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THE SPATIAL MODEL OF NOISE POLLUTION CAUSED BY INCOMPATIBILITY OF LAND USE IN AHVAZ CITY, IRAN

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Abstract

Noise, as unwanted and unfavorable sound, affects people both psychologically and physiologically. When there is either an extreme quantity of noise or a disagreeable sound that causes a short-term disruption in the environment balance, we have been exposed to noise pollution. Nowadays, because of the new trends in urbanism which are based on various equipment capable of producing a large amount of noise, cities have become major hotspots for noise pollution. In addition, poor urban planning and lack of attention to the principles of urban land use have added to the severity of noise pollution and led to the reduction of acoustic comfort.
Ahvaz, as a strategic and industrial metropolis in southwestern Iran, is one of the cities facing the challenge of noise pollution. The purpose of this study is the preparation of spatial model of noise pollution, determination of compatibility coefficient, and evaluation of urban land use proximity using GIS at Ahvaz regions and zones. The research approach is spatial and its methodology is based on compatibility matrix in GIS software. The findings of this study indicate an intense unbalanced distribution of noise pollution in Ahvaz. The results show that two regions from zone one with a coefficient equal to (0.857) and region five from zone one with a coefficient equal to (0.792) had the highest incompatibility coefficient and the lowest level of acoustic comfort. Also, the lowest incompatibility level is related to region four from zone five with the coefficient of (0.015) and region four from zone two with a coefficient equal to (0.016).

Keywords: acoustic comfort, Ahvaz, land use compatibility, noise map, noise pollution

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1. Introduction

Noise as the wrong sound in the wrong place at the wrong time (Savale, 2014) refers to the unwanted sound that can negatively interrupt human or animal life (Goldsmith, 2012). The word noise is derived from the Latin word nausea which is often related to disorder and annoyance, or informally refers to any particular non-musical or undesirable sound. Environmental noise has been defined as any unwanted sound created by human activities harmful to human health and quality of life (Murphy et al., 2009). Therefore, noise in any form is unfavorable and is considered as pollution which leads to sleeplessness, mental instability, or any type of stress reaction (Mohammadi, 2014).

Noise pollution, as one of the most significant environmental problems, especially in rapidly urbanizing areas (Murthy et al., 2007), has not been properly recognized and is steadily increasing in developing countries (Xie et al., 2009). Sound pollution differs from person to person. For some people, the roaring of engines may be exciting and to others it may be annoying (Mohammadi and Shanbehpour, 2017). Noise pollution is not new, but it is increasing year by year and becoming worse (Ebrahimi and Hashemiparast, 2011). Ways of living, culture, urbanism, effects of technology, and social

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aspects can be reflected in the sound environment (Roca and Tramontano, 2014). The main sources of noise pollution in the new urban life include vehicular traffic, neighborhood, electrical appliances, TV and music systems, public address systems, railway, air traffic, and electricity generating sets (Shanbehpour, 2016). According to the World Health Organization (WHO), noise pollution is a serious threat to citizens' health due to the plurality of resources, such as traffic, industry, workplaces, and neighborhoods (Rahimi, 2008).

Urban noise and the absence of acoustic comfort have been linked to several non-auditory, biologically relevant health outcomes, such as increased levels of hypertension, high blood pressure, hearing loss (Karimi, 2010), neurological disorders (Mortazavi, 2013), lowered cognitive capability (Stansfeld et al., 2005), and an increased outbreak of cardiovascular diseases (Babisch, 2000). Exposure to environmental noise from traffic-related sources is reportedly the most annoying of all urban pollution types (Dinno et al., 2011) interfering with the enjoyment of daily activities which largely affects sleep and relaxation patterns (Seto et al., 2007). Moreover, clinical (Ebrahimi and Hashemiparast, 2011) and behavioral effects, interference with spoken communication (Savale, 2014), and sleep disturbance (Lad et al., 2011) are some of the popular parts of urban noise pollution. Hearing loss caused by occupational noise exposure is highly prevalent and constitutes a public health threat needing preventive and therapeutic strategies. As Basner et al. (2014) pointed out, besides noise-induced deafness, utmost effects of noise can be decreased by proper monitoring and control of noise at its source (Basner et al., 2014). On the other hand, noise pollution control needs an appropriate planning and action plan. Investigations have shown several factors in the urban planning process (Taghipour et al., 2019) that contributed to the genesis and intensification of noise pollution and the reduction of acoustic comfort.

Along with urban technologies, the variety of functions and their deployment in cities also lead to unwanted sound production. The consequence is that, in some urban areas, space is mainly occupied by unwanted, useless, and polluting sounds (Artan et al., 2019). Land use planning is a field of science which tends to order and regulate different land uses in urban areas in a proficient situation (Musakwa et al., 2014) to avoid multi-dimensional conflicts (safety, security, environmental health, and urban development) between urban lands (Hashem and Balakrishnan, 2014). In other words, the best land uses are assigned to different parts of the land to have the minimum incompatibility between various activities (Shanbehpour, 2016). Proximity land use can produce negative effects on other land uses because of their interaction. These externalities may be undesirable effects such as noise, air and visual pollution or may be caused by dangerous facilities (Abedini et al., 2015). Ideally, the location and appropriation of space to any land use should be designed to minimize undesirable impacts among adjacent land uses to ensure health protection, safety, and welfare of the community. This aim can be accomplished by reducing noise, air, and visual pollution (Mohammadi and Shanbehpour, 2017) or by increasing the usability and value of lands through maximizing positive externalities (Taleai et al., 2007). One of the important causes of noise pollution in most Iranian major cities in the past two decades has been the increasing urbanization and lack of attention to the principles of land uses deployment (Firoozi et al., 2018). In most cases, rapid and uncontrolled urbanization has resulted in a mixed incompatible land uses which led to the decay of urban landscapes in various dimensions. With a population of 1400000 inhabitants, Ahvaz is the largest and the most important city in the south and southwest of Iran (Statistical Center of Iran, 2018). The concentration of heavy industries in the city fabrics, the existence of decay fabrics with an irregular network structure, unauthorized urban activities in urban contexts, such as repair workshops (Shanbehpour, 2016) and light industries, and the crossing of national railways through the city fabrics have made Ahvaz an unsustainable city in terms of noise pollution.

Therefore, by addressing the challenge of noise pollution in Ahvaz city, this study seeks to answer the following questions:

i. How is the compatibility in land use proximity of Ahvaz?

ii. Which areas have the maximum and minimum land use compatibility coefficients?

1.1. Noise- related land use planning

Environmental noise has been steadily growing during the last few decades and is now becoming an important concern for society (Sheikh and Mitchell, 2018). Growth in the commercialization, mobility, and urbanization of human settlements across the globe has greatly exposed world urban population to harmful noise levels (Bailescu et al., 2019). However, contemporary urban planning strategies are emphasizing urban development densities, mixed-uses, as well as the continuation of automobile-centered traffic planning policies which may lead to higher traffic and environmental noise exposure (Mohammadi and Shanbehpour, 2017). The maximum recommended noise levels generally increase in relation to the amount of commercial activities, which presents challenges for cities' policies in relation to the integration of residential and commercial land uses (King et al., 2012). Nevertheless, how to get a perfect balance between the optimal distance and land use, especially in today's concentrated and big megacities, has become a critical issue.

Thus, position plays a key role in the behavior of all of the components of the acoustic model because the physical planning with an emphasis on urban land use is one of the most important factors affecting the comfort of the citizens (Mohammadi and Shanbehpour, 2017). Being one of the most controversial issues in urban planning, land use planning has always attracted the attention of researchers. Considering the external effects of parcels on adjacent land uses, land use planning as a subdivision of urban planning, tends to design spatial arrangement for different activities to prevent potential land use conflicts (Taghipour et al., 2019). Nevertheless, because of the growth of the population and the increased demand for new land (Sheikh and Mitchell, 2018), decisions on land use have become progressively harder in the last decade. The main objective of urban land use planning is to locate and optimize the use and division of incompatible land uses (Pourmohammadi, 2008) .

The noise-related land use planning broadly identifies those areas of the landscape within a community context that are potentially unsuitable for noise-sensitive types of development inclusind the provision or enhancement of various types of noise buffer and distance between acoustically incompatible land uses. Therefore, this discipline aims to prevent conflict between different land uses (Firoozi et al., 2018). In satisfying the need for increased population density by merging various land uses within a mixed-used development zone, planners, designers, and policymakers often find challenges in controlling noise in the built environment (Sheikh and Mitchell, 2018). Accordingly, the pattern of proximity and compatibility between land uses leading to sound comfort in urban spaces is one of the neglected but important principles of urban planning (Firoozi et al., 2018). The Land Use Compatibility identifies the ways through which land use compatibility problems may be addressed by urban laws during a long term development (Zubala and Sadurska, 2016). It minimizes the adverse effects of “industrial, transportation, and utility” uses that emit noise vibration on sensitive land uses (Basner et al., 2014). Based on land use compatibility rules, it is necessary to separate sensitive and noisy land uses by applying site location instructions in order to determine the spatial distribution of sound-sensitive and sound-producing activities.

2. Materials and methods

Regarding the factors contributing to the degree of compatibility of urban land uses, the problem of land use adaptability analysis is a multi-criteria evaluation problem (Sheikhian et al., 2015). By implementing a macro-scale model using an aggregated evaluation approach (Taghipour et al., 2019), traditional planning techniques, such as "compatibility land use matrix" that attempt to cluster compatible land uses and segregate incompatible land uses in different zones, are used to reduce negative externalities between adjacent land uses (Mohammadi, 2014). However, using macro-scale models can cause some confusing situations because there might be mixed land uses with positive or negative externalities inside the land use zones (Firoozi et al., 2018). For instance, at a micro-level, placing an industrial use adjacent to residential land uses will cause some negative externalities, but at the macro-level, the same industrial activity is needed to provide jobs and the necessary goods for the residents (Mohammadi and Shanbehpour, 2017). Therefore, in order to deal with all the above mentioned factors, this study used a combination of "compatibility land use matrix" and spatial approach adapted in GIS environment as its purpose-oriented and analytical method. Consequently, by analyzing the research background and using international standards of land use in the metropolitan area of Ahvaz, a user-linked database was prepared. In this regard, as the first step, the noisy land uses were selected based on previous studies by considering Ahvaz city conditions.

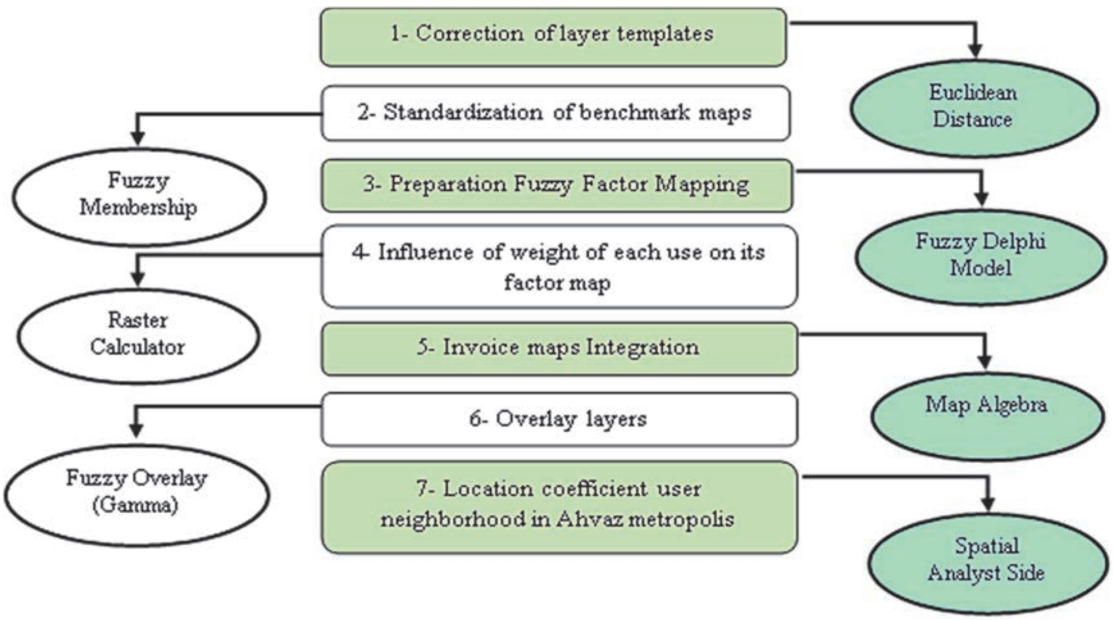

Fig. 1. The process of spatial analysis of research

Then, the distance of acoustic comfort of the selected land uses was extracted according to the existing international standards based on the conditions of Ahvaz city (Table 1). In fact, in this study, the distance factor of residential land use from the sound source is considered as the main research variable to calculate the suitability of land use proximity.

Table 1. Acoustic comfort buffer in noisy land uses (Iranian Municipality's Organization, 2017)

Code	*Layers*	*Distance (m)*
C1	Industrial land use	1500
C2	Military land use	1000
C3	Educational land use	500
C4	Administrative land use	500
C5	Commercial land use	400
C6	Sports land use	600
C7	Travel terminals land use	700
C8	Storerooms storeroom land use	600
C9	Facilities and equipment land use	500
C10	Workshop- Services land use	1000
C11	Passages networks land use	400

By providing a spatial database of the selected land uses, the analysis is done based on the specified distances and the principles of compatibility matrix in GIS software environment (Mohammadi and Shanbehpour, 2017). To measure the proximity conditions of land uses by Euclidean distance tools, the fuzzy membership functions, map algebra, and fuzzy overlay are used in GIS environment. In order to determine the mean spatial neighborhood of land uses in each area, in addition to the spatial analyzer, the fuzzy Delphi model is used for weighting the criteria. The proposed model aims to map perceptual attributes of the sonic environment (Basner et al., 2014). Therefore, the proposed procedure is based on three main stages: First: Sound sources recognition and profiling. Second: Prediction of the soundscape perceptual attributes. Third: Soundscape maps implementation.

2.1. Fuzzy Delphi method

An important representative of qualitative forecasting models is Delphi Method which consists of a panel of experts who give their opinions about a certain event (Aliev and Ahmedov, 2004). The Delphi method involves several rounds of questionnaires sent to experts to draw their views and opinions regarding the research topic in order to set a decision. This method is also known as the agreement approach or internal opinion agreement (thoughts, intuition, and feelings) of a group of experts who were selected or voted on. As Adler (1996) stated, Delphi method is a structured process for collecting and extracting knowledge from a group of experts through a series of questionnaires with controlled feedback (Yusof et al., 2018) which is aimed at acquiring a group consensus (Habibi et al., 2015). The Fuzzy Delphi Method consists of six steps that need to be followed to acquire the required data. The steps are as follows:

Step 1: Expert K was invited to determine the importance of evaluation criteria against the intended variables using the linguistic variables shown in Table 2.

Table 2. Seven Scale Linguistic Variables (Yusof et al., 2018)

LINGUISTIC VARIABLES	*FUZZY SCALE*
Extremely Disagree	(0.0, 0.0, 0.1)
Strongly Disagree	(0.0, 0.1, 0.3)
Disagree	(0.1, 0.3, 0.5)
Partially Agree	(0.3, 0.5, 0.7)
Agree	(0.5, 0.7, 0.9)
Strongly Agree	(0.7, 0.9, 1.0)
Extremely Agree	(0.9, 1.0, 1.0

Step 2: Converting all linguistic variables into triangular Fuzzy numbers as suggested in Table 3, assuming the Fuzzy number is the variable for each criterion for expert K (Eq. 1):

$$i = 1, \ldots, m,$$

$$j = 1, \ldots, n, \qquad (1)$$

$$k = 1, \ldots, k \ dan$$

$$rij = 1 \ K \ [\pm \ r_1 ij r_2 ij \pm rij]$$

Step 3: For each expert, by using the vertex method to calculate the distance between rij, the distance between the two Fuzzy numbers $m = (m_1, m_2, m_3)$, and $n = (n_1, n_2, n_3)$ are calculated using formula (2):

$$(\tilde{m}\tilde{n}) = \sqrt{1/3\left[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2\right]} \qquad (2)$$

Step 4: According to Cheng and Lin (2002), if the acceptable value of d is ($d < 0.2$), experts' consensus is achieved among the experts $m \times n$ if the group's consensus percentage is more than 75% (Aliev and Ahmedov 2004).

Step 5: Fuzzy evaluation aggregated with Eq. (3):

$$\tilde{A} = [\ \tilde{A}_1, \ \tilde{A}_2 \ldots.. \ \tilde{A}\ ] \qquad (3)$$

$$i = 1, \ldots, m$$

Step 6: For each alternative, Fuzzy evaluation $Ai = Ai = (a_1, a_2, a_3)$ is defuzzificated with the formula: $ai = 1\ 4\ (a_1 + 2a_2 + a_3)$, and the alternative ranking sequence can be determined by ai value (Habibi et al., 2015).

Table 3. Fuzzy functions of standardization of urban land use versus residential land use

Fuzzy function type	*Layers*	*Fuzzy function type*	*Layers*
Small	Educational	Small	Industrial
Small	Administrative	Small	Military
Small	Facilities and equipment	Small	Workshop- Services
Small	Commercial	Small	Travel terminals
Small	Passages	Small	Storerooms
-	Residential	Small	sports

Table 4. Fuzzy weight values

Code	*Land use*	*Weight*
C1	Industrial	0.916
C2	Military	0.890
C3	Educational	0.670
C4	Administrative	0.580
C5	Commercial	0.787
C6	Sports	0.750
C7	Travel terminals	0.777
C8	Storerooms	0.699
C9	Facilities and Equipment	0.737
C10	Workshop- Services	0.790
C11	Passages	0.653

3. Results and discussion

3.1. Measuring proximity in noisy land uses

Step 1: The determination of the acoustic comfort buffer in n land uses. At first, the acoustic comfort distance of each function relative to residential land use was determined by Euclidean distance based on the studied background (Mohammadi et al., 2017). Accordingly, residential land use with greater distance from noisy land uses has more acoustic comfort, and vice versa (Rezaei Moghadam, 2014). The output of this step is the preparation of the levels map acoustic comfort map. In this step, 10 compatibility maps of noise pollution have been obtained for the selected land uses. To implement a noise compatible land use control program, the buffer between noisy and noise sensitive land uses were determined based on the rules of the Iranian Municipality's Organization.

Step 2: Standardization of noise maps. In this step, the produced maps are standardized using fuzzy membership functions in GIS software environment. Fuzzy standardization is in the numerical range of (1-0) where (0) indicates compatible proximity and high acoustic comfort, and (1) indicates incompatible proximity and low acoustic comfort.

Step 3: Delphi Fuzzy Factor of weighted land use. In this step, using fuzzy Delphi method, the factor maps of land use zoning are weighted based on the opinions of 30 university professors and Ahvaz municipality experts about the compatibility between proximate land uses in terms of acoustic comfort. In other words, experts rated selected land uses based on their effects on acoustic comfort and finally the calculated average weighted score was known as the land use weight. Delphi Fuzzy is in the numerical range of (1-0) where (0) indicates compatible proximity and high acoustic comfort while (1) indicates incompatible proximity and low acoustic comfort (Fig. 2).

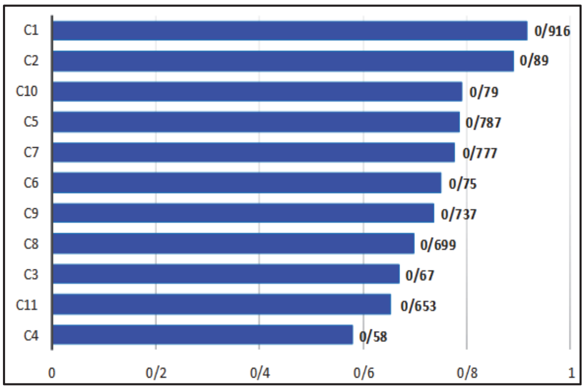

Fig. 2. Delphi Fuzzy Factor weighting of land use

Initially, it is necessary to weigh the factor map of the effective criteria in zoning compliance with the principles of neighborhood urbanization from the perspective of standardized voice comfort (Fuzzy Membership). At this stage, the weighting of each criterion is done using fuzzy logic based on their relative impact on the degree of adaptation and incompatibility with residential use in terms of sound comfort. Fuzzy Delphi method is used to weight the criteria (effective uses). Next, the most important urban land uses affecting proximity to residential land use (e.g. industrial, military, passenger terminals, workshop-services, urban facilities and equipment, warehouses, training, office, sports, commercial, pedestrian networks, etc.), are determined by the rating experts and the average rating is subsequently calculated. Then, the final weight is obtained for each user using the fuzzy Delphi model which is one of the methods of group knowledge acquisition that has been used for more than half a century. The basis of Delphi computation is determined according to experts' views. Therefore, any errors and inconsistencies in the evaluation of the experts' opinions will affect the final results of the calculations.

The first prediction of each expert is presented as a triangular fuzzy number (Eq. 4):

$$Ai = (l_i, m_i, u_i) \tag{4}$$

Then, the predictions are aggregated using the fuzzy mean method (Eq. 5):

$$A_{AVE} = \left(\frac{\Sigma l}{n}, \frac{\Sigma m}{n}, \frac{\Sigma u}{n}\right) \tag{5}$$

Finally, the ratio $\frac{l+m+u}{3}$ is used to determine the mean of the experts' points of view and then the final weight is obtained (Table 4).

After determining the weight of each land use through the fuzzy Delphi model, the effect of these weights was applied on the fuzzy factor maps which have been identical in the previous steps. Therefore, by applying the final weights to land uses, 11 separate maps were obtained for the 11 land uses in which the highest incompatibility rates were associated with proximity to industries and after that with proximity to military land uses.

Step 4: The spatial model of compatibility of land use. Subsequently, after determining the weight of land use layers, using the fuzzy Delphi model, the land use in GIS layers were overlapped and the final map was exported. The result of combining factor maps and the overlapping layers is a raster map in which the pixels value represents the proximity conditions of urban land use related to the residential parts of city. In this map, the proximity rate is shown in five levels from very high to very low compatibility (Fig. 3). Finally, the weight obtained through the fuzzy Delphi model is multiplied by its own layer by the spatial analyzer program in GIS software environment. The final output of this spatial analysis process is the fuzzy mapping using the Gamma 0.9 with high accuracy and lower error. The final map (Fig. 4) shows the compatibility of urban land use in terms of sound comfort with the highest possible accuracy based on fuzzy spatial hypotheses provided in GIS software. The result of the zoning is presented with a color spectrum based on quantity coefficients. The output of the fuzzy map is the basis for answering the main research question that is the spatial coefficient of pollution and noise comfort based on the proximity in the land use of Ahvaz regions.

Step 5: Spatial Coefficient of compatibility in noisy land uses of Ahvaz. After extracting the fuzzy map on the regional scale, in order to determine the spatial coefficient of proximity, using the spatial analyzer by GIS software, the average coefficient of each region was calculated (Table 5). The obtained coefficient is between 0 and 1. The closer the value is to 1, the more incompatibility is seen in the deployment of noisy land uses in these areas. The extracted geo-statistics has shown that regions 1, 2, and 3 with coefficients (0.639), (0.857), and (0.792), respectively, have the lowest degree of compatibility in land use.

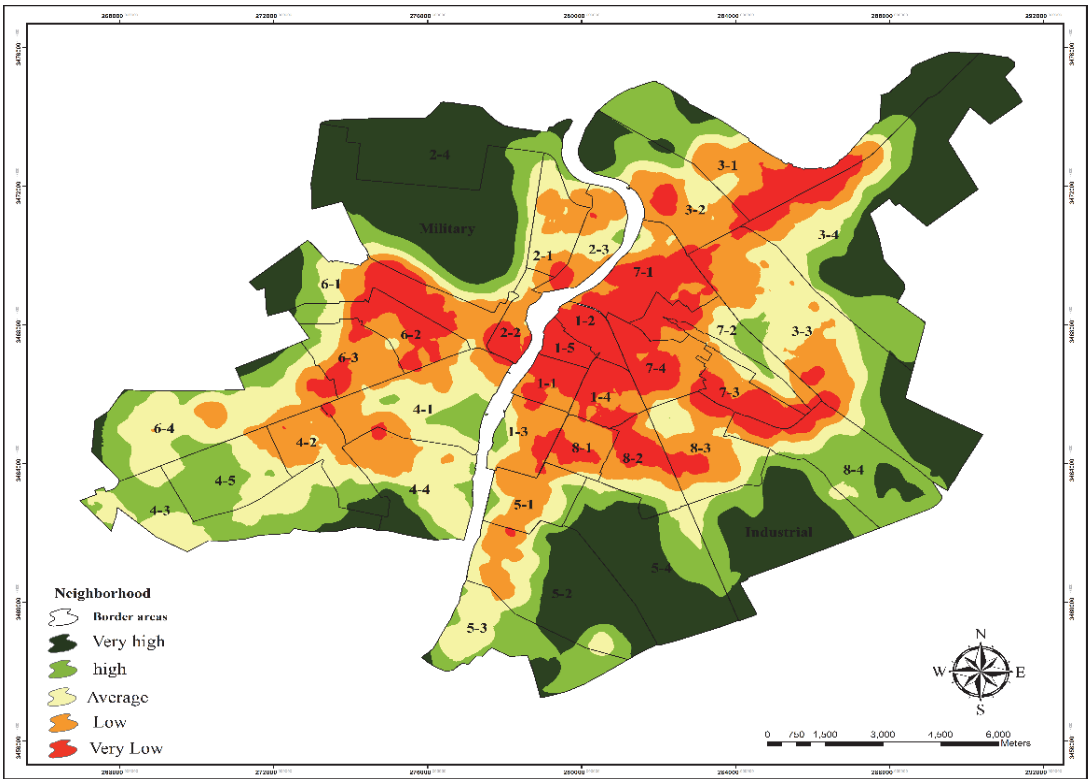

Fig. 3. Noise pollution model caused by incompatibility of land use in Ahvaz

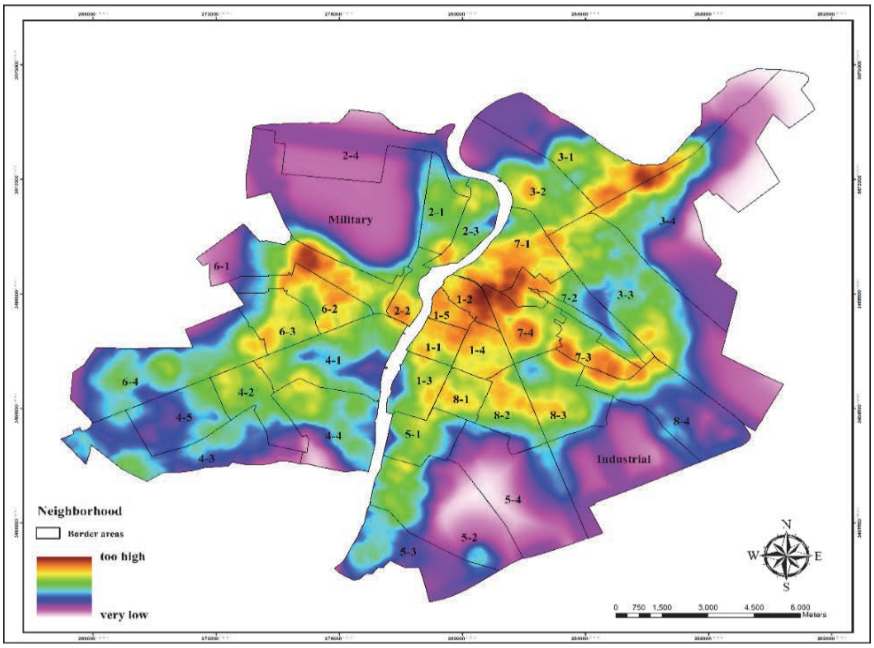

Fig. 4. Noise pollution model caused by incompatibility of land uses in Ahvaz regions by fuzzy overlay

Table 5. Spatial Coefficient of compatibility in noisy land uses of Ahvaz regions

Zone → / Region ↓	1	2	3	4	5	6	7	8
1	0.639	0.271	0.211	0.230	0.269	0.341	0.633	0.478
2	0.857 ↑	0.499	0.277	0.150	0.069	0.488	0.433	0.318
3	0.373	0.388	0.222	0.034	0.043	0.288	0.490	0.235
4	0.584	0.016 ↓	0.103	0.150	0.015 ↓	0.067	0.591	0.139
5	0.792 ↑	-	-	0.151	-	-	-	-
Industrial * Military** Bayer (military and Installations) ***	-	0.059**	-	-	-	-	0.312***	0.015*
medium Coefficient of area	0.649	0.293	0.191	0.143	0.099	0.296	0.539	0.261

In addition, the average proximity coefficient in region 4 from zone 2 with coefficient (0.016) and region 4 from zone 5 with coefficient (0.015) have shown the highest degree of compatibility in proximity of noisy land uses. As can be seen in Fig. 5, the comparative index of compatibility is shown in the 34 regions of Ahvaz.

Today, noise pollution is one of the most important annoying factors in modern work-life environments which leads to irreparable harm to residents' health. From the viewpoint of urban planning science, spatial requirements and considerations and the deployment of urban land uses are the most important factors affecting acoustic comfort or noise pollution.

Therefore, applying appropriate and permissible proximity of land-use is an inevitable necessity because proper proximity, especially with regard to suitable site location of noisy land-use, can specifically reduce noise pollution and provide the acoustic comfort for residents. The aim of this research was the measurement of the spatial coefficient of compatibility in proximity of land-uses in GIS software environment to prepare the spatial model of compatibility in proximity of land-uses. Fuzzy Delphi model was used for weighting the criteria (to determine the best pattern of proximity in land uses). The wording has a few flawsspatial analyzer program (as a GIS extension) was also used to determine the average spatial coefficient for each region. Finally, according to the purpose of the study, the spatial model of acoustic comfort affected by urban proximity in Ahvaz was extracted. The notable findings of this study can be examined from several dimensions.

First: Compatibility in proximity of urban land uses. In this section, the map of land use compatibility was prepared for the urban regions (Figs. 3 and 4). A glance at the map analysis shows a low land use compatibility level in the city center and, particularly, in regions 1 and 2 from zone 1, and region 1 from zone 7. As a result, this part of the city is always experiencing the highest noise pollution and therefore the least acoustic comfort. In these areas, incompatible and impermissible land uses in the vicinity of the residential areas (irregular and impermissible land use mixing) have caused high dissatisfaction of the citizens (Mohammadi and Shanbehpour, 2017).

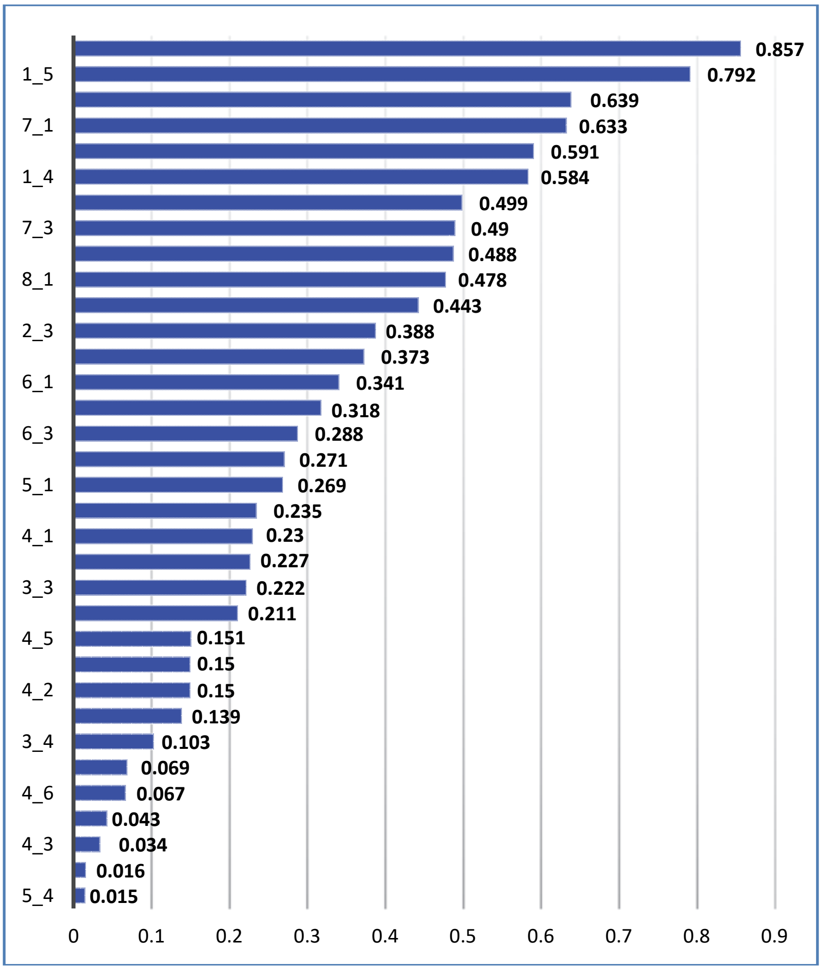

Fig. 5. Spatial coefficient of compatibility in noisy land uses of Ahvaz regions

According to the Department of Environment (DoE), the maximum acceptable noise level in commercial areas is 50-60 dB, 45-50 dB in residential areas, 85 dB in busy traffic areas, 45-35 dB in sensitive areas, and 60 dB in the mixed areas. The concentration and proximity of noisy business activities like foodstuffs stores, car accessories, apparel and electronic equipment with an average sound level above 75 dB (Bari et al, 2017), have been the most important reasons for the high incompatibility in the spatial arranging of land use and consequently the high noise pollution in these parts of the city. It is noteworthy that this area of the city has been the place for small publishing workshops, car repair, carpet weaving, large woodworking workshops, and large welding workshops. This heterogeneous gathering of activities in the old and decay downtown of Ahvaz caused a combination of noisy activities despite the proximity principles. That is why this area is considered as "the noisy hot spot" of Ahvaz. Furthermore, the areas outside the city center in which Ahvaz heavy industries such as Khuzestan Steel, Auxin Steel, Ahvaz Piping, Tube Rolling, and Oil Companies are concentrated have been known as the regions with low acoustic comfort (Fig. 5). Additionally, the Iranian national railroad (Northeast to West and Southwest) which crosses through the middle of Ahvaz urban fabric corresponds precisely to the low-acoustic comfort areas of the city. The spatial pattern of the last two cases (industries location and national rail route) actually reflects an improper land use proximity in this part of the city.

Second: Spatial analysis of noisy land uses. Among the noisy land uses and occupations, heavy industry, passenger terminals, numerous repair shops, military centers, highways, and main roads have been known as the most important noisy activities.The most important activities causing noise pollution include railway and heavy industries of Khuzestan Flour mill, Golriz Co., Misagh Nasr Company, Tubing Factory, stone workshop in zone six , airport in zone three, welding workshop in zone Eight, Takhty stadium in zone four, Enqelab stadium and Karun industrial center in zone seven, the old markets including fruit markets, clothing markets, wholesale construction supplies markets, car supplies markets, dates markets, and electronics markets in zone one, and military centers in zone two. The above-mentioned functions that are generally located within the urban fabrics indicate the fact that the uneven concentration of noisy land uses in the industrial city of Ahvaz has inevitably destroyed the acoustic balance of the city.

Third: Proximity compatibility from the experts' point of view. In addition to spatial database-based analysis, this study has evaluated the opinions of experts in the Delphi model. A review of the experts' opinions on the proximity priorities of other functions with residential land use in Ahvaz in terms of noise pollution has practical implications for Ahvaz management. The analysis of the experts' opinions in the fuzzy Delphi model has shown that the highest incompatibility degree in residential land uses is related to the proximity with industries and after that military and Workshop- Services functions. Experts also believed that among the noisy selected land use, administrative activities and pass ways have the lowest incompatibility with residential land use.

Fourth: In order to enhance the acoustic comfort and sound mitigation in Ahvaz metropolis in terms of the quality of land use planning the following operational approaches are suggested:

a) Preparing a master plan of noise pollutions in Ahvaz metropolis;
b) Locating a new site for the transfer of the polluting industries and workshops, especially from zone six;
c) Implementing a plan for organizing the distribution of occupations (in terms of acoustic comfort) especially in downtown;
d) Developing of green spaces in the downtown and zones two and six by using appropriate vegetation species compatible with the environmental conditions of Ahvaz;
e) Improving the structure of the busy connection networks in the downtown to prevent overcrowding of vehicles traffic and locating the new public parking;
f) Decentralizing the city center and zone one, and developing second and third-degree service cores in zones four, five and six;
g) Moving the railway line to underground, especially in the central parts of the city;
h) Using noise barriers (sound-walls) to mitigate the high noisy rate of urban fabrics in the vicinity of the rail network line and roadways.

4. Conclusions

Noise pollution has been gradually rising during the last decades and is now becoming a significant anxiety for the society. Growth in the commercialization, movement, and urbanization across the world has significantly exposed urban population to harmful noise altitudes. In recent years, there has been a growing consciousness that sound is an essential part of the urban environment, and that it should be considered at the same level of importance as the visual aesthetics in the urban planning procedures.

Physical planning with an emphasis on urban land use is one of the most important strategies affecting the acoustic comfort of the citizens. Thus, being one of the most controversial issues in urban planning, land use planning has always been the focus of research. Nevertheless, making decisions for land use have become progressively harder in the last decade. The main aim of urban land use planning in terms of noise pollution is to locate and optimize the use and division of incompatible land uses. However, achieving this goal in large and multi-functional cities such as Ahvaz seems to be very difficult.

The results of the spatial analysis of urban land uses in Ahvaz confirm this claim. Analyzing the level of noise in noisy land uses of Ahvaz city shows an imbalance in acoustic comfort between different regions of the city which is due to the lack of compatibility between land uses in terms of noise pollution. Inappropriate distribution of noise pollutant land uses like workshops, repair shops, urban terminals, and heavy industries are the most important examples of these land uses.

Based on the map analysis, regions 3-7 and 4-7 as well as 2-6 and 3-6 have received the most effect from the unbalanced distribution of incompatible land uses. Moreover, the findings of compatibility analysis in different regions and zones of Ahvaz have shown that the concentration of service sector activities and the old market of Ahvaz in the central areas of the city attracts more than 250000 daily fluid population. Therefore, these areas are known as "noisy hot spot" of the city.

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