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Examining the associations between perceived built environment and active travel, before and after the COVID-19 outbreak in Shiraz city, Iran

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ABSTRACT

This study aims to evaluate the effects of the COVID-19 pandemic and policies to control the outbreak such as quarantine, jobs closures, and traffic restrictions on active travel of Central Businesses District (CBD) residents in comparison with the non-CBD residents of Shiraz, Iran; and examine the relationship between perceived built environment factors and active travel in the pre- and post-outbreak. The results indicate that the most effective individuals factors on active travel are bicycle and car ownership, and built environment characteristics are walkability, bikeability, security, aesthetics, traffic calming, intersections safety, land uses diversity and density, destination accessibility, street pattern, and bike-sharing infrastructures. Also, the average walking and cycling time of the CBD residents before and after the outbreak is more than that of the non-CBD residents, which is due to the quality of built environment factors in the CBD. A built environment with mixed, diverse, dense and accessible land uses, as well as safe and secure cycling and walking routes have major effects on active travel in the crisis. Hence, it is suggested that policymakers take action to make the environment more people-friendly to maintain citizens' mobility in the critical situation, when many travel modes have lost their efficiency.

1. Introduction

The COVID-19 was first reported in the Wuhan region of China in late December 2019, but it is now confirmed in most countries around the world (Beck & Hensher, 2020). The outbreak is considered an emergency and a risky public health issue at the international level (Chinazzi et al., 2020). Following the COVID-19 outbreak, other countries expanded their planning and monitoring to identify the new possible cases of the disease and try to break the transmission chain (de Haas et al., 2020; Oum & Wang, 2020).

The first case of the disease in Iran was reported on February 19, 2020. Due to the contagious nature of the virus, unnecessary traveling was restricted to prevent the spread of the disease. In this regard, intra- and inter-city travel were banned or severely restricted in many cities of Iran, including Shiraz metropolis. Quarantine, public transportation and jobs closures were also on the agenda.

Meanwhile, people need to leave their houses for essential activities, such as shopping, going to work, and providing other necessities. To do so, they tend to choose nearby destinations. Therefore, the proper access to shops, facilities, and services will have significant impacts on mobility of people and use of active travel modes (cycling and walking) in these critical situations. On the other hand, restrictions on transportation modes, such as private cars and public transportation have also reduced people's mobility. So, it is expected that the restrictions increase the adoption of alternative modes, such as walking and cycling. Walking and cycling are cost-effective and accessible modes that are necessary for daily life, especially in the crisis (Voss et al., 2016). On the other hand, travel mode choice depends on the built environmental characteristics including density and diversity of land use, and residents' access to services (Haselwandter et al., 2015).

As a result, it is expected that there have been differences between Central Businesses District (CBD) residents and non-CBD residents in walking and cycling due to their better access to facilities, especially after the outbreak. The CBD, is located in the central part of a city, together with particular central activities (Hussein et al., 2020; Qi et al., 2020), which have a significant role in urban development and human life (Peng et al., 2020; Yu et al., 2015). CBDs are the complex product of rapid urban growth and waves of economic and technological change.

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Today, cities are characterized by a high-density core that encompasses retail, office, and entertainment space that exists in competition with suburban alternatives linked via sprawling road and transit networks (Rice & Bova, 2020).

Hence, the main objectives of this study are to evaluate the effects of the COVID-19 pandemic and policies such as quarantine, public transportation and jobs closures, and odd-even traffic restrictions to control the outbreak on active travel of the CBD residents in comparison with the non-CBD of Shiraz metropolis and examine the relationships between built environment factors and active travel in the pre- and post-outbreak.

The policies, such as travel restrictions to suppress the disease can cause several psychological problems and challenges, such as depression, and ultimately lead to the emergence of various anomalies in citizens. On the other hand, poor preparedness of the managers, decision-makers, and communities involved with diseases can result in a lack of appropriate planning to reduce and solve problems. In this regard, researchers can help human societies by providing appropriate scientific solutions through careful surveys and recognition of the various dimensions of studied topics. In this way, by identifying the strengths and weaknesses, planners and decision-makers will be better equipped to take appropriate and effective measures.

2. Literature review

Li et al. (2005) by conducting a cross-sectional study, examined the relationship between perceived built environment factors (density of places of employment, household density, green and open spaces for recreation, number of street intersections) and 517 older adults' walking activity among 56 neighborhoods in Portland, Oregon, USA. They found that perceptions of safety for walking and the number of nearby recreational facilities were positively related to high levels of walking activity (Li et al., 2005). Correlations between perceived and objective built environment variables (accessibility, safety, outdoor spaciousness, attractiveness, stores within walking distance, number of establishments within 400, 800, and 1600 m, minimum distance in meters to establishments) and walking in eight neighborhoods in Northern California with negative binomial regression and ordered probit model were analyzed by Handy et al. (2006). Their results showed that increases in accessibility, particularly close proximity to potential destinations had positive effects on walking. Their other findings also illustrated that enhancements to other qualities of the built environment (bike routes, sidewalks, public transit, safety, and attractiveness) could also increase walking (Handy et al., 2006).

The relationships between perceived neighborhood factors and physical activity of 1623 adults aged 20 to 97 years in King County/ Seattle were examined by Shigematsu et al. (2009). They used the validated International Physical Activity Questionnaire and the validated Neighborhood Environment Walkability Scale questionnaire. The results showed that walking was significantly related to almost all neighborhood environment variables (residential density, proximity to nonresidential land uses, ease of access to nonresidential uses, street connectivity, walking/cycling facilities, aesthetics, pedestrian traffic safety, crime safety, and proximity to recreation facilities) in the younger people. However, for older people, only proximity to nonresidential uses and recreation facilities were correlated with walking (Shigematsu et al., 2009). Troped et al. (2011) to examine associations between the perceived built environment and physical activity in U.S. women used logistic regression and data from Nurses' Health Study II in 2005. Their findings indicated that perceived proximity to shops/stores and access to recreation facilities were important correlates of physical activity for women, irrespective of region or sprawl (Troped et al., 2011). Relationships of perceived neighborhood attribute with transport-related cycling and walking in three countries (USA (Baltimore and Seattle), Australia (Adelaide) and Belgium (Ghent)), with the Neighborhood Environmental Walkability Scale and the International Physical Activity Questionnaire, were examined by Van Dyck et al. (2012). Their finding revealed that Proximity to destinations, good walking and cycling facilities, perceiving difficulties in parking near local shopping areas, and perceived aesthetics were positively related to cycling. Besides, perceived residential density, land use mix access, proximity of destinations, and aesthetics were related to walking (Van Dyck et al., 2012).

Ma and Dill (2015) by binary logit and linear regression models, examined the relationships between the objective environment (bike-friendly infrastructure, street connectivity, and accessibility), perceived environment (safety, accessibility, and easy), and bicycling behavior based on data from a random phone survey conducted in the Portland, Oregon. Results of their study showed that the perceived environment and objective environment had different associations with bicycling (Ma & Dill, 2015). Jáuregui et al. (2016) showed that access to parks, aesthetics, and safety from crime had effects on physical activity among Mexican adults. They used multiple regression models to estimate the association between perceived environmental variables and total moderate to vigorous physical activity (MVPA); based on 629 data from a population-based study, which was conducted in Cuernavaca, Mexico, in 2011 (Jáuregui et al., 2016).

The association between perceived environmental attributes and leisure-time and transport-related physical activity of 671 South Africans aged ≥35, by conducting multivariable logistic regressions, was investigated by Malambo et al. (2017). The results indicated that proximity to transit stops, pleasant scenery, sidewalks, shade from trees, traffic, and well-lit streets were significantly associated with leisure-time walking. Also, proximity to transit stops and well-maintained sidewalks were significantly associated with transport-related walking (Malambo et al., 2017). The relationship between perceived social and built environment factors and bicycling was examined by Porter et al. (2018). They used multivariable logistic regression to examine data from an internet-based survey ($N = 801$) conducted in Austin, Texas, and Birmingham, Alabama. Their results showed that all examined environmental factors (residential density, traffic safety, destinations, connectivity, aesthetics, bicycle infrastructure, and safety from crime) significantly affected bicycling (Porter et al., 2018).

The associations of the perceived neighborhood built environment with walking and cycling for transport in inhabitants from Latin American countries were examined by Ferrari et al. (2020). They conducted a cross-sectional study that 9218 participants completed the International Physical Activity Questionnaire-Long Form to measure walking and cycling for transport. The results showed that perceived land use mix-access and the existence of many alternative routes in the neighborhood were associated with higher odds of reporting any walking for transport. The odds of reporting any cycling for transport were higher in participants perceiving more walking/cycling facilities, and better aesthetics (Ferrari et al., 2020). The relationships between perceived built environment scores and leisure-time physical activity of 308 older people in Hangzhou and 304 older people in Wenzhou were examined by Yu et al. (2020). Data were collected using Neighborhood Environment Walkability Scale and International Physical Activity Questionnaire. Yu et al., used a multivariate linear regression method and *t*-test to analyze the data. They found that physical activity was positively associated with walking/cycling facilities and crime safety in both cities. It was positively correlated with residential density, aesthetics, pedestrian/traffic safety in Wenzhou and negatively correlated with access to services in Hangzhou (Yu et al., 2020).

Literature showed that the built environment can affects mobility of people (trip generation, travel mode choice, walking, cycling, etc.) in various ways, which has been known as an influencing factor on individuals' tendency to active travel. The built environment is defined as a human-made space in which people live, work and recreate on a daily basis (Roof & Oleru, 2008). To capture the built environment, land uses density and diversity, design and street pattern, destination accessibility and distance to public transport (often known as the 5Ds) (Ewing &

Cervero, 2010), walkability, bikeability, bike-sharing infrastructures, intersections safety, vegetation, security from crime and traffic calming are the most common criteria addressed in the literature. These criteria are more discussed in the following:

Design represents street network features within a district (Ewing & Cervero, 2010). A well-connected street network, which is suitable for walking and cycling is a network that has many short links, numerous intersections, minimal dead-ends and well-separated from traffic (Adeniyi, 2014).

Diversity is given by the extent of different land use types in a neighborhood (Ewing & Cervero, 2010). Frank and Pivo argued that living in a neighborhood with a greater diversity of land uses increases the likelihood of people walking and cycling. They showed that it can also result in increasing public transportation usage and decreasing car dependency (Frank & Pivo, 1994).

Density as a built environment factor is considered as a ratio of the land uses of a specific zone in the area of that zone (Frank et al., 2010; Koh et al., 2015). This rate is usually higher in the Central Business District (CBD) of cities and is more suitable for active mobility (Dobesova & Krivka, 2012).

Destination accessibility is defined as the ease of reaching different destination locations. It can be measured by distance to various or number of destinations (Ewing & Cervero, 2010).

Distance to transit is represented by the shortest street distance from residences to the closest public transportation station. This criterion is also measured by the number of stations located in a residential district (Ewing & Cervero, 2010). While it is more common to consider a 400-m buffer for this area (Schlossberg & Brown, 2004), some studies also assumed higher values (Duncan et al., 2011; Sehatzadeh et al., 2011).

Walkability and Bikeability refer to build environment factors: (i) sidewalk condition and quality, (ii) comfort, (iii) attractiveness, and (iv) traffic safety and security (Arellana et al., 2020); and represent different perspectives of urbanization such as (i) outcomes of walking and cycling (e.g., places that provide sustainable transport modes or are exercise-inductor); (ii) macro and micro dimensions of cities (e.g., compact urban structures and good quality sidewalks); and (iii) as a proxy to better designs (e.g., human scale and liveability) (Forsyth, 2015; Lucchesi et al., 2020).

Bike-sharing infrastructures can be divided into two categories according to whether they have docking stations or not. A station-based bike-sharing system has fixed docking stations, and users have to rent and return bikes at a station. The emerging free-floating bike-sharing system has no docking stations, and bikes can be parked anywhere that is appropriate. The built-in GPS tracking module allows users to locate and unlock bikes that are nearby via smartphone applications (Xu et al., 2018; Xu et al., 2019).

Aesthetics is defined by various characteristics, for example attractiveness of buildings and landscaping, cleanliness, sights, street and garden maintenance, (quality of) nature, shade, and lack of incivilities (Ball et al., 2001; Zijlema et al., 2020).

Security can be approached on two dimensions, objective (the occurrence of crimes), and subjective (fear of crime, perceptions of personal security). Most studies analyzing the relationship between subjective security and walking have reported that the perceived risk of crime has a negative effect on transport or recreational walking and cycling (Lucchesi et al., 2020; Ruiz-Padillo et al., 2018).

Traffic calming and intersections safety may be solutions to decrease dangers from traffic or conditions that drivers enter intersections and neighborhood crossing without an adequate reduction in speed encounter with varied road users such as pedestrians, cyclists and two-wheelers, which all of them are substantially different in speed, mass, and degrees of protection (Akbari & Haghighi, 2020; Ariën et al., 2014).

In this part, the most important perceived built environmental characteristics were reviewed and based on these, the questionnaire of this study was drafted. The questionnaire is presented in Appendix 1. It is worth noting that the reviewed studies were conducted before the COVID-19 outbreak. To date, to our knowledge no study has been conducted to examine the relationship between perceived built environment factors and active travel after the COVID-19 outbreak.

3. Methodology

3.1. Study context

Shiraz metropolis, an important historical, cultural, social, and economic center in southern Iran was selected for this study (Fig. 1). The earliest reference to the city is on Elamite clay tablets dated to 2000 BCE. The city was the Iranian (Persian) capital during the Zand dynasty from 1750 CE until 1781. The fifth-largest city in Iran and the capital of the Fars province, Shiraz, covers a land area of about 340 Km^2. At the 2016 census, the population of the city was 1.56 million.

The city is located at latitude 29° 36′ and longitude 32′ with eleven regions. Shiraz has a moderate climate with four regular seasons. The daily temperature varies between 40 °C in the summer and -10 °C in the winter. With climate change, precipitation in recent years has changed considerably, reaching levels below 350 mm as a yearly average. The CBD (district 8) with an area of nearly 377 ha and 35,727 people, constitutes 2.5% and of the total area and 26.7% of total population of the city. Fig. 2 shows geographical location of the CBD and other metropolitan districts, and spatial distribution of population density in Shiraz.

The metropolitan is split into 11 districts, each of which has its own municipal authority. In recent decades, Shiraz (as other Iranian cities) has pursued policies in favor of car use. It spends more than 70% of its construction budget to build new roads, highways, and overpasses. Car oriented planning policies have shaped a city, in which people need to drive 10 km on average to reach their destinations. The Shiraz Household Travel Survey reveals the following modal split: private cars 50%, taxis 28%, metro and buses 12%, and all other modes 10% (The survey has not measured walking rates) (Soltani et al., 2018). Also, the average vehicle occupancy rate is only 1.5–1.7. Given the development of car industries in Iran, availability of cheap fuels, low quality of public transportations, and a growing economy, car use trends are expected to increase for a while. However, such high (and increasing) levels of car use are unsustainable in the longer-term. Meanwhile, urbanites who cannot afford a car rely on grossly inadequate public and non-motorized transport systems. So far, 25 bicycle stations have been built in Shiraz, with the aim of creating a clean transportation system infrastructure for short, medium, and medium urban trips. At present, 24 km of bicycle path has been created in the center of the metropolis.

3.2. Questionnaire

The structured questionnaire of this study includes socio-demographic information (age, gender, average monthly income, car, bicycle, and driving license ownership, and the number of cars in the family), information about the walking and cycling trips of the residents before and after the outbreak (purpose, duration, and frequency (per week)) and the most important information about the built environment (land uses density and diversity, design and street pattern, destination accessibility and distance to public transportation, walkability, bikeability, bike-sharing infrastructures, intersections safety, aesthetics, security from crime, and traffic calming). Validity of questionnaire has been confirmed by Lawshe's method (Kennedy et al., 2019; Lawshe, 1975) and several professors of the Faculty of Geographical Sciences and Planning of the University of Isfahan (3 professors) and the Department of Urban Planning of Shiraz University (2 professors).

3.3. Data collection

The sample study of this cross-sectional study includes individuals over 18 years old residing in Shiraz metropolis. The sampling method was a multi-stage cluster. In the first stage, each of the metropolitan

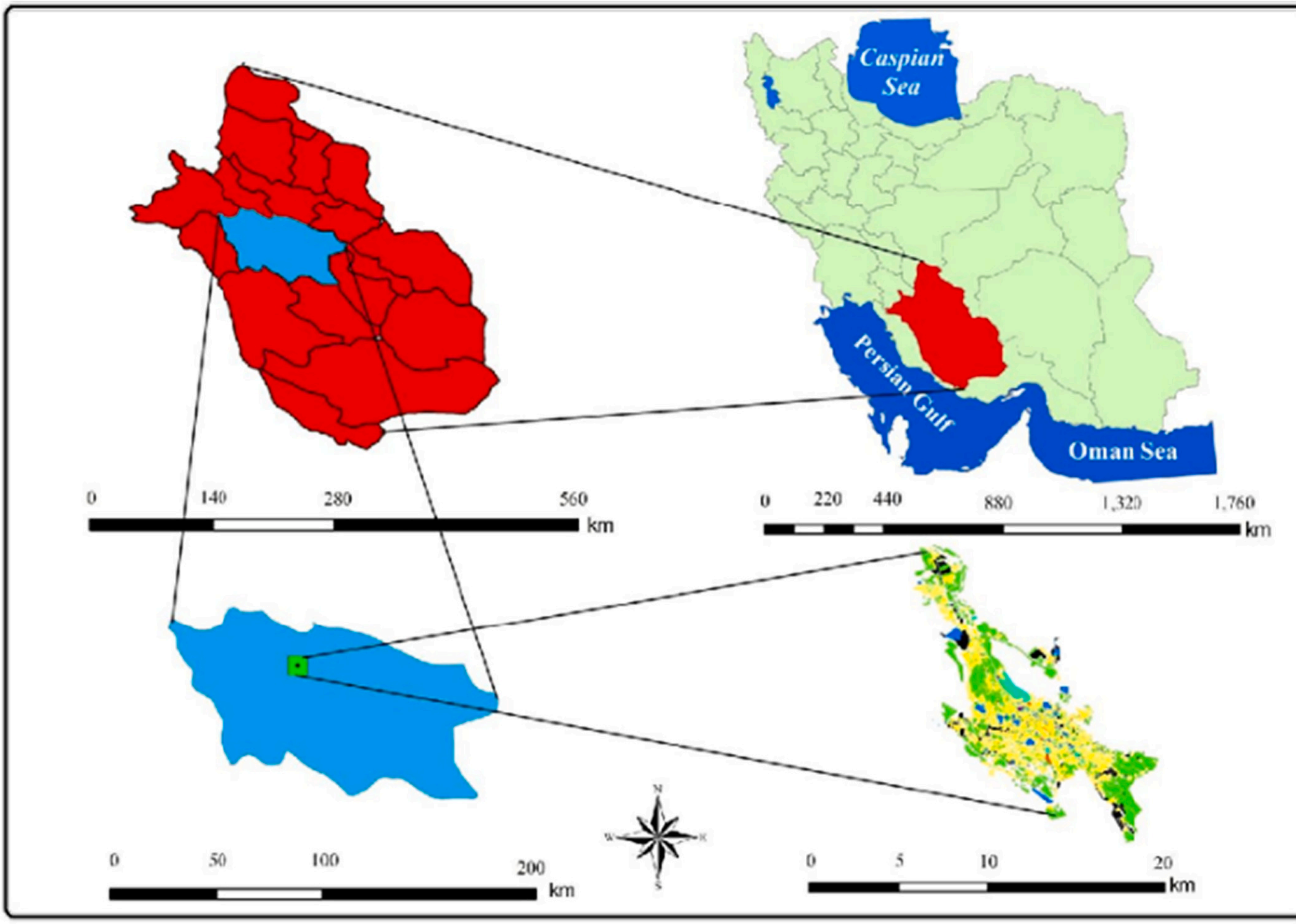

Fig. 1. Shiraz location in Iran.

districts of Shiraz was considered as a general cluster, the districts within them as sub-clusters, and the blocks within the districts as sub-clusters of the districts. Then, proportional to the number of samples allocated in each district, several blocks were randomly selected from each district, and within the blocks, people were interviewed in a systematic random method. In this research, 1265 people took and completed the questionnaire. The interviews were conducted in the field (parks, malls, etc.) for 35 days from 8 am to 8 pm. Inclusion criteria included having at least 18 years old and willingness to participate in the survey and exclusion criteria was reluctant to participate. Each interview lasted between 10 and 15 min and at the end of the interview, the participants were given masks and sanitary gloves as gifts. It is noteworthy that the minimum sample size for CBD residents (population of CBD residents is 35,727), obtained from the Cochran formula, was equal to 380. Also, the minimum sample size for the non-CBD was obtained 384; in order to analysis spatially, by considering the more populated district (254300), the size of sample for each district was obtained 64.

The minimum sample size required for each district $= \frac{254300}{1535000} * 384 = 63.4$.

$$\text{Cochran formula}: n = \frac{\frac{Z^2pq}{d^2}}{1 + \frac{1}{N}\left(\frac{Z^2pq}{d^2} - 1\right)}$$

where: N is the total population, n is the sample size, Z is the value for the selected alpha level, e.g. 1.96 for a 95% confidence level. p is the estimated proportion of an attribute that is present in the population. q is 1-p (in this study, p and q are considered 0.5). d is the acceptable margin of error for proportion being estimated (in this study, d is considered 0.05).

3.4. Data analysis

The socio-demographic, travel, and the built environment data were considered as independent variables and the duration of active travel per week, walking, and cyling were considered as the dependent variables. Multivariate regression and SPSS-23 software were utilized for determining the effective factors. Definitions of variables are presented in Table 1.

4. Results

Among 386 residents of the CBD, a majority are men; a large majority are employed; a majority have a driving license, a small majority own a private car, and a minority have a bicycle. Among 879 residents of the non-CBD, a small majority are men, a majority are employed, a majority have a driving license and a private car, and a minority have a bicycle. The related socio-demographic characteristics are shown in Table 2.

Table 3 shows that for CBD residents, walking and biking trips, before and after the outbreak, included shopping, religious, recreational, work, and others purpose. Also, for non-CBD residents, they include shopping, religious, recreational, work, and others purpose.

The results also reveal that before the outbreak, the average walking and cycling time per week of CBD and non-CBD residents were 132 and 42 min and 78.4 and 25 min, respectively. After the outbreak, these were 89 and 57 min and 62.9 and 29.6 min for the residents of CBD and non-

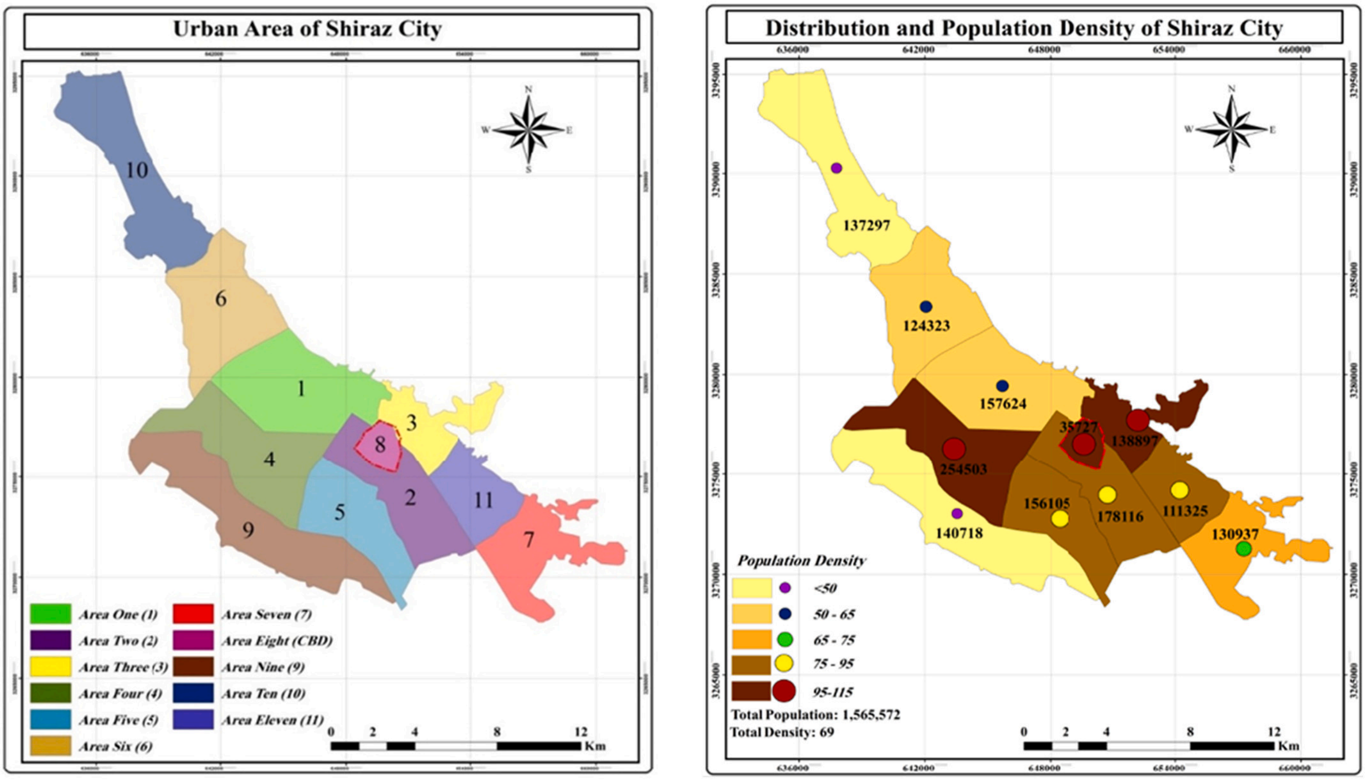

Fig. 2. Spatial distribution of population density, and geographical location of the CBD in Shiraz.

Table 1
Definitions of variables.

Symbol	Variables	
Trip (walking and biking) variables before & after the pandemic		
TRDT	Active Trip duration	Average total active travel time (minute) per week
TRWT	Walking duration	Average walking time (minute) per week
TRBT	Biking duration	Average biking time (minute) per week
Trip purpose variables before& after the pandemic		
PRSH	Shopping	If the trip purpose is shopping =1, 0 otherwise
PRRG	Religious	If the trip purpose is religious =1, 0 otherwise
PRRC	Recreational	If the trip purpose is recreational =1, 0 otherwise
PRWK	Work	If the trip purpose is work =1, 0 otherwise
Household characteristics		
HHSZ	Size	Number of persons in the household
HHCR	Car	Number of cars in the household
Individual characteristics		
IDSX	Sex	If male = 1, 0 otherwise
IDED	Employed	If Employed = 1, 0 otherwise
IDlE	Low education	If education is <8 (8 = middle school) = 1, 0 otherwise
IDME	Middle education	If education is 8–12 = 1, 0 otherwise
IDhE	High education	If education is >12 (12 = high school) = 1, 0 otherwise
IDDL	Driving license	If the status of the driver's license is yes = 1, 0 otherwise
IDCO	Car ownership	If the status of having a private car is yes = 1, 0 otherwise
ICBO	Bike ownership	If the status of having a private bike is yes = 1, 0 otherwise
Characteristics of the built environment		
NHDE	Density	
NHDY	Diversity	
NHDG	Design	
NHDA	Destination accessibility	
NHDP	Distance to public transport	
NHBS	Bike-sharing infrastructures	5-point Likert scale
NHWR	Walkability	(very poor = 1, excellent = 5)
NHBR	Bikeability	
NHCT	Security	
NHTC	Traffic calming	
NHIS	Intersections safety	
NHVT	Aesthetics and vegetation	

Table 2
Socio-demographic characteristics of CBD and non-CBD participants. (N = 1265).

	CBD (n = 386)		Non-CBD (897)		*Chi*^{2}	p
	n	%	n	%		
Sex						
Male	231	60	512	58.2	38.6	<0.001
Female	151	40	367	41.8		
Currently working						
Yea	317	82	660	75	43.2	<0.001
No	69	18	219	25		
Age category						
18–39 years old	219	56.7	402	45.7	34.1	<0.001
40–64 years old	99	25.6	323	36.7		
Over 65 years old	68	17.7	154	17.6		
Having a DRIVING license						
Yes	293	78	602	68.5	32.4	<0.001
No	93	22	277	31.5		
Car ownership						
Yes	216	56	530	60	1.4	0.48
No	200	44	349	40		
Bike ownership						
Yes	127	33	226	25.7	58.0	<0.001
No	259	67	653	74.3		
Education						
+ 12	172	44.6	408	46.4	0.9	0.74
8–12	126	32.6	245	27.8		
−8	88	21.8	226	25.8		

Note: Significant ($p < 0.05$), non- significant ($p > 0.05$), p: Pearson's chi-square test significance value.

CBD, respectively. The average total active travel time per week of the CBD and non-CBD residents before the outbreak also were 174 and 103.4 min, respectively. After the outbreak, these were 146 and 92.5 min for the residents of CBD and non-CBD, respectively (Fig. 3). The increases in the duration of cycling are due to other modes restrictions, such as private cars and public transportation. Therefore, it can be said that people choose a bicycle as an alternative mode for their daily trips.

Spatial distribution of the city districts in terms of average perceived built environment characteristics in three categories (appropriate: 4–5, relatively appropriate: 3–3.99, and inappropriate: 1–2.99) is showed in Fig. 4. In general, features such as land uses diversity and density, design and street pattern, transit and destination accessibility and bike-sharing infrastructures are in appropriate condition in the CBD, while other features except for vegetation have relatively appropriate quality. Regarding the non-CBD, land uses diversity in districts 1 and 3; bike-sharing infrastructures in district 3, vegetation in districts 1, 3, 6, and 11, and destination accessibility in districts 3, 4, and 5 have perceived appropriate quality. Other characteristics such as bikeability, walkability, traffic calming, intersections safety, and security are in inappropriate and relatively appropriate condition, so that district 10 has inappropriate quality, it is approximately true for district 9. Overall, districts adjacent to the CBD are in relatively appropriate condition.

The regression modeling was conducted to predict factors affecting the duration of active travel, walking and biking of the CBD and the non-CBD in the pre- and post outbreak. The results of the multivariate regression method indicate that the most important factors affecting the CBD's active travel duration before the outbreak are bike ownership, car ownership, safety of intersections, walkability, land uses density and diversity, and destination accessibility. The effective factors after the outbreak are walkability, bikeability, traffic calming, vegetation, land uses diversity, and destination accessibility.

Regarding the non-CBD, the effective factors on the duration of active travel before the outbreak include bike ownership, car ownership and traffic calming; while after the outbreak, the most important factors are bike ownership, walkability, bikeability, traffic calming, vegetation, security, land uses density, and destination accessibility (Table 4).

Factors affecting the CBD residents' walking duration before the outbreak are car ownership, walkability, land uses density and diversity, and destination accessibility. The effective factors after the outbreak are walkability, intersections safety, land uses density and diversity, and destination accessibility.

Regarding the non-CBD, the effective factors on walking duration before the outbreak include car ownership, traffic calming, walkability, intersections safety, land uses diversity, and destination accessibility; while after the outbreak, in addition to traffic calming, walkability, intersections safety, land uses diversity, and destination accessibility; security and vegetation are also effective (Table 5).

The results of the multivariate regression method also indicate that the most important factors affecting the CBD residents' biking duration before the outbreak are vegetation, safety of intersections, bikeablity, design and street pattern, and bike-sharing infrastructures. The effective factors after the outbreak are bikeability, traffic calming, vegetation, safety of intersections, design and street pattern, and bike-sharing infrastructures. Regarding the non-CBD residents, the effective factors on the duration of cycling before the outbreak include traffic calming, vegetation and aesthetics, safety of the intersections, security, and design and street pattern; while after the outbreak, the most important factors are bike ownership, traffic calming, vegetation and aesthetics, safety of the intersections, and design and street pattern (Table 6).

In order to evaluate the sensitivity of models to changes in the effective variables, three scenarios were assumed for active travel, walking, and cycling. Scenario one or worst condition, car ownership and bike ownership are equal to 1 and 0, respectively; and built environment characteristics are in inappropriate conditions. Scenario two or moderate condition, car ownership and bike ownership are equal to 1 and 1, respectively; and built environment characteristics are in relatively appropriate conditions. Finally, car ownership and bike ownership are equal to 0 and 1, respectively; and the built environment characteristics are in appropriate conditions in scenario three or best condition. Then, duration of active travel, walking, and cycling of the CBD and non-CBD residents in the pre- and post-outbreak were predicted by models in the scenarios. The results of sensitivity analysis show that duration of total active travel, walking, and cycling of CBD and non-CBD residents in the pre- and post-outbreak, from worst to best condition have significant increases (almost fivefold) (Figs. 5 to 7).

Table 3
Percentages of trip purposes per walking and biking, before and after the COVID-19 outbreak.

	CBD				Non-CBD			
	Before		After		Before		After	
	Walk	Bike	Walk	Bike	Walk	Bike	Walk	Bike
Shopping (%)	30.1	35.2	53	42	26.4	40.7	44.6	51.6
Religious (%)	25	15.4	9.6	3.4	35.3	20.7	3.4	4.7
Recreational (%)	32.1	39.5	28.2	36.2	25.9	30.2	35.6	32.5
Work (%)	8.1	7.4	5	16.6	5.5	4.6	10.1	7.7
Other (%)	4.7	2.5	4.2	1.8	6.9	3.8	6.3	3.5
Sum (%)	100	100	100	100	100	100	100	100

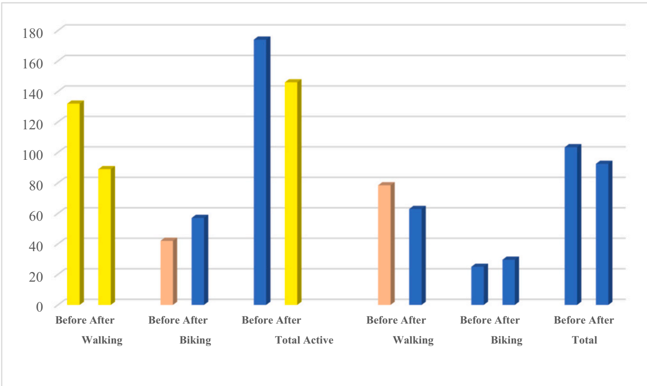

Fig. 3. The average walking, cycling, and total active travel time (minute) per week before and after the outbreak.

5. Discussion

In this study, the COVID-19 outbreak effects on active travel of CBD residents in comparison with the non-CBD; and the relationship between built environment characteristics and active travel in the pre- and post-outbreak were assessed using a multivariate regression method. The results indicate that the most important individuals factors affecting active travel are bicycle and car ownership, and built environment characteristics are walkability, bikeability, security, vegetation and aesthetics, traffic calming, intersections safety, land uses diversity and density, destination accessibility, design and street pattern, and bike-sharing infrastructures.

After the outbreak, in general, shopping and recreational trips by active travel modes increased and religious trips decreased significantly. Also, work trips on foot of the CBD residents remained almost unchanged, but that of the non-CBD increased. However, changes in these trips by bike increased in the CBD and decreased in the non-CBD.

Results of statistics also indicate that the average walking and cycling time of CBD residents before and after the outbreak is more than that of the non-CBD. On the other hand, spatial distribution shows that built environment characteristics such as land use diversity and density, design and street pattern, transit and destination accessibility, and bike-sharing infrastructures are in appropriate condition in the CBD, while other features except for vegetation have relatively appropriate quality. Although, regarding the non-CBD, characteristics such as bikeability, walkability, traffic calming, intersections safety, and security are in inappropriate and relatively appropriate conditions. Hence, the difference between average active travel of the CBD and non-CBD residents is due to the quality of built environment characteristics in the CBD such as better access to the facilities and services, diversity and density of land uses, bikeability, and walkability. Besides, districts near and adjacent to the CBD have relatively appropriate built environment characteristics. However, the built environment effects on active travel in the crisis in both CBD and non-CBD were confirmed by sensitivity analysis. In the three scenarios, the duration of total active travel, walking, and cycling of residents of CBD and non-CBD after the outbreak have raised

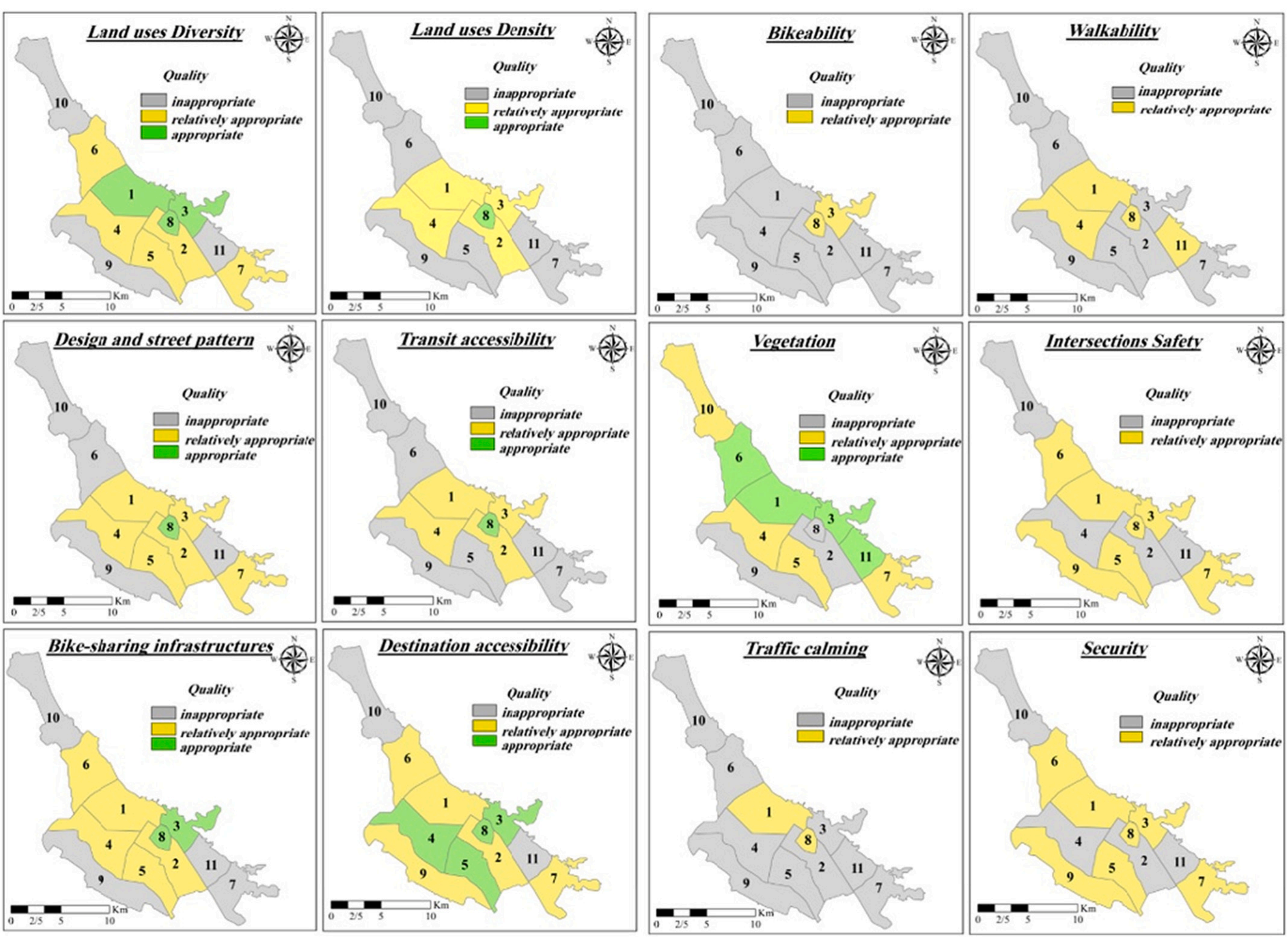

Fig. 4. Spatial distribution of Shiraz districts in terms of perceived built environment characteristics in three categories.

Table 4
Outcomes of active travel regression models and coefficient of variables.

MODEL	F-test	R square	Constant	Bike ownership	Car ownership	Walkability	Bikeability	Security	Vegetation and aesthetics	Traffic calming	Intersections safety	Land uses density	Land uses diversity	Destination accessibility
CBD before	38.16***	0.53	61.3***	51.7***	−35.6***	15.1**					8.36***	14.2***	17*	19.2***
CBD after	21.7***	0.54	28.5**			12.8**	16.6**		27.7***	15.5*			10.2*	14.7*
Non-CBD before	47.53***	0.53	51**	31.4**	−18.6**					8.5*				
Non-CBD after	23.7***	0.39	32.4**	26.1**		18.2***	12.4**	3.4*	17.5*	19.1**		5.6*		10.8**

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

remarkably than before.

Private car also harms active travel time (total and walking) of the CBD and non-CBD residents before the pandemic. But after that, due to the traffic restrictions, owning a personal car does not affect active travel. It can be said that since cycling duration has increased, the bicycle has turned into an alternative mode to personal cars. Nakanishi and Black (2016), and Hou (2019) also showed that having a personal car reduced walking and cycling (Hou, 2019; Nakanishi & Black, 2016). Accordingly, coherent schemes of traffic restrictions in car-dependent countries after the end of the pandemic can increase cycling and walking. Also, people-friendly walking and cycling infrastructures in critical situations, which private cars are not efficient, are necessary to maintain mobility of citizens.

Bicycle ownership has a major impact on total active travel as its significant effect on the CBD and non-CBD models were confirmed before the outbreak. However, after the outbreak, bicycle ownership does not affect the CBD residents' total active travel. This is probably due to the high density of land uses and the closeness of the facilities in these districts where the residents tend to walk rather than cycling. Besides, due to quality of bike-sharing infrastructure in the CBD, bicycle ownership does not have a major impact on residents' cycling in the pre- and post-outbreak. Regarding the residents of non-CBD, bicycle ownership greatly affects their total active travel in both pre- and post-outbreak and cycling in the post-outbreak. In these districts due to low-density land uses and inappropriate bike-sharing infrastructures, residents travel long distances on their bicycles in critical situations. Therefore, the role of bicycle ownership for residents of these districts is greater than that of the CBD. Further researches are needed to identify the role of bike-sharing infrastructures in cycling after the outbreak.

Hence, policies to increase bicycle ownership or use of bike-sharing systems can be effective in maintaining the active travel of people in such critical situations when other methods (such as public transportation and private cars) are not as efficient as before. Also, preventive and incentive measures to increase cycling from early ages are necessary to turn it into a habit. In support of this, previous researchers stated that most elderly cyclists had cycled throughout their lives, and only a few of them started cycling at these ages (Johnson & Rose, 2015; Leger et al., 2019; Ryan et al., 2016). Then, it can be expected that having a cycling background can make this mode resilient in critical situations. Future studies should consider that cycling background could be a criterion in cycling after the COVID-19 outbreak.

A properly built environment that increases the use of active transportation, enhances independent mobility and facilitates physical activities (Organization, W. H, 2007). Previous studies indicated that security, safe intersections, traffic calming, aesthetics, bikeability, walkability, and street design were effective factors in walking and cycling (Ball et al., 2001; Cheng et al., 2019; Cheng et al., 2020; Van Cauwenberg et al., 2018; Yang et al., 2018). The present study also show that despite inappropriate walkability in the non-CBD, this feature has a significant effect on walking for both the CBD and the non-CBD before and after the pandemic. Also, the effect of relatively appropriate bikeability on the CBD's cycling is obvious.

Security of the built environment has a positive effect on the non-CBD's walking after the outbreak and the non-CBD's cycling before that. Therefore, it is suggested that proper lighting of routes and increasing the number of police stations as well as police patrolling can be considered to make the residents feel safer while walking and cycling, especially in these critical situations. Vegetation and Aesthetics only affect the non-CBD's walking after the outbreak, while despite inappropriate vegetation in the CBD, it has positive effects on cycling for both the CBD and the non-CBD before and after the outbreak. The spatial distribution shows that intersections safety is in relatively appropriate conditions in seven districts such as CBD, the results of regression models also indicate that intersections safety has significant effects on the citizens' cycling and walking; while traffic calming has low-quality in the non-CBD districts, but has positive effects on their walking and

Table 5
Outcomes of walking regression models and coefficient of variables.

MODEL	F-test	R square	Constant	Car ownership	Walkability	Security	Vegetation and aesthetics	Traffic calming	Intersections safety	Destination accessibility	Land uses diversity	Land uses density
CBD-before	31.4 ***	0.41	27.2 ***	−36.6 ***	23.6 **					20 **	12.6 **	11 *
CBD-after	28.56 ***	0.34	29.5 *		24.74 **				25.9 **	19.7 **	11.2 *	18.3 ***
Non-CBD-before	31.63 ***	0.38	45.4 ***	−38.2 ***	11.34 *			18.27 ***	19.7 **	17.2 **	8.5 ***	
Non-CBD-after	31.7 ***	0.33	43.4 **		23.17 ***	12.8 **	7.93 *	10.8 **	12.1 **	21.3 **	15.8 **	

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 6
Outcomes of biking regression models and coefficient of variables.

MODEL	F-test	R square	Constant	Bike ownership	Bikeability	Security	Vegetation and aesthetics	Traffic calming	Intersections safety	Design and street pattern	Bike-sharing infrastructures
CBD-before	26.33 ***	0.28	38.1 ***		48.6 **		21.27 *		25.6 **	12.5 **	35.6 ***
CBD-after	26.45 ***	0.31	41.7 **		43.8 *		32.93 **	20.9 *	54.7 ***	10.2 *	21 **
Non-CBD-before	17.24 ***	0.29	18 *			8.95 **	10.7 **	14.6 ***	11.1 **	24.4 **	
Non-CBD-after	75.6 ***	0.53	48.7 **	115.4 ***			12.8 **	13.57 ***	8.5 **	20.8 *	

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

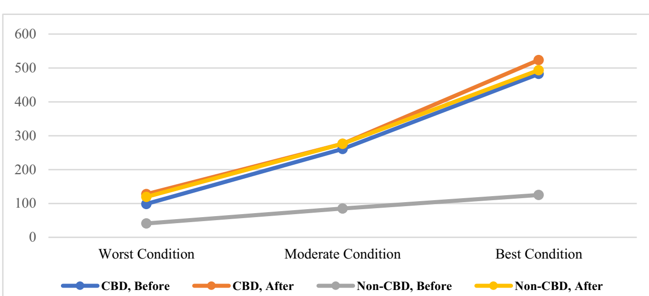

Fig. 5. Total active travel duration (minute) in three scenarios.

cycling after the outbreak.

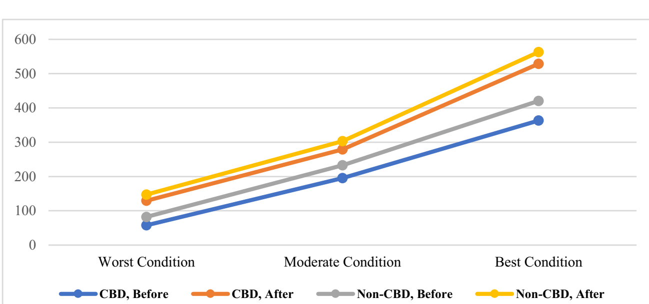

Fig. 6. Walking duration (minute) in three scenarios.

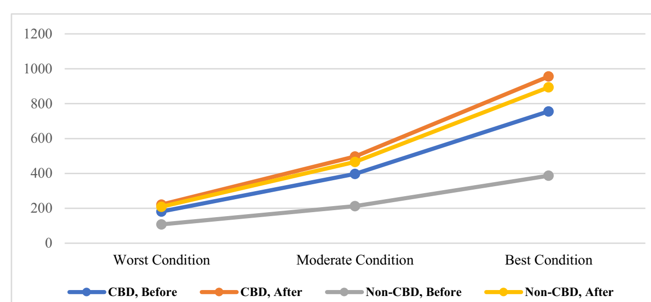

Fig. 7. Cycling duration (minute) in three scenarios.

Previous studies showed that land uses diversity and density, and destination accessibility increased the likelihood of walking and cycling (Buffel et al., 2016; Ewing & Cervero, 2010; Foster et al., 2014; Frank & Pivo, 1994; Koh et al., 2015). In this study, their effects on walking and cycling in the pre- and post-outbreak were also confirmed. However, the effect of land uses density on walking was only confirmed for the CBD and has no effect on all citizens' cycling. The spatial distribution also shows that land use density in districts of non-CBD is in relatively- and inappropriate conditions; while, land uses diversity and destination accessibility have appropriate and relatively appropriate quality. Dobesova and Krivka (2012) also indicated that land uses density rate is usually higher in the CBD in which it is more suitable for active mobility (Dobesova & Krivka, 2012). It is worth noting that, in both pre- and post-outbreak the effect of transit accessibility on walking and cycling neither approved for the CBD nor the non-CBD.

6. Conclusion

Maintaining the social interactions, mobility, and health of citizens amid the growing challenges of the COVID-19 pandemic are highly important. In the critical condition of the pandemic where many travel modes have lost their efficiency, alternatives and resilient modes are crucial to achieving this goal. In this study, cycling and walking, as alternatives, and factors affecting them in the CBD and the non-CBD districts of Shiraz metropolis in the pre- and post-outbreak have been evaluated. The results showed that a people-friendly environment with mixed, diverse, dense and accessible land uses, as well as safe and secure cycling and walking routes have major effects on mobility and active travel of citizens in this crisis. Hence, it is suggested that urban planners and policymakers take action to make the environment more people-friendly to maintain citizens' mobility in critical situations.

7. Recommendations and limitations

The research field study was conducted at the time of the quarantine scheme, traffic restrictions, and closure of organizations and some jobs. So, it is suggested that the effect of the COVID-19 outbreak on active travel be investigated in situations when traffic restrictions will have been lifted and organizations and jobs have returned to normal situations.

In this study, dependent variables (walking and cycling) were analyzed separately by multivariate regression or aggregated as active travel. However, other methods, such as multilayer perceptron artificial neural network (MLP-ANN), when we have two independent variables should be conducted to examine the effect of these variables simultaneously.

Total moderate to vigorous physical activity (MVPA) did not examine in this study. So, it is recommended that future studies evaluate the association between MVPA and perceived built environmental factors in the post-outbreak.

Recent studies argue that both objective and subjective measures should be included when possible, because different associations were found between the objective measures and perceived measures of the same environmental attributes with active travel behavior (Barnett et al., 2020; Ma & Dill, 2015). In this study, subjective built environment factors were investigated. Subjective measures have often been considered a substitute for objective measures when objective data are unavailable, while in order to evaluate the effects of the built environment characteristics on active travel during the COVID-19 outbreak, both objective and subjective measures are necessary.

Furthermore, it is recommended that future studies evaluate the effect of bike-sharing in the resilience of bicycle during the critical situation, as well as the effect of cycling background in the resilience of this mode. In addition, considering the change of travel behavior such as the number of trips, travel distance, the share of major transport modes, the share of trip purpose, and regional deference of them in future research are essential; especially travel behavior of older people who are more vulnerable to bacteria and viruses due to the weakening of their immune system.

Credit author statement

Amin Shaer: Writing - Original Draft, Methodology, Software, Formal analysis, Writing - Review & Editing, Investigation, Validation

Meysam Rezaei: Validation, Investigation, Resources, Writing - Review & Editing, Visualization, Methodology, Software

Behnam Moghani Rahimi: Writing - Review & Editing, Supervision, Resources,

Fatemeh Shaer: Resources, Writing - Original Draft, Project administration, Investigation,

Declaration of competing interest

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

Appendix 1. Questionnaire

1- Individuals informations

Questionnaire title: Evaluation of the COVID -19 Pandemic Effects on Active Travel

1-Age: ……… 2-Gender: ……….. 3-Family members: …….. 4-Residential location:………………….

5-Job: …… 6-Education: ………. 7- Monthly income: ………… 8-Number of cars in the household:…….

9-Having a Driving license: yes ☐ no ☐ 10-Car ownership: yes ☐ no ☐

11-Bike ownership: yes ☐ no ☐ 12- Possibility to use the car: as a driver ☐ as a car passenger ☐

2- Travel informations before and after the outbreak

Questionnaire title: Evaluation of the COVID -19 Pandemic Effects on Active Travel

What trips do you usually make by foot and bike during the week in the neighborhood and city during the outbreak and quarantine?

	Before the outbreak						After the outbreak					
	Walking			Cycling			Walking			Cycling		
	Duration	Frequency	Purpose	Duration	Frequency	Purpose	Duration	Frequency	Purpose	Duration	Frequency	Purpose
1												
2												
3												
4												
⋮												

3- The built environment informations

Questionnaire title: Evaluation of the COVID -19 Pandemic Effects on Active Travel

How satisfied are you with each of the following in the neighborhood?	**1**	**2**	**3**	**4**	**5**
Walkability					
Bikeability					
Security					
Traffic calming					
Intersections safety					
Aesthetics and vegetation					
Density of land uses					
Diversity of land uses					
Design and street pattern					
Destination accessibility					
Distance to public transport					
Bike-sharing infrastructures					

(Very poor=1 ,…, Excellent=5)

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