Investigation of the urbanization contribution to the COVID-19 outbreak in Iran and the MECA countries

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Abstract

The main objective of this research was to disclose the correlative contribution of urban-associated factors affecting the COVID-19 outbreak in the macro-scale of MECA countries and the downscaled micro-scale of the provincial divisions in Iran. For this purpose, the correlation coefficients between the variables and clustering analysis were used to expose the possible effects. Results revealed the comparatively strong relationships between some independent variables (e.g., total greenhouse gas emissions, CO₂ emissions, nitrous oxide emissions, and urban population) and confirmed cases (R from 0.619 to 0.695), demonstrating the possible effective role of urbanization and its induced GHG emissions on the COVID-19 outbreak in the country level of the MECA region. Therefore, the results significantly confirmed the strong relationships between some independent variables (e.g., total population, urban population, fuel consumption, NO₂–CO₂ emissions, energy use, and total intra-changed travels) and confirmed cases (R from 0.724 to 0.945), explaining an explicit relationship between urbanization processes and the COVID-19 outbreak in Iran. Besides, the HCA results revealed the substantial role of the urban population and urban-induced energy use and gas emission in clustering locations regarding the COVID-19 outbreak in both the MECA region and Iran. The main implication of this research is to give a practical correlation between Coronavirus infection and urban constitution, aiming to increase the health of urban societies by creating effective planning in the future.

Keywords COVID-19 outbreak · Clustering analysis · Greenhouse gas (GHG) emissions · Population · Urbanization

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1 Introduction

During the last decades, we faced plentiful studies associating the urbanization growth with some environmental, social, and health issues. For instance, the urbanization role on carbon emission has been investigated repetitively by researchers (e.g., Cordell et al., 2009; Dhakal, 2010; Zarzoso & Maruotti, 2011; Liddle, 2011; Zhu et al., 2012; Jorgenson, 2012; Knight et al., 2013), revealing the significant contribution of urban regions to CO₂ emissions in the national and global scales. Similar correlative researches have been probed between urban growth and social behavior (e.g., De Meester et al., 2013; Gehl et al., 2006; Şatir & Korkmaz, 2005). Meanwhile, the effects of urbanization on human health issues such as the obesity prevalence (Eid et al., 2008; Feng et al., 2010) have been carried out to understand physical and environmental factors affecting population health (Mackenbach et al., 2014).

At the end of 2019, a novel Coronavirus, namely SARS-CoV-2, resulted in an acute respiratory illness epidemic in Wuhan, China, which was defined as Coronavirus Disease 2019 (COVID-19) by the World Health Organization (WHO) (Alhazzani et al., 2020). After this outbreak, the nature of living and working patterns in the urban areas was transformed into new challenges (Salama et al., 2020; Acuto, 2020). For example, by the ongoing COVID-19 pandemic, the densely urban spaces were nearly defenseless in terms of disease outbreaks because the pandemic status affected the millions of inhabitants, living in the compressed urban regions (Desai, 2020). The urban areas as the hubs for transnational commerce and mobility and densely populated regions can magnify the pandemic risks (Manawadu et al., 2020). Even, the sprawled cities (with a lower density of population) can be characterized as responsive to high mobility that is the susceptible status regarding the initial pandemic spread (Aguilar et al., 2020).

Owing to the historical experiences of the 1918 influenza pandemic, Garrett (2007) has reported a positive and significant relationship between the mortality rates and the state-level population density in the USA, while Mills et al. (2004) have noted no significant associations between mortality rate and population density in the US large cities (Hamidi et al., 2020). Hence, the different relations between the pandemic spread and urban variables are complex and need more multi-variable analysis. During the last year of 2020, many studies were carried out regarding the COVID-19 pandemic. For instance, several studies have focused on the influences of COVID-19 outbreak on the urban activities, systems, processes, and health (e.g., Chapman & Tsuji, 2020; Fatmi, 2020; Feng et al., 2020; Girdhar et al., 2020). In the vice versa, some scholars have addressed the possible links between urban air pollution and illness outbreaks in the different regions and countries (e.g., Conticini et al., 2020; Magazzino et al., 2020; Ogen, 2020; Travaglio et al., 2020; Yongjian et al., 2020). The aforementioned studies have found that several factors could be associated with an increased risk of COVID-19 cases in the world.

Nevertheless, the lack of sufficient similar studies is the main research problem for the Middle East, Central Asia, and Iran territories. In addition, insufficient works have also exposed different inexperienced and initial results. For example, in Iran, some initial works have attempted to disclose the GIS-based hotspot maps for the COVID-19 outbreak in Iran in the last months based on the limited rate of infected and confirmed cases (e.g., Mahmoudzadeh & Daneshvar, 2020; Mazar et al., 2020). In this regard, some possible effective factors on the COVID-19 outbreak have been explained such as high-level population density (Ahmadi et al., 2020). Furthermore, some clinical studies, with limited hospital-based data, have been performed to indicate the role of physical characteristics of

the human body on confirmed and suspected COVID-19 cases such as age and sex (e.g., Nikpouraghdam et al., 2020; Zali et al., 2020).

Hence, the main novelty of the present study is to assess the contribution of urban-associated factors affecting the COVID-19 outbreak in the country level of the Middle East and Central Asia (MECA) countries and in the provincial level of Iran, which has not been investigated in the previous works. It seems that the world is still fighting COVID-19 and the severity of the crisis varies by place to place (Hu, 2020). Then, more studies in different regions should be carried out to recognize the complexity of the pandemic status and its influencing factors. Now, the main hypothesis of the research is retained as the urbanization and its related population and processes (e.g., GHG emissions) have a positive association with the pandemic status of COVID-19 outbreak in both scales of the MECA region and Iran.

2 Data and methods

2.1 Study area

In this research, we obtained two levels of study areas. In the first level and according to the International Monetary Fund (IMF) dataset, the Middle East and Central Asia (MECA) region is defined as the economic issues (IMF, 2017). The MECA region, including 26 countries of Afghanistan, Armenia, Azerbaijan, Bahrain, Cyprus, Egypt, Georgia, Iran, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Oman, Pakistan, Qatar, Saudi Arabia, Syria, Tajikistan, Turkey, Turkmenistan, United Arab Emirates (UAE), Uzbekistan, and Yemen, is located between 10°–45° N latitude and 24°–88° E longitude (Ghanbari & Daneshvar, 2020). Among these countries, three countries of Cyprus, Turkmenistan, and Yemen were removed due to a lack of sufficient data for COVID-19 confirmed cases (Fig. 1). In the second level, the provincial divisions in Iran are assumed to further comparative and correlative research, including 31 provinces (Fig. 2).

2.2 Data preparation

Based on two levels of the study areas, we were obliged to consider all dependent and independent variables in the international (MECA countries) and national (Iran) scales. The dependent variables relate to total deaths and confirmed cases of COVID-19 up to December 31, 2020, which were collected on the international scale from Coronavirus source data as a collection of the COVID-19 data maintained by Our World in Data (OWID, 2020) via <https://ourworldindata.org/coronavirus-source-data>. However, the announcement of the confirmed cases on the national scale for Iran has been restricted on March 23, 2020, due to governmental decision (<https://www.irna.ir/news/83725207>). Hence, we estimated the cumulative confirmed cases for each province based on the latest official report of confirmed cases via <https://www.worldometers.info/coronavirus/country/iran> in addition to the sample daily/ weekly update (WHO, 2020) and risk status of COVID-19 in Iran via <http://www.emro.who.int/irn/iran-news>.

The independent variables in the scale of MECA countries were assumed as the latest annual data extracted from the World Bank (2020). On this basis, ten variables, namely land area (km²), total population (inhabitants), urban population (inhabitants), urban population growth (annual %), the population in urban agglomerations of more than 1 million

Fig. 1 Geographical distribution of the MECA countries concerning **a** total urban population in 2019 and **b** total confirmed cases of COVID-19 in December 31, 2020

Fig. 2 Geographical distribution of the provincial divisions of Iran concerning **a** total urban population in 2019 and **b** total confirmed cases of COVID-19 in December 31, 2020

(% of the total population), CO₂ emissions (kt), methane emissions (kt of CO₂ equivalent), nitrous oxide emissions (kt of CO₂ equivalent), total greenhouse gas emissions (kt of CO₂ equivalent), and energy use (kt of oil equivalent), were collected from the World development indicators of the World Bank datasets via <https://databank.worldbank.org/source/world-development-indicators>. The mentioned variables, which were dominantly related to the urban development and its emission indicators, were prepared based on the latest time scale (dominantly in 2018) and were arranged for 23 countries of the MECA region (Table 1). Meanwhile, the main sources for urban development and emission databases could be considered from the latest revision of world urbanization prospects via <http://esa.un.org/unpd/wup> (WUP, 2018) and statistical data of greenhouse gas emissions via <http://edgar.jrc.ec.europa.eu> (EDGAR, 2018).

The independent variables in the scale of provincial divisions of Iran were also obtained from official reports of national statistics such as the balance sheet of the energy use in Iran extracted from the Iranian Ministry of Energy via <https://isn.moe.gov.ir/Statistical-Report>

Table 1 Dependent variables based on the COVID-19 dataset for the MECA countries (up to December 31, 2020)

Country name	COVID-19 total confirmed cases	COVID-19 total deaths
Afghanistan	51,526	2191
Armenia	159,409	2823
Azerbaijan	218,700	2641
Bahrain	92,675	352
Egypt	138,062	7631
Georgia	227,420	2505
Iran	1,225,142	55,223
Iraq	595,291	12,813
Israel	423,262	3325
Jordan	294,494	3834
Kazakhstan	201,196	2761
Kuwait	150,584	934
Kyrgyzstan	81,034	1355
Lebanon	181,503	1468
Oman	128,867	1499
Pakistan	482,178	10,176
Qatar	143,834	245
Saudi	362,741	6223
Syria	11,434	711
Tajikistan	13,296	90
Turkey	2,208,652	20,881
UAE	207,822	669
Uzbekistan	77,060	614
Total	7,676,182	140,964

ts (MOE, 2019), the GIS-based statistics of the population data gathered from Statistical Center of Iran via <https://www.amar.org.ir/english/Iran-Statistical-Yearbook> (SCI, 2018), and the transportation yearbook obtained from Iranian Road Maintenance and Transportation Organization via <http://rmto.ir/Pages/SalnameAmari.aspx> (RMTO, 2019). In this regard, ten variables were attained including land area (km²), total population (inhabitants), urban population (inhabitants), urban points (no.), urban density (no. per km²), fuel consumption (m³), energy use (kt), total intra-changed travels (travel), CO₂ emissions (kt), and NO₂ emissions (kt).

2.3 Data analysis

Based on the main objective of this research, regarding the correlative contribution of urban-associated factors to the COVID-19 confirmed cases, the geographical distribution of the total urban population in 2019 and total confirmed cases of COVID-19 on December 31, 2020, was represented as the sample spatial visualization of the variables for MECA countries and provincial divisions of Iran (Figs. 1 and 2). The correlation coefficients were used between the dependent and independent variables using the Pearson test in SPSS, exposing the possible direct effects. According to these correlation matrices, a hierarchical clustering analysis (HCA) was used to cluster the cases (23 countries or 31 provinces)

based on the variables. In this regard, the Euclidean distance measure for the variables and Ward's method for the linkage rule were used for the clustering procedure. A similar procedure has reported by Ghanbari and Daneshvar (2020). The clustering analysis was assumed based on all 10 independent variables in addition to one dependent variable (confirmed cases) in the scales of the MECA region and Iran.

3 Results and discussion

3.1 Analyses of the country level of the MECA region

3.1.1 Estimation of the variables

On December 31, 2020, the COVID-19 outbreak was recorded in 23 countries of the MECA region by a total of 7,676,172 confirmed cases and 140,964 total deaths (OWID, 2020). Iran with a total of 1,225,142 confirmed cases and 55,223 total deaths is the most injured country in the region, which has been affected seriously by pandemic status with 16% and 39% of total confirmed cases and mortality rates of the MECA countries. Based on the confirmed cases above 300 k, six countries of Turkey, Iran, Iraq, Pakistan, Israel, and Saudi Arabia reflected the overall confirmed cases of COVID-19 by 69% of the total region (Table 1). Meanwhile, based on the total deaths above 5 k, six countries of Iran, Turkey, Iraq, Pakistan, Egypt, and Saudi Arabia have represented approximately 80% of the total mortality rate of the study area.

Synchronizing, six countries of Turkey, Iran, Iraq, Pakistan, Israel, and Saudi Arabia have the highest total greenhouse gas (GHG) emissions with a total of 2586 Mt of CO₂ equivalents (60% of the study area). This fact has been reported for three countries of Iran, Turkey, and Saudi Arabia by Ghanbari and Daneshvar (2020), describing the contribution of mentioned countries to high-level total GHG emissions, CO₂ emissions, and energy use of the MECA region. According to Table 2, the overall contribution of six countries to the total urban population and total urban-based energy use of the MECA region is recorded as 264.5 million habitants (66% of the study area) and 734.2 Mt of oil equivalent (62% of the study area), respectively. Some other urban-associated indicators are presented in Table 2 like as urban population growth, the population in urban agglomerations, methane, and nitrous oxide emissions. For instance, the highest amount of the total urban population, methane, and nitrous oxide emissions belong to Pakistan, Turkey, and Iran by 45–50% of the study area. Therefore, the highest level of urban population growth and population in urban agglomerations belongs to some globalized high-income countries of Bahrain, Oman, Kuwait, and UAE.

3.1.2 Correlation coefficients

The possible relationships between the COVID-19 outbreak and influencing indicators are investigated in this section. On this basis, the Pearson test was applied to correlate dependent and independent variables in the country scale of MECA countries (Table 3). The results significantly (at the confidence level of 99%) confirmed the comparatively strong relationships, with the positive and direct associations, between some independent variables (i.e., total greenhouse gas emissions, CO₂ emissions, nitrous oxide emissions, and urban population) and confirmed cases (R from 0.619 to 0.695). The wind-rose diagram

Table 2 Independent variables based on the annual world development indicators for the MECA countries

Country name	Land area	Total population	Urban population	Urban population growth	Population in urban agglomerations	CO ₂ emissions	Methane emissions	Nitrous oxide emissions	Total greenhouse gas emissions	Energy use
Afghanistan	652,860	38,928,341	9,477,100	3.32	11	8672	13,763	3424	40,429	4500
Armenia	28,470	2,963,234	1,864,017	0.31	37	5156	3426	1023	11,817	2959
Azerbaijan	82,670	10,139,175	5,534,464	1.47	23	37,620	19,955	2673	54,830	14,322
Bahrain	778	1,701,583	1,401,305	4.59	0	31,694	3379	131	35,085	14,158
Egypt	995,450	102,334,403	42,030,812	2.04	26	238,560	51,977	25,110	283,632	74,826
Georgia	69,490	3,989,175	2,184,950	0.53	29	10,128	5019	2352	20,418	4390
Iran	1,628,760	83,992,953	61,266,765	2.01	26	661,710	121,298	25,191	790,647	237,075
Iraq	434,128	40,222,503	27,085,311	2.54	25	190,061	24,351	5007	221,790	49,481
Israel	21,640	8,655,541	8,209,306	1.99	58	65,166	3416	1751	74,273	22,696
Jordan	88,780	10,203,140	9,057,879	1.70	21	25,108	2115	605	29,548	8180
Kazakhstan	2,699,700	18,776,707	10,495,828	1.49	16	247,207	71,350	17,822	391,007	76,667
Kuwait	17,820	4,270,563	4,137,312	1.67	73	98,734	12,691	704	108,563	33,879
Kyrgyzstan	191,800	6,524,191	2,298,401	2.76	0	9787	4291	1567	17,999	3795
Lebanon	10,230	6,825,442	6,067,668	0.29	35	24,796	1150	462	27,155	7494
Oman	309,500	5,106,622	4,082,797	4.03	30	63,457	16,858	1146	84,602	24,327
Pakistan	770,880	220,892,331	77,810,763	2.68	20	201,150	158,337	30,651	368,460	89,887
Qatar	11,610	2,881,060	2,757,615	1.85	0	103,259	41,124	339	130,969	44,076
Saudi	2,149,690	34,813,867	28,255,384	1.94	48	563,449	62,903	6517	631,428	213,505
Syria	183,630	17,500,657	9,156,781	2.17	32	28,830	12,783	6001	39,458	10,802
Tajikistan	138,790	9,537,642	2,469,421	3.03	0	5310	5408	1848	26,443	2805
Turkey	769,630	84,339,067	61,857,510	1.99	37	372,725	78,853	35,612	499,268	121,541
UAE	71,020	9,890,400	8,332,898	1.75	61	206,324	26,120	2413	252,656	70,474
Uzbekistan	425,400	33,469,199	16,635,580	1.79	7	91,811	47,333	13,192	153,272	43,660
Total	11,752,726	757,957,796	402,469,867	47.92	614	3,290,714	787,898	185,541	4,293,749	1,175,499

Table 3 The correlations between independent variables and total confirmed cases of COVID-19 among the MECA countries

Indicators	Test	Total confirmed cases
Land area	R	0.268
	Sig	0.216
Total population	R	0.409
	Sig	0.053
Urban population	R	0.695
	Sig	0.000
Urban population growth	R	−0.068
	Sig	0.758
Population in urban agglomerations	R	0.193
	Sig	0.378
CO ₂ emissions	R	0.619
	Sig	0.002
Methane emissions	R	0.511
	Sig	0.013
Nitrous oxide emissions	R	0.684
	Sig	0.000
Total greenhouse gas emissions	R	0.642
	Sig	0.001
Energy use	R	0.580
	Sig	0.004

No. of country cases: 23

for the aforementioned relationships between confirmed cases of COVID-19 and ten independent variables in the MECA countries is plotted in Fig. 3, revealing the possible role of total GHG, CO₂, and nitrous oxide emissions from urban areas in the illness outbreak.

Hence, at the country level of the MECA region, the COVID-19 outbreak could be dependent on urbanization and its induced GHG emissions. Therefore, the moderate relationships, with the positive and direct associations, were estimated between some other independent variables (i.e., energy use, methane emissions, and total population) and confirmed cases (R from 0.409 to 0.580). This fact perhaps describes the direct effect of the unsustainable urbanization processes (i.e., high demand for energy and high emission of air pollutions) on the COVID-19 outbreak. Contrarily, the meaningless relationships were observed between confirmed cases and three independent variables (i.e., land area, the population in urban agglomerations, and urban population growth). Meanwhile, due to the natural dependence between total confirmed cases and total deaths caused by COVID-19, which was obtained as a correlation coefficient of 0.705 at the confidence level of 99% in Table 4, the main dependent variable is assumed as total confirmed cases in the next sections of the research.

3.1.3 Clustering analysis

Based on the hierarchical clustering analysis (HCA), the MECA countries were clustered as a dendrogram plot (Fig. 4). On this basis, 23 countries were classified based on one

Fig. 3 A wind-rose diagram for the relationships between total confirmed cases of COVID-19 and ten independent variables in the MECA countries

Table 4 The correlations between total deaths and total confirmed cases of COVID-19 among the MECA countries

Indicators	Test	Total confirmed cases
Total deaths	R	0.705
	Sig	0.000
	N	23

dependent and ten independent variables in three clusters from A to C. In the first cluster, four countries of Iran, Turkey, Egypt, and Pakistan revealed a group with a high concentration of urbanization and confirmed cases of COVID-19 in the MECA region, which are susceptible areas for infection spread affected by respiratory disease. The main characteristic of these countries depends on their large amount of urban population share from the total urban population of the study region (above than 60%). In adding up, the share of the total population in these countries is higher than 65% of the total population in 23 countries. Hence, the HCA result indicates the substantial role of the total population and urban population in clustering countries regarding the COVID-19 outbreak.

3.2 Analyses of the province level of Iran

3.2.1 Estimation of the variables

Based on the latest official report of confirmed cases in Iran, the total confirmed cases and deaths caused by the COVID-19 have been reported as 1225.1 k and 55.2 k, respectively. Among 31 provincial divisions in Iran, the highest confirmed cases above

Fig. 4 Clustering dendrogram of the MECA countries based on the inter-group relations between urbanism and the COVID-19 infections

50 k belong to seven provinces of Tehran, Khuzestan, Khorasan-Razavi, Esfahan, Gilan, Qom, and Mazandaran with overall confirmed cases of COVID-19 as 65% of the country (Table 5).

These seven provinces have the most provincial contribution to the total population and urban population settlements with nearby 46% (36.6 million inhabitants) and 51% (29.9 million inhabitants), respectively (Table 6). Indeed, these provinces are involved in the highest values of national CO₂ emissions with 252 Mt of CO₂ equivalents (49% of national emissions), the highest values of national fuel consumption with 12.9 M m³ (50% of national consumptions), and the highest values of total intra-changed travels with 64,949 travels (44% of national travels).

Other urban-associated indicators are presented in Table 6 like energy use, NO₂ emissions, urban point numbers, and urban density. For example, the highest amount of NO₂ emissions belongs to the aforementioned seven provinces by 60% of the total national emissions. Gilan province has the highest value of urban density with 0.39 no. per km². Tehran and Bushehr provinces have the highest amount of national energy use by 25% of the national level (27.7 Mt). Furthermore, the large value of urban point numbers belongs to Esfahan province with 109 urban points.

Table 5 Dependent variable based on the COVID-19 dataset for the provincial divisions of Iran (up to December 31, 2020)

Province name	COVID-19 total confirmed cases
Alborz	27,000
Ardabil	10,000
Azarbaijan-G	31,000
Azarbaijan-S	37,000
Bushehr	45,000
Chaharmahal-B	3000
Esfahan	73,000
Fars	42,000
Gilan	68,000
Golestan	23,000
Hamedan	16,000
Hormozgan	13,000
Ilam	7000
Kerman	12,000
Kermanshah	21,000
Khorasan-J	2000
Khorasan-R	111,000
Khorasna-S	19,000
Khuzestan	115,000
Kohgiluyeh-B	3000
Kordestan	18,000
Lorestan	42,000
Markazi	9000
Mazandaran	58,000
Qazvin	4000
Qom	59,000
Semnan	11,000
Sistan-B	22,000
Tehran	311,000
Yazd	5000
Zanjan	8000
Total	1,225,000

3.2.2 Correlation coefficients

Based on Table 7, the correlations were estimated between independent variables and total confirmed cases of the COVID-19 among the provinces of Iran. The results significantly (at the confidence level of 99%) confirmed the very strong and strong relationships, with the positive and direct associations, between some independent variables (i.e., total population, urban population, fuel consumption, NO₂ and CO₂ emissions, energy use, and total intra-changed travels) and confirmed cases (R from 0.724 to 0.945). Based on a wind-rose diagram for the relationships between confirmed cases of COVID-19 and ten independent variables in Iran, a strong relationship was observed between confirmed cases and the urban

Table 6 Independent variables based on the annual national development indicators for the provincial divisions of Iran

Country name	Land area	Total population	Urban population	Urban points	Urban density	Fuel consumption	Energy use	Total intra-changed travels	CO ₂ emissions	NO ₂ emissions
Alborz	5833	2,712,400	2,512,737	18	0.31	957,616	2984	6600	16,274	930
Ardabil	17,800	1,270,420	866,034	28	0.16	299,894	1365	1969	3811	82
Azartabaijan-G	37,411	3,265,219	2,136,203	44	0.12	766,254	3420	5444	13,061	201
Azartabaijan-S	45,651	3,909,652	2,809,424	65	0.14	949,688	5717	5118	23,458	480
Bushehr	23,198	1,163,400	835,955	39	0.17	489,101	12,227	2914	25,595	618
Chaharmahal-B	16,328	947,763	607,444	41	0.25	247,317	1049	4389	3791	122
Esfahan	107,018	5,120,850	4,507,309	109	0.10	1,894,061	10,779	11,917	51,209	918
Fars	122,608	4,851,274	3,401,675	104	0.08	1,716,506	4868	10,409	29,108	346
Gilan	14,042	2,530,696	1,603,026	55	0.39	941,259	2911	4576	20,246	1005
Golestan	20,117	1,868,619	995,615	32	0.16	396,143	1742	3309	5606	95
Hamedan	20,173	1,758,268	1,097,217	31	0.15	445,700	2250	4016	12,308	236
Hormozgan	70,697	1,776,415	971,822	40	0.06	730,721	1131	1626	21,317	132
Ilam	20,103	580,158	395,263	26	0.13	165,751	502	2578	1740	31
Kerman	183,285	3,164,718	1,858,587	74	0.04	1,125,013	2263	6421	18,988	90
Kermanshah	24,998	1,952,434	1,468,615	34	0.14	446,740	2480	3658	9762	200
Khorasan-J	151,193	768,898	453,827	30	0.02	239,825	490	1881	2307	5
Khorasan-R	118,018	6,434,501	4,700,924	78	0.07	1,772,099	6792	19,408	38,607	373
Khorasna-S	28,434	863,092	484,346	24	0.08	179,756	1466	2275	3452	33
Khuzestan	64,055	4,710,509	3,554,205	82	0.13	1,321,217	12,049	5466	37,684	728
Kohgiluyeh-B	15,504	713,052	397,461	18	0.12	183,795	456	1017	1426	18
Kordestan	29,137	1,603,011	1,134,229	31	0.11	392,162	1775	3220	8015	121
Lorestan	28,294	1,760,649	1,134,908	28	0.10	389,055	1326	2390	5282	67
Markazi	29,127	1,429,475	1,099,764	36	0.12	460,409	2859	2077	17,154	326
Mazandaran	23,756	3,283,582	1,897,238	61	0.26	1,387,065	4472	5166	26,269	779
Qazvin	15,567	1,273,761	952,149	27	0.17	447,494	2125	2793	15,285	396

Table 6 (continued)

Country name	Land area	Total population	Urban population	Urban points	Urban density	Fuel consumption	Energy use	Total intra-changed travels	CO ₂ emissions	NO ₂ emissions
Qom	11,240	1,292,283	1,229,964	8	0.07	455,286	1363	1957	11,631	158
Sennan	97,491	702,360	560,502	21	0.02	281,242	1276	1618	3512	12
Sistan-B	180,726	2,775,014	1,345,642	39	0.02	878,952	10	5104	5550	12
Tehran	18,814	13,267,637	12,452,230	48	0.26	5,165,078	15,455	16,459	66,338	3177
Yazd	73,477	1,138,533	971,355	23	0.03	483,400	3086	1505	10,247	55
Zanjan	19,164	1,057,461	711,177	23	0.12	307,396	1478	1294	4230	68
Total	1,633,259	79,946,104	59,146,847	1317	–	25,915,995	112,166	148,574	513,262	11,815

Table 7 The correlations between independent variables and total confirmed cases of COVID-19 among the provinces of Iran

Indicators	Test	Total confirmed cases
Land area	R	−0.055
	Sig	0.771
Total population	R	0.925
	Sig	0.000
Urban population	R	0.945
	Sig	0.000
Urban points	R	0.346
	Sig	0.056
Urban density	R	0.305
	Sig	0.096
CO ₂ emissions	R	0.830
	Sig	0.000
NO ₂ emissions	R	0.905
	Sig	0.000
Fuel consumption	R	0.928
	Sig	0.000
Total intra-changed travels	R	0.724
	Sig	0.000
Energy use	R	0.787
	Sig	0.000

No. of province cases: 31

population (Fig. 5). Hence, in the province level of Iran, the COVID-19 outbreak certainly depends on urbanization and its population abundance. Therefore, there are weak relationships, with the positive and direct associations, between some other independent variables (i.e., urban density and urban point numbers) and total confirmed cases (R from 0.305 to 0.346). Contrarily, a meaningless relationship was observed between confirmed cases and land area. Hence, the COVID-19 outbreak in Iran has no sufficient significant correlation with physical indicators such as land area, urban density, and urban point numbers.

3.2.3 Clustering analysis

The provinces in Iran were clustered as a dendrogram plot using HCA (Fig. 6). On this basis, 31 provinces were classified based on one dependent and ten independent variables in three clusters from A to C. The first cluster, including only Tehran province, revealed a great populated and urbanized region of Iran with the most confirmed cases of COVID-19 on the national scale. Tehran has the highest rate of air pollutions, inversions, CO₂, and total GHG emissions in Iran (e.g., Daneshvar & Abadi, 2017; Khalesi & Daneshvar, 2020) so that is very susceptible to the spread of any pandemic status with health issues.

Meanwhile, 11 and 19 provinces in clusters B and C were clustered, respectively. Later then, Tehran, Khorasan-Razavi, Khuzestan, and Esfahan provinces have the highest confirmed cases of COVID-19 and the large amounts of urban population fuel consumptions, and NO₂–CO₂ emissions. In summarizing, the HCA in the province level of Iran revealed

Fig. 5 A wind-rose diagram for the relationships between total confirmed cases of COVID-19 and ten independent variables in the Iran provinces

the substantial role of the urban populations and urban-associated pollutant gas emissions in clustering provinces regarding the COVID-19 outbreak.

4 Discussion

The MECA region has contributed to ~9% of the total population in the World in 2019 (World Bank, 2020). At the end of December 31, 2020, this region has also contributed to ~9% of the total confirmed cases of COVID-19 (OWID, 2020). Some recent investigations regarding (MECA) countries have demonstrated the greenhouse gas (GHG) emissions from urban origins above 80% (Ghanbari & Daneshvar, 2020; Tavakoli et al., 2016). Accordingly, the International Energy Agency has reported that about 90% of the urban-based CO₂ emissions can belong to developing countries (IEA, 2018) such as MECA countries. Hence, the MECA region is an attractive place to study pandemic status. Among this region, Iran has contributed to ~10% of the total population and ~16% of confirmed cases of COVID-19, exposing a risky condition in comparison with other countries.

The present paper attempted to discover the influencing factors on the illness outbreak based on the statistical analysis on different levels. In the first level, results exposed that six countries of Turkey, Iran, Iraq, Pakistan, Israel, and Saudi Arabia, contributing to the urban population by 66%, greenhouse gas (GHG) emissions by 60%, and urban-based energy use of the MECA region by 62%, have earmarked 69% (5,297,266 cases) of overall confirmed cases of COVID-19 in the study area. Accordingly, statistical examination revealed the comparatively strong positive and direct relationships between total confirmed cases

Fig. 6 Clustering dendrogram of the provincial divisions of Iran based on the inter-group relations between urbanism and the COVID-19 infections

and some independent variables such as total greenhouse gas emissions, CO₂ emissions, nitrous oxide emissions, and urban population (R from 0.619 to 0.695). Hence, at the country level of the MECA region, the COVID-19 outbreak could be dependent on urbanization and its induced GHG, CO, and NO₂ emissions. This finding is adopted with other researches, such as Bilal et al. (2020), Yongjian et al. (2020), Travaglio et al. (2020), and Conticini et al. (2020), indicating a significant relationship between urban-based GHG and NO₂ emissions and the outbreak of COVID-19. The possible reason relates to the highest NO₂ concentrations combined with downwards airflow, which prevent efficient dispersion of air pollutions and increase illness outbreaks (Ogen, 2020). The mentioned pollutant gas concentrations, which are caused by economic growth, could foster COVID-19 by making the respiratory system more susceptible to infection (Mele & Magazzino, 2021).

Furthermore, the relationship between urbanization and GHG emissions, influencing the citizens' health, has been revealed in the other work (see Carozzi & Roth, 2020). Meanwhile, we found that urban density has no appropriate relationship with the COVID-19 outbreak in the country level of the MECA region. It seems that urban density can be considered as an effective factor in the commencement of the pandemic status not during the outbreak. Carozzi et al. (2020) describe a similar fact, demonstrating that the densely urban points get the head start on the spread of the first peak of the pandemic in the USA but in

the period of pandemic status, the sprawled and low-dense pre-urban areas can be categorized as prone areas.

In the next step, a similar indication was also examined at the provincial level of the study in Iran. In this regard, seven provinces of Tehran, Khuzestan, Khorasan-Razavi, Esfahan, Gilan, Qom, and Mazandaran with overall confirmed cases of 65% revealed the most contribution to the urban population (51%), national CO₂ emissions (49%), national fuel consumption (50%), and total intra-changed travels (44%). Based on the very strong and strong relationships between confirmed cases and some independent variables such as total population, urban population, fuel consumption, NO₂–CO₂ emissions, energy use, and total intra-changed travels (R from 724 to 0.945), the COVID-19 outbreak certainly depends on the urbanization and its population abundance. The previous works have noted that the provinces of Tehran, Khorasan-Razavi, and Esfahan are more susceptible to the COVID-19 outbreak due to the high metropolitan areas, population, and intra-changed travels (Ahmadi et al., 2020). In the metropolitan areas, GHG emissions and air pollution are recorded as high concentrations measures where the physical health of the population is directly threatened (Magazzino et al., 2020). Hence, the pandemic status of COVID-19 in Iran, during the year 2020, definitely depended on the provinces and territories including the high level of urban population rates and their related fuel consumption, energy use, and NO₂–CO₂ emissions. Ultimately, we can approve the research hypothesis in the study areas, with the strongest evidence in Iran, demonstrating that the urbanization and its related population and processes (e.g., GHG, CO₂, and NO₂ emissions) have a positive association with the pandemic status of COVID-19 outbreak.

5 Conclusion

Among the MECA countries, the first suspected and confirmed cases of COVID-19 infection were observed in United Arab Emirates (UAE) on January 27, 2020, and accordingly, the Iranian health organization has announced the first cases on February 19, 2020 (Behzadifar et al., 2020). Afterward, the WHO officially reported the COVID-19 outbreak as a pandemic status on March 12, 2020 (Mikhael & Al-Jumaili, 2020). Now at the end of December 31, 2020, the COVID-19 is confirmed in 218 countries and territories with a total of 83.42 million confirmed cases and 1,818,116 total deaths (OWID, 2020). Hence, it seems that the world is still fighting COVID-19 and more studies in different regions should be carried out to recognize the complexity of the pandemic status and its influencing factors. In this regard, The main objective of the present research was to disclose the correlative contribution of urban-associated factors (independent variables such as urban population) affecting the COVID-19 confirmed cases (dependent variable) in the country level of the MECA region and downscaling the research in the provincial level in Iran.

Based on the results, the COVID-19 outbreak can be dependent on the urbanization and its induced fuel consumption or energy use, GHG, CO₂, and NO₂ emissions in the MECA region and Iran. Contrarily, results revealed that the COVID-19 outbreak could not relate to the physical indicators such as land area, urban density, and urban point numbers. Accordingly, further researches should divide two categories of physical and functional indicators due to their diverse effects on the COVID-19 status. This practical recommendation can decrease the paradoxical findings regarding relationships between urbanization and illness outbreaks. Besides, the HCA results revealed the substantial role of the urban populations

and urban-associated gas emissions in clustering locations regarding the COVID-19 outbreak.

The high level of the urban population in the megacities is a main vulnerable condition regarding a pandemic, which indicates for urban planners, designers, policymakers, and administrators to reconsider their sustainability quotient on denser or compact cities (Desai, 2020). Furthermore, influenced by the COVID-19 outbreak, the lockdown and quarantining of many urban areas are influencing globalized urban lifestyles at various scales (Salama, 2020). Hence, the main contribution of this research is to give a useful correlation between Coronavirus infection and urban constitution, aiming to increase the health of urban societies by creating effective planning in the future.

The implication of the results can be considered for both practical and academic applications. The practical implication is to identify the urbanization role in the COVID-19 status within the MECA countries and Iran, which is applicable for health policymakers, urban managers, and environmental planners. Besides, the academic implication is to associate the theoretical backgrounds to conduce the researchers to define unique concepts, subjects, and study areas. Eventually, the limitations of this research relate to the inadequacy of data mining for independent indicators, countries, and time-interval curbs. More indicators and countries should be considered in further researches to overcome these limitations by assuming the co-registered time intervals such as daily or monthly scales.

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Declarations

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