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Detecting vacant urban spaces for infill development using UAV for sustainable development (A case study of Ahvaz metropolis, Iran)

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ABSTRACT:The vacant and abandoned land can be an important source for the endogenous urban development. Ahvaz is one of the largest cities in the southern part of Iran which experienced rapid physical expansion and now the city extract resources from peripheral areas to provide services to its citizens. Detecting appropriate land for new development is crucial for urban authorities. This research aimed to identify vacant urban land in Ahvaz using UAV images. Two criteria of "Urban Morphology" and "Distribution Pattern" have been the basis for extracting urban vacant lands. The results showed the largest area of vacant land belongs to the cover of "barren with vegetation" and in terms of the distribution pattern of vacant land, the largest and smallest vacant land parcels are related to zones 2 and 1 of Ahvaz city.

Keywords: UAV, vacant urban land, infill development, Ahvaz city

I. INTRODUCTION

The intense concentration of the population in cities of metropolises of the developing countries, has caused horizontal growth of cities. According to the statistical data of the World Bank, between 1960 and 2018, the number of cities with more than one million people increased from 14.14% to 24.01% (World Bank, 2021); While at the same time, the global increase in urbanization was equal to 21.66 percent. The share of the population in the largest cities has decreased from 17.58% to 16.11% (IBRD-IDA, 2019). This divergence is particularly prominent in developed countries in Europe and the United States. These show the sprawl development in almost 60 years; consequently, this global problem has caused the destruction of the environment and pressure on the natural ecosystem of the earth in the outskirts of the cities, and made the provision of services to city dwellers difficult (Hamidi et al., 2022). One of the approaches to balanced and logical development of the city is infill development. (Arvin and Pourahmad, 2022: 193). In this approach, instead of outward growth, vacant lands within cities are used such as barren, wasteland, brownfields, etc. (Khazaei, 2022: 69).

The city, with all its complexity and interwoven components, in its totality includes two main components "mass" and "space"and endogenous development can happen in masses or urban spaces. Apart from the things that can be suggested for this model of urban development, the important point is to identify and recognize these areas in different parts of the city. Conventional and traditional identification methods are often time-consuming and costly. Therefore, it is very important using a method that can identify areas with high accuracy and speed, as well as at a lower cost, that can be used for infill development (Peter et al., 2020: 2205).

Unmanned aerial vehicles can play a role in supporting sustainable development, including in the context of infill development. UAV can also be used to support infill development in a number of ways such as surveying and mapping, Environmental monitoring, and existing infrastructure, etc. This information guides the planning and design of new developments in a more efficient and sustainable manner. UAV is used to monitor and assess the environmental impacts of infill development. This information is important to identify potential areas of concern and inform the development of mitigation strategies.

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Overall, the use of UAVs in infill development and sustainable development more broadly can help to address some of the challenges associated with urbanization and promote more efficient and sustainable development practices.

Vacant lots not only make the city look unpleasant, but also usually become a place of accumulation of construction debris and household waste (Stewart et al., 2019: 203). The accumulation of construction debris, which in turn leads to the waste piling up of garbage, threatens residents' health and obnoxious urban landscape and vacant urban land is a significant barrier to sustainable neighborhood development(Chen & Conroy, 2023). Therefore, empty urban lands and brownfields are the prime option for redevelopment. Now it is very important for urban planners and decision makers to identify and generally obtain locational information from vacant land (Song et al., 2020: 672). However, accurate mapping of vacant lands has its implications due to the morphology of urban spaces as it includes various features such as abandoned structures, bare land, vegetation or a combination of them. Such diversity usually challenges their identification (Zhou and Ehlers, 2022: 2). Even when using high-resolution remote sensing images, this goal is difficult to achieve. In general, and from the aspect of typology, vacant urban land can be placed in four broad categories (Figure 1).

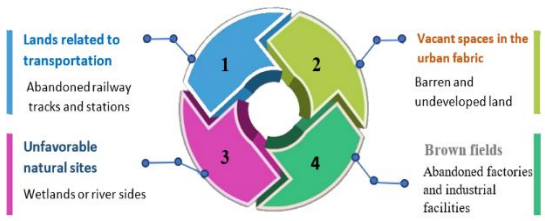

Figure 1. Typology of urban vacant land (adopted from Newman et al., 2018)

Transportation-associated land: land and spaces related to transportation systems, including railways, highways and other roads. Natural sites: located within built-up areas, these sites have not been used due to their physical/environmental constraints. They include drainage areas, wetlands, hillsides, steep slopes, riverbanks and river.Unattended areas and reserve parcels: these sites are empty and inactive and look like leftover spaces within the urban fabric. They very often feature vegetation but are not parks or gardens. Some of these sites are already earmarked for future expansion/development.Brownfield sites: land or premises previously used and currently underused. Reusing such a site may be complicated by having to deal with existing structures or contamination. Typically, there are derelict buildings or structures on site. Previous uses include industry, mining, military activities, agriculture or commerce (Xu & Ehlers, 2022: 3).
Examining the physical development of Ahvaz city shows that during the past decades 58% of the physical development of the city was based on demographic changes and 42% was due to horizontal growth, also Ahvaz highest rates of population growth among large cities in the country. The industrial nature of the city has attracted migrants in different parts of the province and from cultural point of view, some of the citizens still have a higher birth rate than the national level, and for this reason, the population growth will continue in the medium-term future (Shahid Chamran University of Ahvaz: 2018). Therefore, to accommodate this population, new lands are needed for residential purposes.Vacant lands in the inner parts of the city can be one of the important opportunities to place new development. the current research aimed to apply a method to identify parts of the vacant urban spaces of the city using data obtained from UAV photogrammetry and with the ability to be used in the infill development of Ahvaz.

I. Theoretical Foundations

This section starts by presenting a brief overview of the different definitions of vacant land and measuring the morphology and distribution pattern of vacant urban lands.

The term of vacant land is broad and diverse, but it is usually defined as under-utilized lands including bare soil, derelict land, abandon buildings and structures, brownfields, green fields, uncultivated land or marginal agricultural land and recently razed land. In general, there are two representative views on the meaning of urban vacant land (UVL) to date. The first, presented by the American Planning Association, is that UVL refers to land not used for any purpose or without any buildings or other physical structures (Davidson and Dolnick, 2004). According to the second view, UVL refers to unused or abandoned land, including land that is currently unused and without any buildings, and land with buildings that have been abandoned or deserted (Németh and Langhorst, 2014; Kim et al., 2015; Kim et al., 2018). Moreover, the Chinese government established the concepts of "vacant land" and "idle land" in land management practice. The National

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Standard of Current Land Use Classification in China defines vacant land as a land use type referring to the unused land within an urban, village, or industrial and mining area (SAPRC, 2017).According to the Measures for the Disposal of Idle Land released in 2012, idle land is state-owned land that has been supplied for construction but has not reached the prescribed development intensity (MLRPRC, 2012).In the concepts compared above, vacant land is a positive term with no uniform definition, while idle land is a normative one that reveals policy intervention in land use. Here, a definition of UVL is presented from a positivism perspective.

From a positivist point of view, urban vacant land is unused urban land within a developed urban area, urban planning area, or urban administrative district (Song et al, 2020: 672). From this perspective, note that an unused status with no current human activity is the key criterion for designating land as vacant land. The vacant land is not limited to land that has not been developed and constructed upon, but also includes abandoned or deserted land that has been developed with buildings, structures, ancillary facilities. (Kim et al., 2016).However, protective land and green infrastructure, such as parks and green spaces that are developed for recreation or landscape are excluded from vacant land (Anderson and Minor, 2019: 1274).Wild green spaces with no artificial management, such as wild grassland along roads or rivers within urban areas, fall within the definition of urban vacant land.

To identify the vacant lands of the study area in different evaluated classes, two macro indicators "morphology" and "distribution pattern" of vacant lands have been used.

II. Data and Research Method:

The data obtained from aerial photography of May 2019, unmanned aerial vehicle (UAV) by Shahid Chamran University, as well as secondary documents. In order to prepare and produce a map of vacant spaces of the city with the ability to be Auvl=S/(N) (1)

Siuvl=(0.25×P)/√S (2)

Where A is the average area of empty blocks; S, the area of an empty block; N, number of empty blocks; Si is the shape index of empty blocks and P is the diameter of empty blocks.

used for the infill development, the images taken by the drone were standardized using Agisoft PhotoScan and then converted into a map in ArcGIS. The following steps were taken to prepare the imagesfrom the drone:

First identification, flight design, ground control points and marking were designed. In the second step Ground mapping operations included creating a ground navigation station, determine the location of the main stations and control points. In the third stage flight operations were carried by out pre- and post-flight controls, unmanned bird navigation and receiving collected data.

And finally, data processed aerial triangulation, point cloud filtering, ortho-photomosaic production, control geometric correctness and output conversion comprised drawing and cartography and creating a spatial database (Majdizadeh et al., 2022).

To achieve the research goals, it was realized by extracting the indicators of urban vacant spaces such as the morphology and distribution pattern of these spaces. In order to perform the required analysis, first the location of vacant lands of Ahvaz were identified using images and then the suitable locations for infill development were classified into 6 groups, their number and area assigned. In the following, by using the index of the shape of the vacant plots and the Kernel function, the density and distribution of the mentioned spaces were examined and their map was produced.

Measuring the morphology of vacant urban land:

As the typology indicates, the morphology of vacant land on images varies between man-made structures, bare soil, vegetation, or a mix (Xu & Ehlers, 2022). The morphology of the mentioned sections is a function of criteria such as the area of vacant plots, their average area, the number of empty blocks and finally the shape index of empty blocks in the city, which are obtained from equations (1) and (2):

Assessment of the distribution pattern of vacant urban land:

The second indicator for identifying vacant urban lots is the distribution pattern of these lots. In order to determine the pattern of distribution of land and vacant plots, first, shares of parcel and area of UVL were used to measure the UVL occurrence probability: (3) and (4):

$R_p=N_{uvL}/N_{Lu}$(3)

$R_a=S_{uvL}/S_{Lu}$ (4)

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where Rp is the proportion of UVL parcel number to total land parcel number; Nuvl is the number of UVL parcels; Nlu is the total number of whole land parcels; Ra is the proportion of UVL area to total land area; Suvl is the area of UVL; and Slu is the total land area.

Kernel density estimation, a nonparametric method that reflects the degree of spatial aggregation of observed variables by using two-dimensional smooth estimation surfaces (Xu and Gao, 2016; Liu et al., 2017), was then used to estimate UVL density

I. The study area

Ahvaz city as the centre of Khuzestan province with a population of 1,262,581 people (Deputy of Planning of Ahvaz Municipality, 2022), is the seventh most populous city of Iran (Sajjadian and Daman Bagh, 2022: 151), which is located in the southern part of the country (Figure 2).

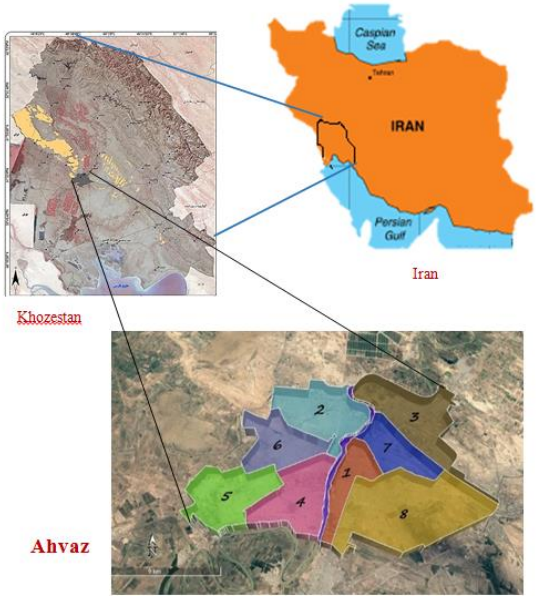

Figure 2. Location of Ahvaz and its eight zones

Ahvaz is considered one of the most extensive cities in Iran. In recent decades, this city has experienced extensive growth in terms of population and the size of the city due to socio-economic developments. Ahvaz metropolis included eight urban zones which is administered by 8 municipalities (Table 1). In 1976, the area of Ahvaz was nearly 3700 hectares, after a decade the size of the city reached 6900 hectares. In 1991, the size of the city was estimated at 10615 hectares by the master plan of the city (Bahadori, 2019: 14).

Table 1. General characteristics of the eight zones of Ahvaz City

Zones	Area (ha)	Percentage of Total Area	population (2022)	Percentage of the total population	Population density (per ha)
1	1106.6	6	148583	12	135
2	2113.08	16	114317	9	39
3	1318.36	18	187735	15	59
4	2527.09	12	163380	13	65
5	2154.74	10	112402	9	52
6	2110.53	11	175951	14	83
7	1718.71	10	155819	12	91
8	3098.11	17	204394	16	66
Total	18806.4	100	1262581	100	67

Source: Statistics Department of Ahvaz Municipality Planning Deputy, 2022

In 1986, with the change of the scope of the master plan, the size of the city changed to 20615 hectares, and the size of the city between 1996 and 2011 was 21257 and 21266 hectares, respectively. Finally, in 2012, due to the separation of zone 5 from Ahvaz and its joining to the new city of Kut Abdollah, the size of the city decreased to 18,709.87 hectares (Arvin and Zanganeh, 2020: 78).

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III. RESULTS:

Typology of vacant land in Ahvaz city

Vacant urban lands of Ahvaz can be classified into different types according to land cover, land use, and land ownership. Based on land cover,vacant land of Ahvaz divided into 6 categories such as barren with vegetation, wet land around Karun, barren without cover, barren with shrubs, vegetation in combination with buildings and vegetation (Fig. 3).

Figure 3. Vacant lands of Ahvaz city based on coverage: 1) barren with vegetation; 2) Wet lands around Karun; 3) Barren; 4) Barren with shrubs; 5) Vegetation in combination with buildings; 6) Vegetation. (Source: Research results)

Based on land use, urban non-passage spaces can be classified into two categories 1) empty residential land and 2) empty industrial land. According to the type of ownership, lands are included Private, Public, endowment, Cooperative and Mixed ownership.

Morphology of vacant land in Ahvaz

After preparing the images and applying equations (1) and (2), it was found that the amount of vacant land in Ahvaz city based on land cover is equal to 372 plots with an area of 701.7 hectares (Figure 4). As shown in Table 2, the largest number of vacant lands was obtained from the category "barren without cover" with 106 plots, while the largest area of vacant land with 256.9 hectares belonged to "barren with vegetation". Also, the lowest amount with 28 empty plots and 65.2 hectares belongs to the class "barren with shrubs". In general, barren lands (including: barren with vegetation, barren with shrubs, and barren without cover) with a total of 446.2 hectares, occupy the majority of Ahvaz's vacant land in terms of coverage. The ratio of the number of empty plots of land to the total city plots (urban mass) is only less than 3%, while the ratio of the area of empty plots to the total area of the city is more than twice the ratio of the number and about 7.5 percentage (Table2).

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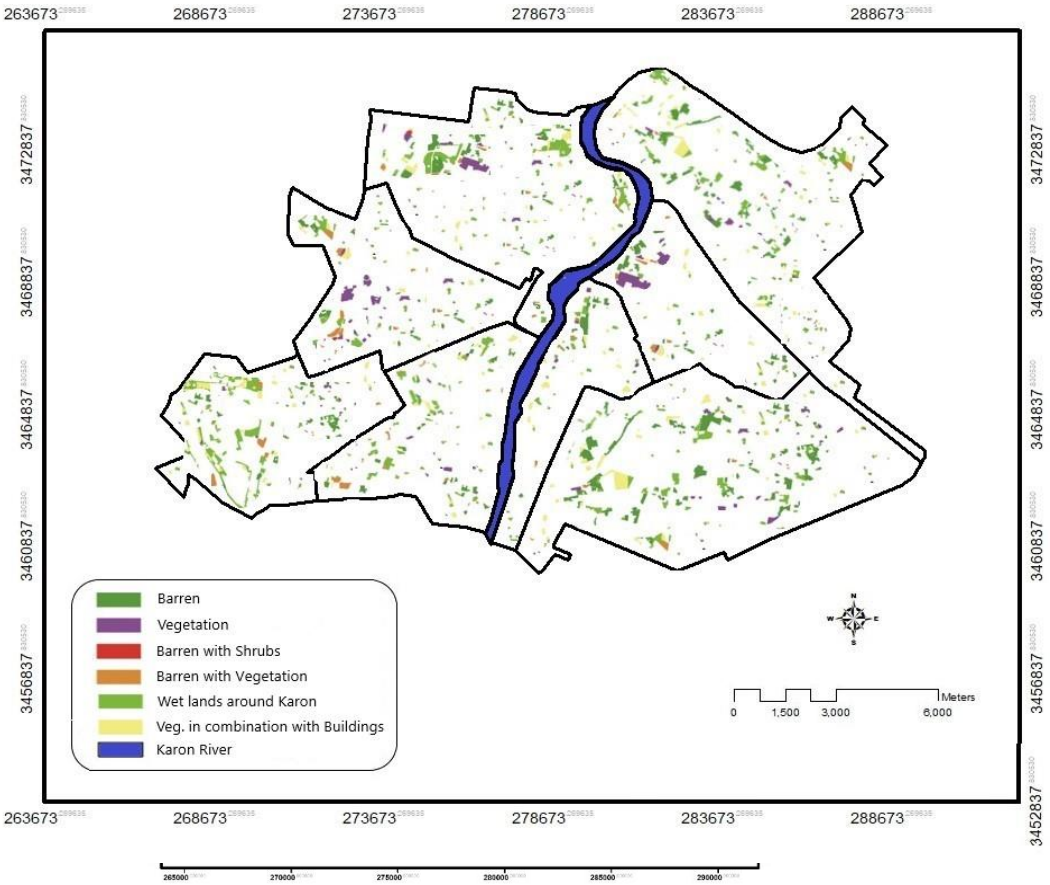

Figure 4. Vacant land in Ahvaz based on land cover
(Source: Research results)

Table 2. types of empty land in Ahvaz city based on land cover

Type of Lands	Number of parts	Area of parts (ha)	Average area of vacant block (ha)	Probability of Occurrence(%)	
				Ratio of the number of empty plots to total number of plots	Ratio of the area of empty plots to the total area
Barren with vegetation	88	259.6	2.95	0.76	2.76
Wet lands around Karun	48	79.3	1.65	0.36	0.84
Barren without vegetation	106	131.4	1.23	0.79	1.39
Barren with shrubs	28	65.2	2.32	0.21	0.69
Vegetation in combination with buildings	35	68.9	1.97	0.26	0.73
Vegetation	67	97.3	1.45	0.5	1.03
Total	372	701.7	1.89	2.79	7.45

(source: research findings)

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Distribution pattern of vacant land in Ahvaz city

The distribution of the classified lands and the area of its eight zones were analyzed in order to evaluate more closely and examine the distribution pattern of vacant urban land in Ahvaz, (Table 3).As shown in Table 3, the most and least vacant plots in Ahvaz, with 123 and 12, respectively, belonged to zones 2 and 1. Considering the fact that Zone 1 is located in the central area of the city, the small number of vacant plots seems reasonable.

The least amount of vacant land seems to be found in more developed areas. In other words, the relationship between the development of different parts of the city and the amount of vacant land is an inverse relationship.However, despite the fact that zone 2 is the most developed part of Ahvaz city, the presence of a high number of vacant lands is the result of annexation of new and undeveloped neighborhood "Kian Shahr" in recent years.The ratio of the area of vacant plots to the total urban area of zones 2 and 1 is 11.97 and 2.62 hectares, respectively. Highest and least average area of empty plots with 2 and 0.67 hectares are located in zones 6 and 5, respectively. The total average area of the city is equal to 1.88 hectares, which indicate that the empty lands are mostly outside the current built area. In terms of the average values of the shape index, zone 2 is still the leader with 1.95, while in terms of this index, zone 3 has the least number with values of 1.28.

The largest number of vacant lands in Ahvaz were identified in zones 2, 8 and 4, respectively, while the least ones are seen to zones 1, 7 and 5. In terms of area, zone 2 is still the first rank of vacant land in the city and zones 8 and 6 in the next. By examining other data in table (3), it is clear that zone 2 of Ahvaz Municipality is not ranked first only in the index of the averagearea of vacant blocks. Also, this zone ranks fourth and second in terms of the number and total area of city blocks.

By comparing the three key indicators of the research (the ratio of vacant plots to the total city plots, the ratio of empty area to the total area of the city and the average values of the shape index) and by examining the eight zones of the city, it was found that the 5th zone of Ahvaz municipality has the most harmony and homogeneity in terms of the indicators. In this context, zones 3, 7 and 1 are in the next places. From this point of view, zones 2, 6 and 4 have the least homogeneity (Figure 5).

Table 3. Morphological characteristics of vacant urban land plots in the 8 zones of Ahvaz

ZONE	TOTAL NUMBER OF BLOCKS	THE TOTAL AREA OF BLOCKS (HA)	NUMBER OF BLOCKS	AREA OF EMPTY BLOCKS (HA)	THE AVERAGE AREA OF VACANT BLOCK (HA)	PROBABILITY OF (%) OCCURRENCE		AVERAGE VALUES OF SHAPE INDEX
						The average area of vacant block (ha)	The ratio of the area of empty blokes to the total area of the city	
1	1378	726.34	12	19.6	1.63	0.87	2.69	1.32
2	1471	1549.56	123	185.5	1.50	8.36	11.97	1.95
3	1839	1343.61	34	39.4	1.15	1.84	2.93	1.28
4	1601	1090.18	49	55.3	1.12	3.06	5.07	1.35
5	1592	913.66	32	21.5	0.67	2.01	2.35	1.48
6	1072	1000.91	34	68.2	2	3.16	6.81	1.65
7	1414	1157.21	19	31.7	1.66	1.34	2.73	1.39
8	2941	1631.06	69	69.5	1	2.34	4.26	1.31
TOTAL	13308	9412.53	372	701.7	1.88	2.79	7.45	1.35

(Source: Research results)

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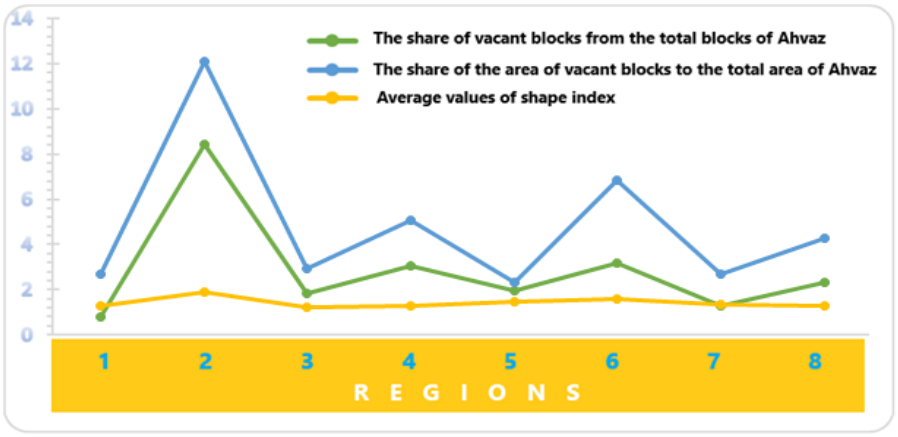

Figure 5. Comparison chart of three key research indicators (Source: Research results)

IV. Conclusion

Lack of land for housing construction in developing countries is a common problem. With more and more people living in urban areas, agricultural and natural areas are being increasingly built over, causing land needed for natural habitats and foodproduction to be lost. At the same time, rapid urbanization has resulted in fragmented urban development and the abandonment of infrastructures, meaning that many urban areas have become vacant land indicated by their unused, underused, derelict or abandoned situation.Sustainable urban development makes the reuse, redevelopment or recycling of such areas a key strategy for reducing land consumption and combating urban sprawl (Xu & Ehlers, 2022).One of the solutions to face this problem is infill development in unused vacant spaces in the urban mass. Identifying these spaces is often associated with obstacles and difficulties such as time and cost.

The use of traditional and filed methods to identify vacant land in the city and also considering the area of 20 thousand hectares of Ahvaz city cannot be efficient. Moreover, the existence of unused spaces in the center and outskirts of urban masses also make the problem more complicated. Current research on vacant land is mainly approached from an urban planning perspective the aim of identifying the vacant lands of Ahvaz with the ability to be used in the infill development using drone images. In order to achieve this goal, two major indicators of the morphology of empty urban land and the distribution pattern of empty spaces in the city of Ahvaz were used.

The results of the research showed that out of the total number of 13308 urban plots and blocks in Ahvaz, 372 are vacant spaces that can be used for infill development. This number includes an area of more than 700 hectares from the area of about 9412 hectares of Ahvaz city. In general, the number of vacant spaces is 2.79% of the total number of plots and 7.45% of the total area of Ahvaz urban mass.

Based on land cover and regarding to the six classes of research, the largest number with 88 cases and an area of 259.6 hectares, includes 2.76% of the vacant plots of the city. The vegetation layer combined with the building, with 35 cases and an area of 68.9 hectares, was the least covered case with 0.73 hectares.

Most of the plots and vacant lands located in the zone 2 in the northwestern area of Ahvaz, which has the highest development rating of the city due to the annexation of the Kianshahr area to the urban fabric and this area of the city in the recent years. Zone 1 is located in the central part has the least number of vacant lands where there are the oldest structures of Ahvaz. From spatial point of view the city of Ahvaz can be divided into two parts by the river of Karun. The western part including zones 2, 4, 6 and 5 has the highest number of vacant plots which could be used for infill development (Fig 5). While in the opposite part, which includes zones 3, 1, 7. 8 with a total area of 4,858.22, with larger area has smaller number of vacant plots in the western part of the river.

By analysing the data and the discussion, the research recommended the following proposals: 1) The vacant lands of the research area from the point of view of land use and ownership should also be calculated and compared with the results of

this research. 2) By calculating the capacity of identified vacant lands, their population potential should be calculated from different aspects. 3) By using GIS and the involvement of factors such as access to the highway, identified vacant lands should be prioritized for infill development (Fig 6).

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