al., 2019; Luo et al., 2020). Long-distance travels are a major factor in the spread of a disease. Mobility and length of stay spatially transmit a pandemic (Belik et al., 2011; Bayramzadeh and Fari, 2019; Poletto et al., 2013; Muley et al., 2020). In addition to analyzing the impact of public transportation systems on the spatial distribution of Covid-19, it is important to examine the seasonal trend of this relationship. Changes in seasonal and environmental factors have a direct effect on the disease. Recognition of seasonal patterns in the occurrence of disease dates back to the time of Hippocrates. Factors such as the functioning of the human immune system, seasonal changes in the levels of vitamins such as vitamin D and melatonin and infection of the pathogen cause changes in the rate of infection. Environmental changes directly affect the abundance, survival and severity of the pathogen (Auda Fares, 2011). Awareness of seasonal changes and time trends of the disease are important for prediction, crisis management and immunization programs (Knottnerus, 1992; Fleming et al., 1991; Turabian, 2017; Mousavi et al, 2025). Two points are important in the seasonal increase of diseases: simultaneous occurrence of many phenomena in a season and human behaviors such as increased social interactions or exposure to disease agents and polluted environments. In epidemiology, the study of time series includes cases of seasonal variations (those that occur regularly at certain times of the year) and periodic changes (those that appear too much or happen over several years). Awareness of these changes can be related to their causes such as agent ecology, climate, atmospheric phenomena, humans' concentration and activity and exposure to various factors. In order to detect seasonal changes, time intervals are measured in small units such as days, weeks, months and seasons (Pascal & Dobson, 2005; Turabian, 2017). In this study, the human mobility factor on the spatial expansion of Covid-19 over a one-year period from March 20th, 2020 to March 20th, 2021 was investigated.

2. METHODOLOGY

On normal days, 200 and 54 trains run from Sadeghieh to Farhangsara and Karaj stations, respectively and during holidays, 130 and 37 trains run to Farhangsara and Karaj stations, respectively. Sadeghieh station is one of the busiest stations in Tehran. In some days during 2020-2021, according to the statistics of Tehran Urban and Suburban Railway Operation Company, the number of people entering Sadeghieh station has reached over 19000. The existence of shopping malls and private companies has caused a large number of people to enter this neighborhood for shopping or working every day. In this research a linear equation and a cross-correlation coefficient were used. Research data was entered into GIS and its density maps were prepared. A Forecast function was used to estimate the future incidence. The number of infected people was measured in 14 day groups.

2.1. Study Area

This study was descriptive and analytical. The study area, Sadeghieh (Fig.1) is a neighborhood in west Tehran. From Sadeghieh subway station, two trains move; one to east Tehran, Farhangsara station and the other to Alborz province, Karaj station.

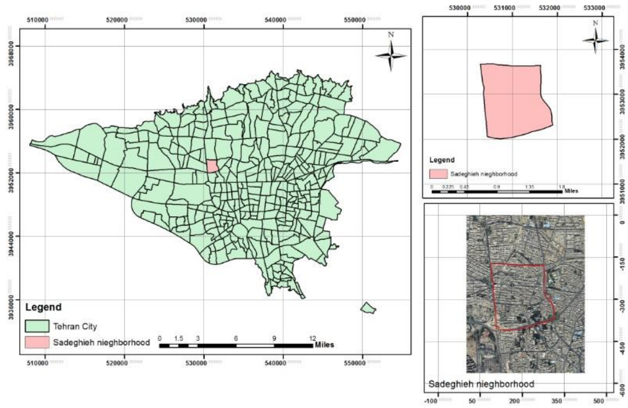

Fig 1. Sadeghieh Study neighborhood
(Source: Authors, 2025)

3. RESULTS

First, to show the number of Covid-19 infected people separately for each season within 2020-2021, its data was entered into GIS and its density maps were prepared. In order to investigate the spatial spread of the disease and its relationship with the number of subway passengers, a linear equation and a cross-correlation coefficient were used.

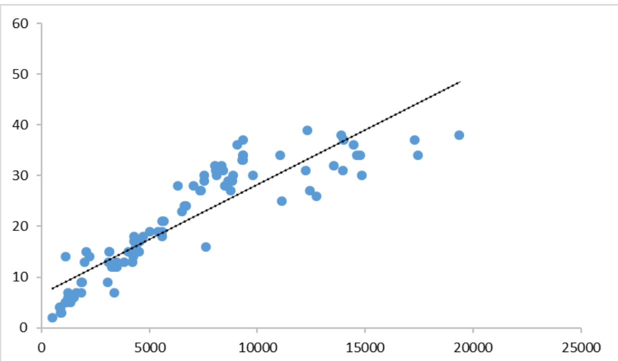

Fig 2. Linear distribution of infected people with Covid-19 and the number of passengers in Sadeghieh subway station in Tehran in spring
(Source: Authors, 2025)

According to the information in (Fig. 2) in spring, the spatial prevalence of Covid-19 showed a positive trend with the number of passengers. The best fitted model was linear with R^2= 0.8115 and the equation $y = 0.0022x + 6.593$.

The best fitted model in summer was a linear type with R^2= 0.7082 and the linear equation $y= 0.0039x + 19.438$ (Fig. 3). The dispersion of points in this season showed an increase in the number of infected people. The linear model in autumn showed that the relationship between the variables followed a sinusoidal trend. As R^2 obtained from this equation was equal to 0.6022 and its linear equation was $y=0.0086x + 38.114$.

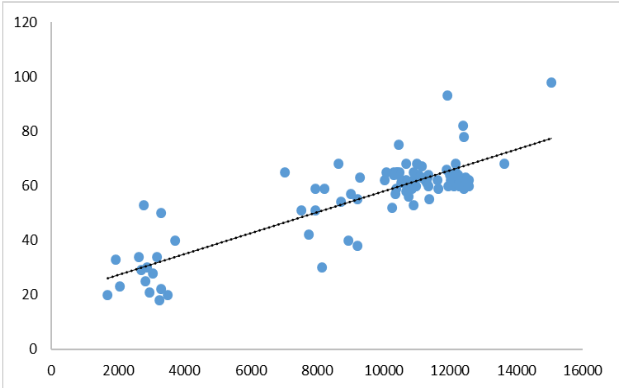

Fig 3. Linear distribution of infected people with Covid-19 and the number of passengers in Sadeghieh subway station in Tehran in summer
(Source: Authors, 2025)

The influence of other factors caused the measured variables in this equation not to have a positive trend (Fig. 4). High mobility and density in Sadeghieh neighborhood, seasonal changes and suitable temperature for pathogen multiplication maximized the incidence in this season.

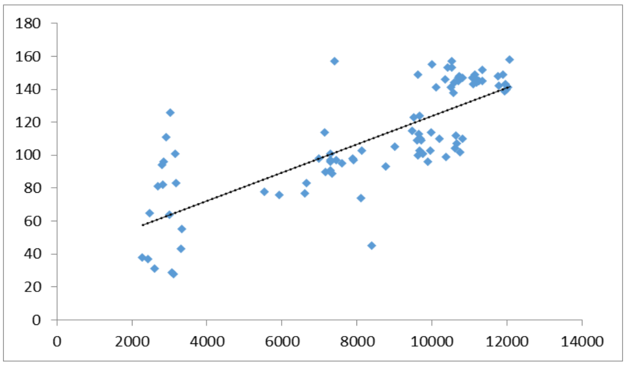

Fig 4. Linear distribution of infected people with Covid-19 and the number of passengers in Sadeghieh subway station in Tehran in autumn
(Source: Authors, 2025)

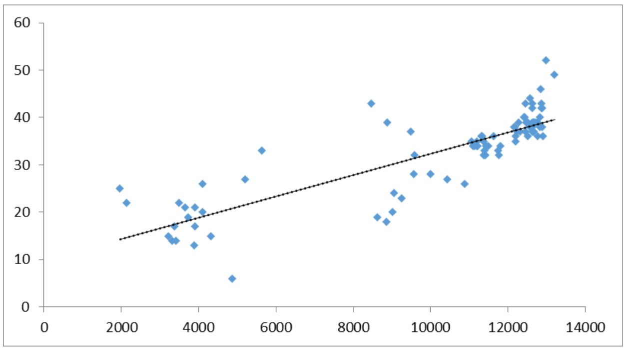

Fig 5. Linear distribution of infected people with Covid-19 and the number of passengers in Sadeghieh subway station in Tehran in winter.
(Source: Authors, 2025)

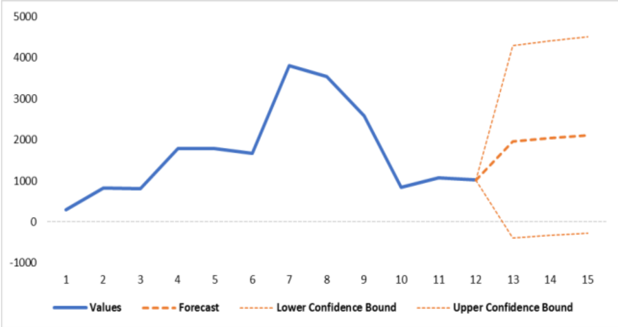

Fig 6. Infected cases and predicted cases in Sadeghieh neighborhood of Tehran
(Source: Authors, 2025)

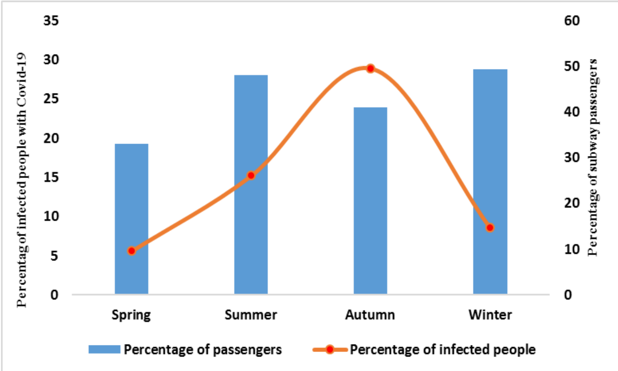

Fig 7. The percentage of infected people with Covid-19 and the number of passengers of Sadeghieh subway station in Tehran in the four seasons within 2020-2021
(Source: Authors, 2025)

In winter, the linear distribution of variables followed a positive trend that $R^2 = 0.7055$ and its equation was $y = 0.0023x + 9.8497$ (Fig. 5). Despite the increase in the number of passengers in this season, the incidence decreased, which showed seasonal changes had a significant effect on the incidence.

The linear distribution of the measured variables in spring and summer showed the relationship between the variables but in autumn, the variables did not go through the same process. As showed in fig. 4, in autumn, despite the decrease in the number of subway passengers, there was a significant increase in the number of infected people. As the highest average of infected people belonged to this season; and despite declaring quarantine and reducing the use of public transportation which was one of the factors of disease transmission to different regions showed an increasing trend. Despite the decrease in population size, the number of cases increased in daily trips which was affected by an increase in the number of susceptible individuals in this season. From autumn to winter, the linear distribution of variables moved toward equilibrium and the curves showed the relationship between population density and incidence.

4. DISCUSSION

After calculating the slope of the line, a Forecast function was used to estimate the future incidence. Figure 6 showed an increase in the infection with a slow trend. The dotted lines are the upper and lower limits of the forecast and the middle line is the average of the forecast.

Figure 7 shows the percentage of infected people with Covid-19 and the percentage of passengers entering Sadeghieh subway station. In autumn, the number of infected people was more than the number of passengers. Using the cross-correlation coefficient between the studied indicators in Sadeghieh neighborhood with an error rate of 0.05, the number of passengers per day was measured by the number of infected people in 14 days.

Figure 8 shows cross-correlation among the indices and the upper and lower limits of the correlation coefficient.

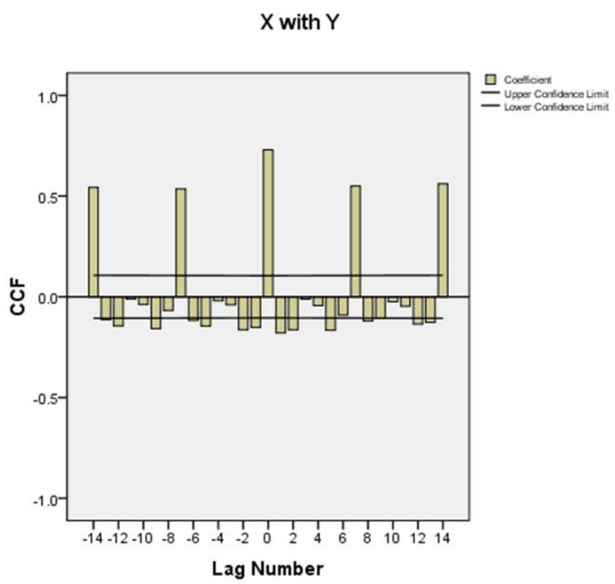

Fig 8. Cross correlation between indicators of passengers and the number of infected people with Covid-19 in Sadeghieh neighborhood
(Source: Authors, 2025)

According to Fig 8 The highest correlation coefficient was related to the simultaneous situation and to 7-day and 14-day delays. The highest coefficients were due to the onset of mild symptoms on the first day of infection and the onset of complete symptoms within 14 days after infection. It showed the sensitivity of infected people and their referral to medical centers. According to the results of this test, a person who carried a disease whose symptoms have not yet appeared could infect those around him for fourteen days.

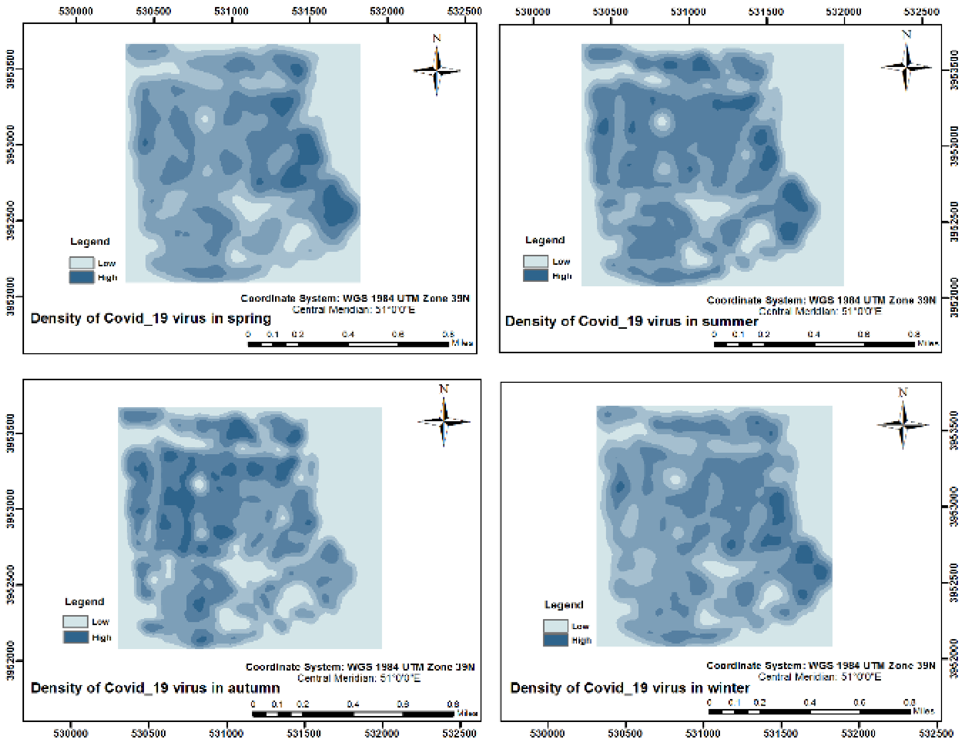

Fig 9. Spatial distribution of infected people with Covid-19 in Sadeghieh neighborhood in different seasons within 2020-2021

(Source: Authors, 2025)

Figure 9 shows the spread of Covid-19 disease in different seasons in Sadeghieh neighborhood within 2020-2021. The scattering of points increased from spring to summer. Based on the data used in the preparation of this map, this increase was seen from late spring; and it continued uniformly throughout the summer. The trend in summer was almost the same every day. In autumn, the spatial spread of the disease reached a critical stage; and it has been declining since late autumn. In winter, the dense points reduced. The trend was almost the same throughout winter. Except autumn, when maximum density and sudden changes in the spread of the disease were observed, in other seasons of the year, the spread of the disease and its increase and decrease occurred uniformly. Even in summer, the incidence increased throughout the day. Therefore, temporally only in autumn, the spread of this disease had a sudden and different increase compared to other seasons.

Examination of diagrams and maps showed that the spread of the disease was affected by both human mobility and seasonal factors. As, at certain times of the year, the rate of spread of the disease increased to some extent that control of human mobility could not reduce its incidence (Changruenngam et al., 2020). This limited mobility during peak periods of the disease caused an increasing spread in geographical locations. Increasingly infected environments put more people at risk. High density plus the number of people who enter Tehran every day has caused the administrative, medical, and commercial places and also entertainment centers in this city to be crowded and overcrowded. This mobility and population density increase during the day. The arrival of carriers in subway stations and their departure to different areas, caused the spread of the disease in the city.

5. CONCLUSION

Mobility and population density in subway stations was in the same trend with the number of infected people with Covid-19 according to the results obtained from the calculation of the slope of the line. Using cross-correlation coefficient, it was determined the number of passengers per day was positively correlated with the number of infected people on the same day and on the seventh and fourteenth days in the study area. Therefore, the mobility of human society was one of the important factors in the spread of this disease in society. The spread of the virus increased with the onset of summer holidays. Decreased immune levels and favorable weather conditions helped the virus to be multiplied in autumn. In addition to increasing the incidence, the number of deaths also increased. In this case, adhering to health protocols- using masks and social -distancing - was not effective. Only by enforcement and strict quarantines, could society be prevented.

In a study entitled Significance of geographical factors to the COVID-19 outbreak in India, using the variable linear regression, Gupta et al. (2020) examined factors such as temperature, rainfall, evapotranspiration, sunlight, humidity, wind speed, topography and population density and the relationship with the approved Covid-19 items. The relationship between sunlight and temperature was positive. Of course, the spatial relationship between Covid-19 and climatic, topographic and social factors had to be done in the long run.

In another study, Changruenngam et al. (2020), examined the effect of human mobility on the transmission dynamics of human influenza in Belgium and Martinique spatially and temporally. Using modeling, they provided a geographical and temporal pattern of the epidemic. The results of their study showed that the disease first spread to densely-populated urban areas and then to neighboring areas and villages. They considered human mobility to be an important factor in the spread of infectious disease.

In this study, the spatial prevalence of Covid-19 and the impact of public transportation systems (subways) on the spatial spread of this disease was investigated in different seasons in Sadeghieh neighborhood of Tehran temporally. Using line slope calculations, it was found that, in most days of the year, the spread of the disease follow followed the same trend with the number of subway passengers.

Disease distribution maps showed a gradual increase and decrease in the number of infected people with Covid-19 in most seasons. The increase of the number of cases in summer and autumn was due to changes of the immune system and climate changes that affected the frequency of pathogens. Also, the presence of more people outside the home due to summer vacations and increase of travels and closed spaces at home and work due to cold in autumn, lack of ventilation in closed spaces and the simultaneous increase in diseases such as colds and the flu could be mentioned.

In a society like Iran, due to the level of incomes, it is not possible not to use public transportation or reduce the number of people who use it. In subways, the seats are marked in order to distance people, and the use of masks is mandatory in subway stations and trains. But overcrowding at stations and trains prevents distances among people. Therefore, in order to protect people and comply with health protocols, other measures must be considered.

Managing the current state of transportation systems, especially in times of increased morbidity and mortality, is one way to protect people against this crisis. Quarantine and control must be done before the onset of the disease.

Wu et al. (2020), in their research, considered proper management of transportation networks as a factor in controlling Covid-19 disease and introduced public transportation systems as the most important factor in transmitting the disease from one place to nearby areas (Rahimi rise et al.,2020). Controlling public transportation with the help of intelligent systems can be an effective way to identify people who have carried the disease or have traveled with infected people with Covid-19 in a train or bus.

Also, as a program to increase safety of people in times of crises such as the outbreak of Covid-19, creating suitable and safe routes for walking and cycling was recommended in order to increase the choice of people and reduce the number of passengers of public transportation systems.

Floating working hours and telecommuting can reduce congestion in transportation at certain times of the days. Creating more facilities for online shopping will prevent the presence of people in the passages and shopping centers, which are usually crowded areas of the city.

Estimating the number of effected people in the future can provide solutions for better control and improvement of community conditions. In this case, it will be possible to take effective measures such as vaccination or quarantine before the infection increases

DECLARATIONS

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