

## Article

# New Approach to Selecting Civil Defense Centers in Al-Riyadh City (KSA) Based on Multi-Criteria Decision Analysis and GIS

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**Abstract:** Maintaining and enhancing the quality of civil defense services are of importance to citizens' life in any city. During the past few decades, the expansion of settlements in Al-Riyadh City has led to a shortage in the distribution of the civil defense centers (CDCs) there. The main aim of this study is to implement the Weighted Sum Method (WSM) and Analytic Hierarchy Process (AHP) to evaluate the distribution of the CDCs in Al-Riyadh City. Eight criteria (i.e., distance from the existing civil defense center, accident density, population density, distance from the road, distance from commercial centers, distance from educational services, distance from industrial areas, and distance from residential areas) were used. The areas under the curve (AUC) of the Prediction Rate Curve (PRC) show that almost all of the AHP models are better than the WSM model. We suggest establishing five CDCs in Al-Riyadh City in areas that are lacking CDCs and characterized by a high population density and consequently a high rate of accidents. We recommend highly long-term planning for establishing new CDCs in cities where there is rapid areal expansion (e.g., Al-Riyadh City).

**Keywords:** GIS; AHP; multi criteria decision making; MCDM; civil defense centers; LAND use; Saudi Arabia; suitability map



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## 1. Introduction

Civil defense is a set of measures to protect citizens and public and private property from the dangers of fires, disasters, wars, and various accidents. It plays a key role in any country by assisting those who are afflicted and providing safety for transportation, communications, and evacuation plans as defined by the civil defense system [1]. Efficient utilization of these resources is a major responsibility of decision-makers in a country and can have a considerable impact on the quality of the service provided by civil defense. The tasks of civil defense can be summarized as: (i) providing relief to those affected by emergency situations; (ii) firefighting, fire extinguishing, rescue, and ambulance services; (iii) establishing operating rooms and civil defense centers (CDCs) and identifying those affected; (iv) storing various materials and equipment needed in war emergencies and catastrophic situations; (v) preparing and implementing the necessary procedures and providing cash support; and (vi) implementing plans for evacuation and providing shelter in emergency situations [2].

Selecting sites for the optimal location of civil defense centers is an important application for geographic information systems (GISs), which can play a significant role in decision-making [3]. The main task of the civil defense center is acting in the event

of fire and other emergencies, where the time of arrival of help during a disaster is the dominant criterion. The determination of the optimal location for emergency facilities such as CDCs has a long history in the field of management and operations research using different methods [4]. Several studies have been conducted in the field of the selection and evaluation of civil defense centers [5–11]. The authors of [12] used the travel-time method to determine the geographical variation in hospital use in Estonia, while [13] used both travel-time and straight-line techniques to determine health service areas in southwest England. Some of these studies used Multi-Criteria Decision Analysis (MCDA) to select the best location for CDCs.

MCDA methods have been applied in different studies. For example, [14] used Analytical Hierarchy Process (AHP) to develop land suitability maps for selected crops. In addition, [15] used AHP to select suitable areas for professional adventure tourism to help in formulating tourism development strategies. The authors of [16,17] used MCDA for winter wheat cultivation and viticulture, respectively. The authors of [18–20] used Analytic Hierarchy Process (AHP) to locate groundwater potential zone watersheds using a GIS and remote sensing. For evaluating the quality of life, [21] used AHP and the location–allocation method to improve the spatial distribution of services and enhance the quality of life in districts. In addition, AHP has been used in environmental and watershed management [22,23].

For civil defense, MCDA methods have been used. Many researchers have used a GIS to determine locations for fire stations [24]. For example, [25,26] used the Fuzzy AHP method to select the optimal location of new fire stations. We have stated some of the common MCDA methods that have been used around the world in Table 1. This study aims to implement the Weighted Sum Method (WSM) and AHP methods to select suitable sites for CDCs in Al-Riyadh City.

Our study utilizes, for the first time, MCDA represented by AHP and the WSM to determine new CDC locations in Al-Riyadh City. In addition to the Introduction, this paper consists of four sections structured as follows. Section 1 focuses on a description of the study area. Section 2 deals with the methods and data used. Results and a discussion are presented in Section 3. Finally, Section 4 summarizes the main conclusions.

**Table 1.** Multi-Criteria Decision Analysis (MCDA) methods used in various studies.

Ref	Method	Technology	Country
[27]	AHP	Solar power site suitability	Algeria
[24]	AHP	Fire Risk Assessment	China
[28]	AHP	Site suitability investigation	Egypt
[29]	AHP	Neotectonic landscape deformation	Greece
[30]	AHP	Land-use suitability	Mexico
[20]	AHP	Groundwater potential	Pakistan
[19]	AHP	Groundwater potential	Saudi Arabia
[31]	AHP	Land Use Suitability	Saudi Arabia
[26]	AHP	Developing a fire risk map	Turkey
[32]	AHP	Agricultural land use suitability	Turkey
[33]	AHP Boolean logic	Waste landfill sites	Iran
[34]	Buffer zones	Accessibility of fire hydrants	Lithuania
[35]	Euclidean distance	Health care facilities	Saudi Arabia
[36]	Euclidean distance	Emergency department accessibility	United States
[37]	Fuzzy AHP	Analysis of accessibility	Brazil
[25]	Fuzzy AHP	Optimal location for fire stations	Turkey
[38]	Location–allocation	Emergency evacuation planning	Bangladesh
[39]	Location–allocation	Locating fire stations	Belgium
[40]	Location–allocation	Available sites for fire stations	India
[41]	Location–allocation	Fire station allocation	Iran

Table 1. Cont.

Ref	Method	Technology	Country
[21]	Location–Allocation	Evaluating Quality of Life	Saudi Arabia
[4]	MCDA	Locating fire stations	Dubai
[42]	MCDA AHP	Identifying potential flood hazard zones	Iran
[43]	Network Kernel Density Estimation	Urban fire risk locations	China
[44]	Service areas	Fire response systems	Ghana
[45]	Weighted overlay	Site layout planning	Turkey
[46]	WLC	Best practice approach for WLC	-
[47]	WLC	Regional hazard map	United States
[16]	MCE	Viticulture suitability using MCE	Syria
[17]	MCDA, MCDS	Land suitability assessment	Syria

## 2. Materials and Methods

### 2.1. Study Area

Al-Riyadh City is the capital of the Kingdom of Saudi Arabia and the largest city in the Arabian Peninsula (Figure 1). It covers a total area of ~2894 km<sup>2</sup>. The city lies at an altitude of 600 m above sea level (Figure 1). It is characterized by a desert climate with hot summers, short and mild winters, and low humidity levels throughout the year. The temperature changes substantially between night and day, typically 28 °C and 43 °C, respectively. The city of Al-Riyadh, in general, has low rainfall, which falls mainly in March and April. However, the city is exposed periodically to heavy rain events leading sometimes to flash floods [48]. It is also exposed to dust storms, which sometimes severely affect visibility, reducing it to less than 10 m [49].

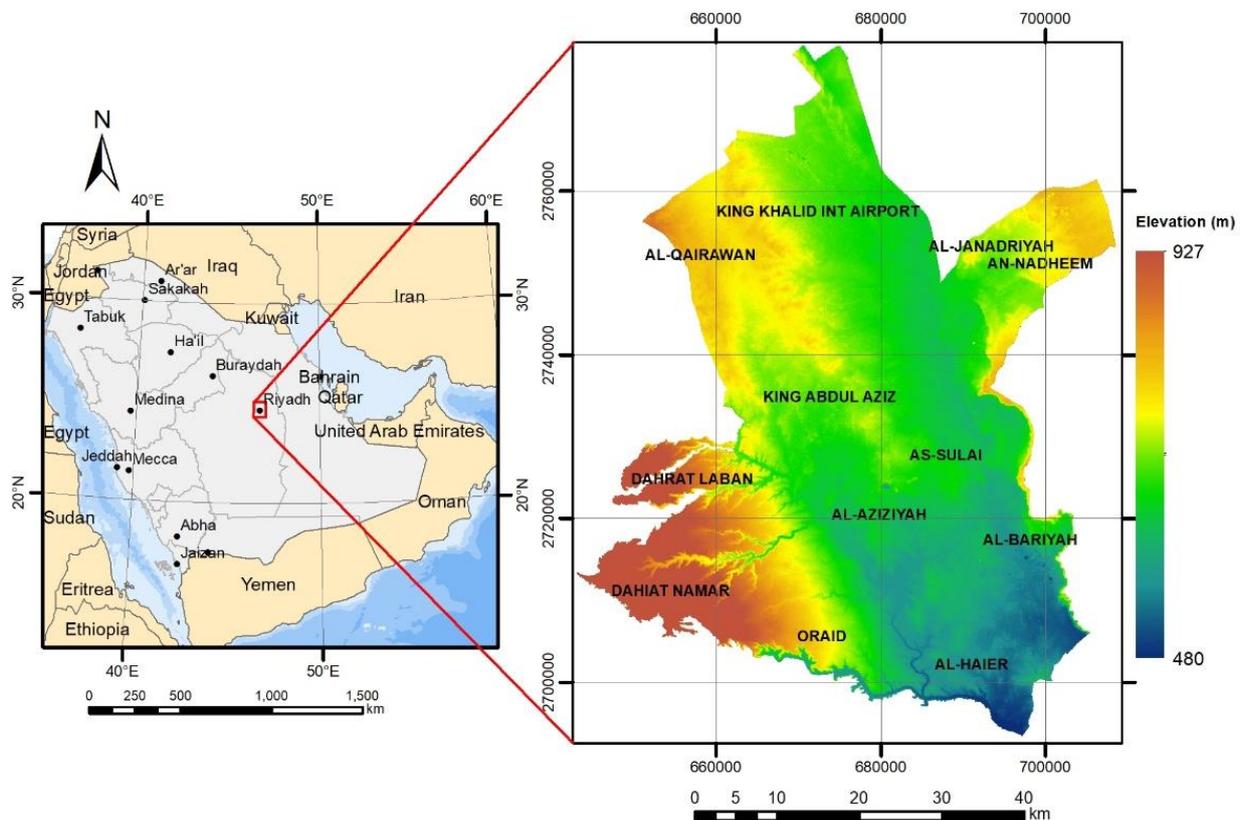
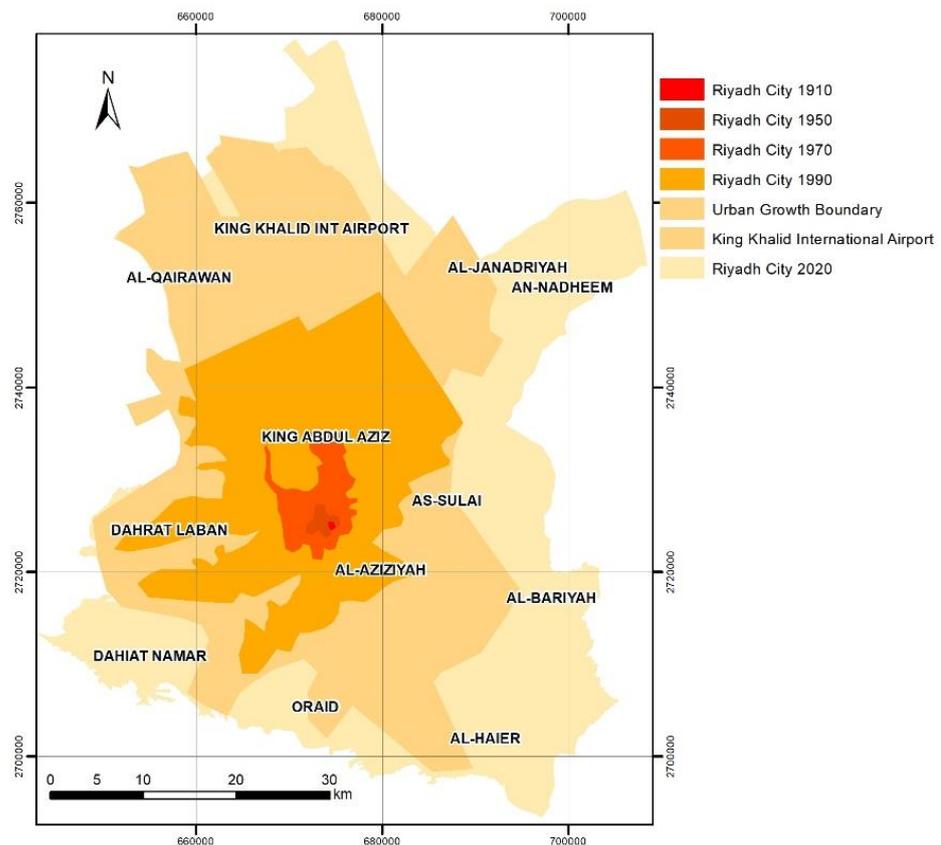


Figure 1. Location of Al-Riyadh City, Kingdom of Saudi Arabia.

Al-Riyadh City has experienced rapid population and areal growth since 1900 [50] with an annual rate of growth of more than 8% (Figure 2; [50]). The population growth of Al-Riyadh City over the 12 years from 2007 to 2019 was ~2.6 million (from 6 to 8.6 million) [51]. As the population grows and the city of Al-Riyadh expands, there will be a need for more CDCs. Hence, it is imperative to effectively determine new locations for emergency facilities to adequately serve civilians and ensure that lives and urban infrastructure are protected.



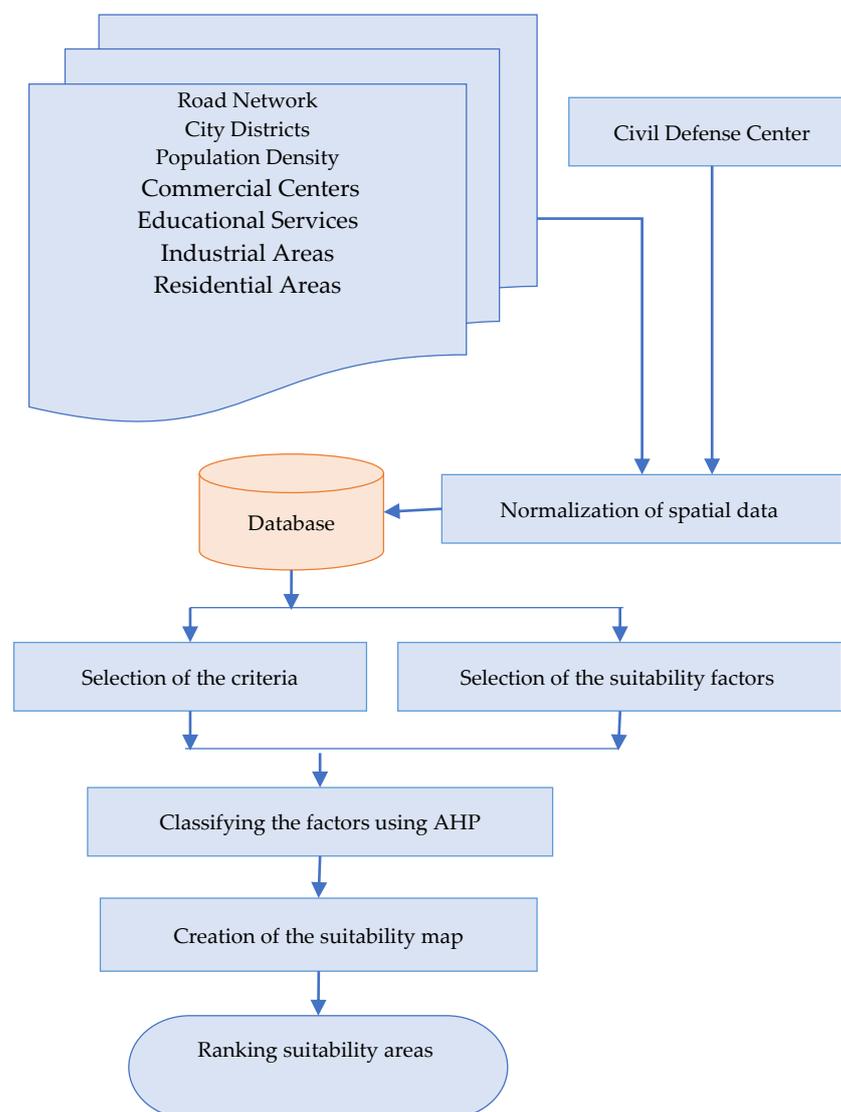
**Figure 2.** Al-Riyadh City and the urban growth boundaries (1910, 1950, 1970, and 1990) [52].

## 2.2. Geodatabase

Before selecting effective criteria to determine suitable sites for CDCs, we reviewed several papers, e.g., [25,53,54]. A geospatial database for Al-Riyadh City was constructed and several thematic layers were used. The layers include road and street networks, the administrative division of city districts, land use, and population density. This dataset was obtained from the Municipality of Al-Riyadh, which is affiliated with the Ministry of Municipal and Rural Affairs and the General Directorate of Civil Defense (Table 2). We followed the workflow shown in Figure 3. to find suitable areas for new CDCs. We used the assembled maps to generate the eight factors (Table 2 and Appendix A) used to determine suitable sites. For instance, the land use map was used to estimate the layers C5, C6, C7, and C8.

**Table 2.** Coding criteria and data sources of the prediction-factor layers.

Criteria Code	Factors Description	Maps	Source of Map
C1	Distance from existing civil defense center	Civil defense center	General Directorate of Civil Defense
C2	Accident density	Accidents	General Directorate of Civil Defense
C3	Population density	Population density	Municipality of Al-Riyadh
C4	Distance from the road	Road and street network	General Directorate of Civil Defense
C5	Distance from commercial centers	Land use	Royal Commission for Riyadh city
C6	Distance from educational services	Land use	Royal Commission for Riyadh city
C7	Distance from industrial areas	Land use	Royal Commission for Riyadh city
C8	Distance from residential areas	Land use	Royal Commission for Riyadh city



**Figure 3.** The workflow used.

As we have several prediction factors in the models, multicollinearity tests were tried between these factors to detect and remove highly correlated factors [55]. Table 3 shows that there are no very high correlations between the factors. The maximum correlation is between distance from commercial centers (factor C5) and distance from educational services (factor C6). This is 0.767. The correlation between accident density (factor C2) and population density (factor C3) is 0.692, which can be considered a bit high.

**Table 3.** Correlation between layers C2–C8.

Correlation	C2	C3	C4	C5	C6	C7	C8
C2	1						
C3	0.692	1					
C4	0.286	0.421	1				
C5	0.471	0.666	0.484	1			
C6	0.287	0.562	0.549	0.767	1		
C7	0.366	0.542	0.297	0.458	0.502	1	
C8	0.173	0.266	0.317	0.553	0.625	0.411	1

### 2.3. Multi-Criteria Decision Analysis

MCDA has been widely used as key tool in many studies (Table 1). Such a technique can be implemented through the application of a scientifically determined and well-structured method. We used two of the common methods (i.e., WSM and AHP) to design new CDCs in Al-Riyadh City. Below, we summarize the methods used.

#### 2.3.1. Weighted Sum Method (WSM)

The WSM is a simple method using multiple factors with the same weighting value. Therefore, significant inadequacy in inputs is not considered [56]. In this study, each factor was coded (Table 2) and classified into five classes (Table 4). These were 1, 3, 5, 7, and 9 for the non-suitable, less suitable, moderately suitable, suitable, and most suitable locations for CDCs, respectively. The suitability of each class for a CDC location was used for weighting classes (Table 4). The summation of all factors was taken based on Equation (1) [57].

$$WSM = \sum_{i=1}^n w_j a_{ij} \quad (1)$$

where  $n$  is the number of factors,  $a_{ij}$  is the actual value of the  $i$ -th and  $j$ -th criteria, and  $w_j$  is the weight of the  $j$ -th criterion.

**Table 4.** Classified criteria.

Criteria	Reclassification	Range	Criteria	Reclassification	Range
C1	1	0–3000	C4	9	0–200
	3	3000–5000		7	200–1000
	5	5000–7000		5	1000–3000
	7	7000–9000		3	3000–6000
	9	9000–35,000		1	6000–14,700
C2	1	0–1	C5	9	0–200
	3	1–20		7	200–2000
	5	20–35		5	2000–5000
	7	35–50		3	5000–8000
	9	50–75		1	8000–35,000
C3	1	0–1	C6, C7 and C8	9	0–200
	3	1–500		7	200–2000
	5	500–4000		5	2000–5000
	7	4000–13,000		3	5000–8000
	9	13,000–24,000		1	8000–35,000

For smooth classification of data, we reclassified all used layers into five classes (Table 4). The map version of the classified layers is presented in Appendix A.

### 2.3.2. AHP Method

AHP was first proposed by [56] and provides a scheme for working in a hierarchical structure to solve complex problems where the used parameters in each layer are compared in pairs. This allows us to assess the comparative standard coefficient weights with alternative schemes [58,59]. The AHP method is flexible and structured because it relies on a simple principle of finding the relationship between standards and alternatives. The comparison method for each pair is the most commonly used process for the calculation of criteria weight coefficients in MCDA applications [60]. The eight criteria for CDC suitability are coded in Table 4.

The preferences matrix is a result of a pairwise comparison of all the elements in a specific hierarchy level. Equation (2) illustrates the structure of an  $(n \times n)$  square matrix where  $(n)$  is the number of elements that have been compared. Equation (3) is an expression of the principle of preference, where two elements that are identical to each other are expressed according to the preference by the number 1. Therefore, the elements in the diagonal of the matrix are equal to 1. Equation (4) explains how to calculate preferences in the other elements.

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \text{ or } [a_{ij}], \text{ where } i, j = 1, 2, \dots, n \quad (2)$$

$$a_{ij} = 1, \text{ for } i = j, \quad (3)$$

$$a_{ij} = \frac{1}{a_{ji}}, \text{ for } i \neq j. \quad (4)$$

### 2.4. Civil Defense Site Selection and Validation

Six (i.e., one WSM and five AHP) suitability maps were estimated to select suitable CDCs. The highest weight pixels are nominated as suitable sites. To validate the suitability of the nominated defense centers in Al-Riyadh City, we used an existing defense center map as a reference [61] and ignored the distance from the civil defense center (C1) factor in the six models.

The Area Under the Curve (AUC) of the Prediction Rate Curve (PRC) is a common quantitative measurement used to evaluate site selection models. It is used to evaluate suitability models in different fields, such as landslide prediction [61]. A PRC is usually represented by a two-dimensional plot, where the x-axis is the suitability index rank of CDCs (%) and the y-axis is the cumulative percentage of the CDC percentages. Ref. [62] reported that an AUC of N50% for a model is reasonable for acceptability. The higher the AUC, the more suitable is the model. We evaluated our models used to select the suitable sites for CDCs by using the AUC of the PRC for all suitability maps. To validate the six suitability maps, we calculated the AUC of the PRC using the existing 70 CDCs within Al-Riyadh City. Then, the AUC of the PRC was used to select the best suitability maps (Results section; Figure 4).

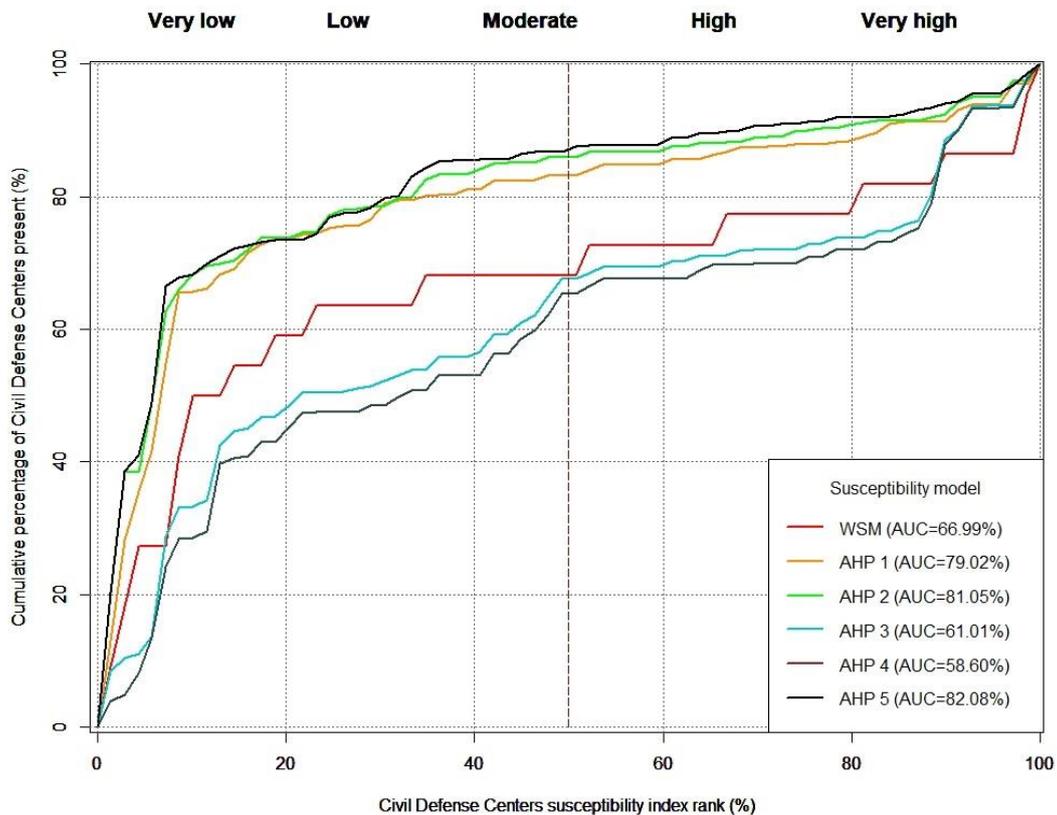


Figure 4. PRC plot evaluation of the six CDC models.

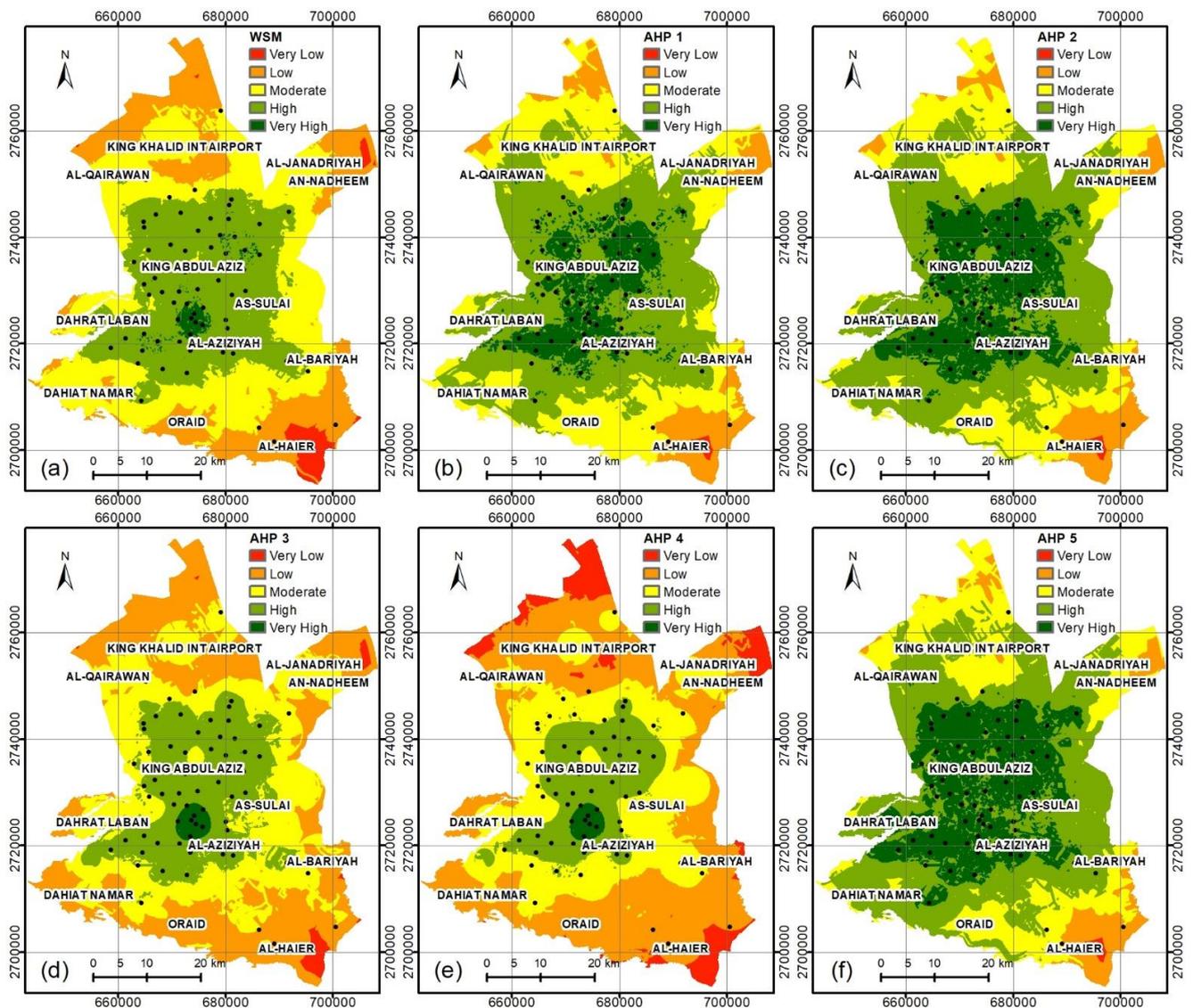
### 3. Results and Discussion

#### 3.1. WSM and AHP Assessment

For the WSM, only one set of weights was tested (as the weights of the predictive factors for the WSM are equal to each other). For the AHP method, we tested several weights to create the spatial distributions of the CDC maps within Al-Riyadh City experimentally. Table 5 shows the WSM and the best weights of the predictive factors for the AHP models (five sets) used to estimate the CDC suitability maps. Figure 5 shows the spatial distributions of the CDC maps within Al-Riyadh City. For each model, each predictive factor has its specific weight, which differs from one model to another. Six maps were created using the WSM and AHP methods based on eight predictive factors (Table 2). Each map includes five classes, which are very low, low, moderate, high, and very high CDC suitability (Tables 2 and 4). The AHP maps were created with the best AUC of the PRC. The spatial distributions of the five classes for the CDC maps (WSM and five AHP) show some similarity. They can be classified into two groups—group 1 (i.e., Figure 5a,d,e) and group 2 (i.e., Figure 5b,c,f), where each group has high similarity for the maps (Figure 5). The very high suitability class of group 1 shows a restricted distribution in a very small zone within the center of Al-Riyadh City, while the very high suitability class of group 2 shows a wide distribution within Al-Riyadh City. That is clear in the AUC of the PRC for the six tested models (Figure 4), where we assumed that the weight of the accident density (C2) factor is low for the AHP-3, AHP-4, and WSM models, while it is high for the AHP-1, AHP-2, and AHP-5 models (Table 5). Therefore, we found that the reason for the decreasing AUC of the PRC for the AHP-3, AHP-4, and WSM models and the increasing AUC of the PRC for the AHP-1, AHP-2, and AHP-5 models is the lack of recent information on accident density (C2), which has changed with the rapid expansion of Al-Riyadh City.

**Table 5.** The weight of the predictive factors suggested for the six models (WSM and five AHP).

Weight	C2	C3	C4	C5	C6	C7	C8
WSM	0.143	0.143	0.143	0.143	0.143	0.143	0.143
AHP-1	0.020	0.041	0.324	0.070	0.172	0.079	0.294
AHP-2	0.021	0.021	0.229	0.110	0.151	0.077	0.390
AHP-3	0.154	0.421	0.223	0.043	0.070	0.048	0.042
AHP-4	0.174	0.488	0.080	0.061	0.066	0.066	0.066
AHP-5	0.030	0.029	0.278	0.100	0.118	0.038	0.407

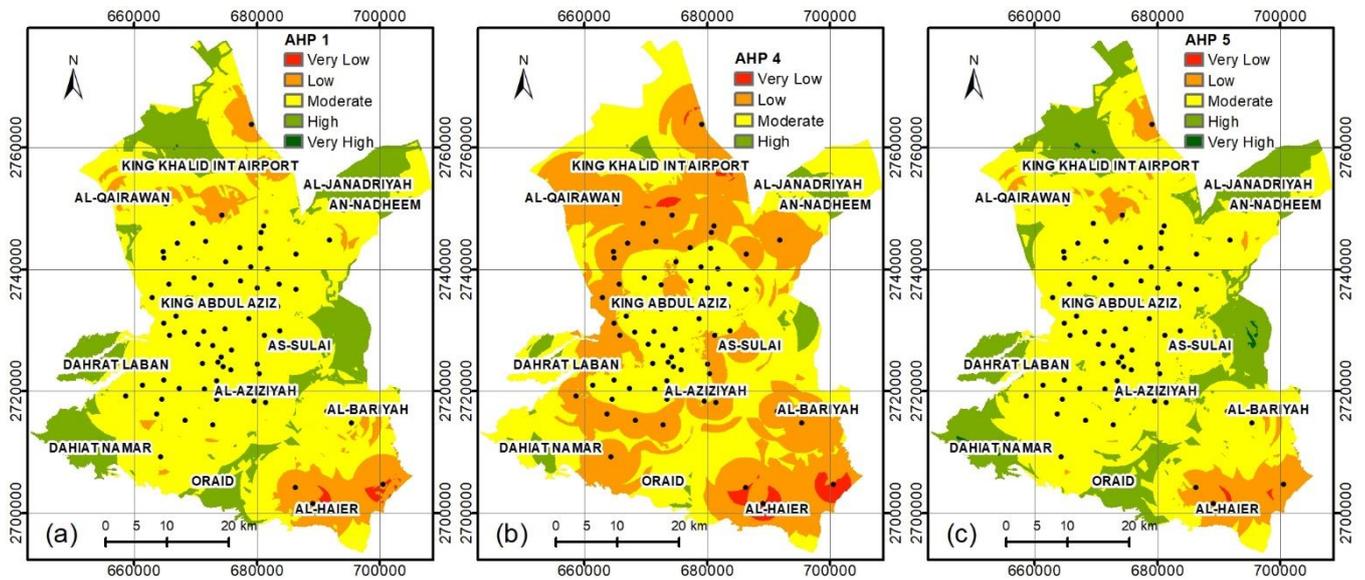


**Figure 5.** Spatial distribution of the CDCs of the study area using models (a) WSM, (b) AHP-1, (c) AHP-2, (d) AHP-3, (e) AHP-4, and (f) AHP-5.

### 3.2. Re-Estimation and Validation of the Most Successful Models

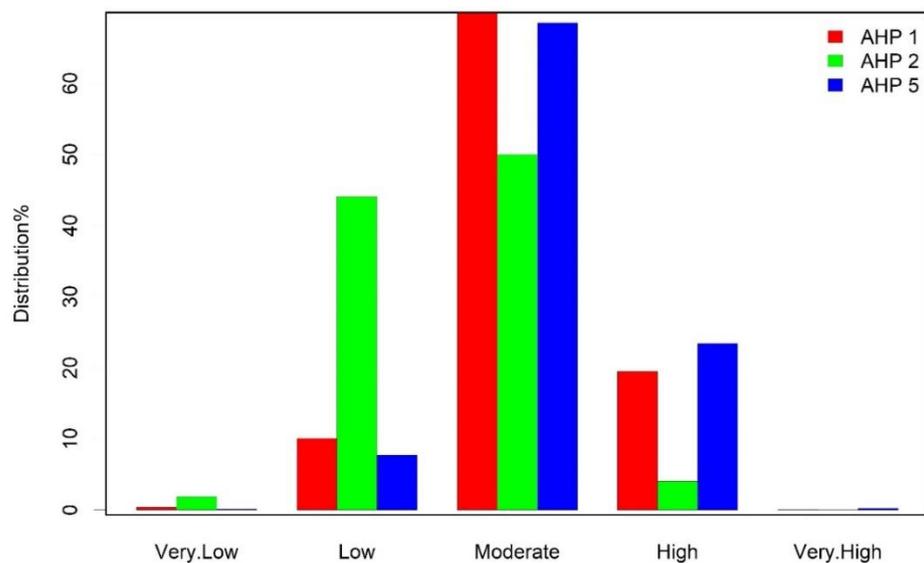
In Figure 4, we calculated the AUC of the PRC to validate the six tested CDC models (Figure 5), where the AUC of the PRC for the WSM, AHP-1, AHP-2, AHP-3, AHP-4, and AHP-5 maps were 66.99%, 79.02%, 81.05%, 61.01%, 58.6%, and 82.08%, respectively. The best overall models are AHP-5, AHP-2, and AHP-1, while the worst models are AHP-4, AHP-3, and WSM. We re-estimated the suitability map of CDC sites for models AHP-1,

AHP -2, and AHP-5 by integration of the existing civil defense center factor with the other factors for these three models (Figure 6).



**Figure 6.** Best spatial distribution of the CDC maps after adding the existing CDC factor to the three models, which are (a) AHP-1, (b) AHP-4, and (c) AHP-5.

Based on the results, we assumed that the civil defense center factor has the highest weight, and the normalized weight for the AHP-1, AHP-2, and AHP-5 models is 0.411, 0.434, and 0.474, respectively. We compared the three nominated models to display their spatial distribution within Al-Riyadh City (Figure 7). All these models are normally distributed. It can be seen that the AHP-5 model is positive in skewness, where the skew is towards a high and very high ranking, while the AHP-2 model is negative in skewness. The AHP-1 model is symmetrically distributed for the weight of the rank. Table 6 shows the new suggested weights for the three nominated models after normalizing the weights of the eight factors.



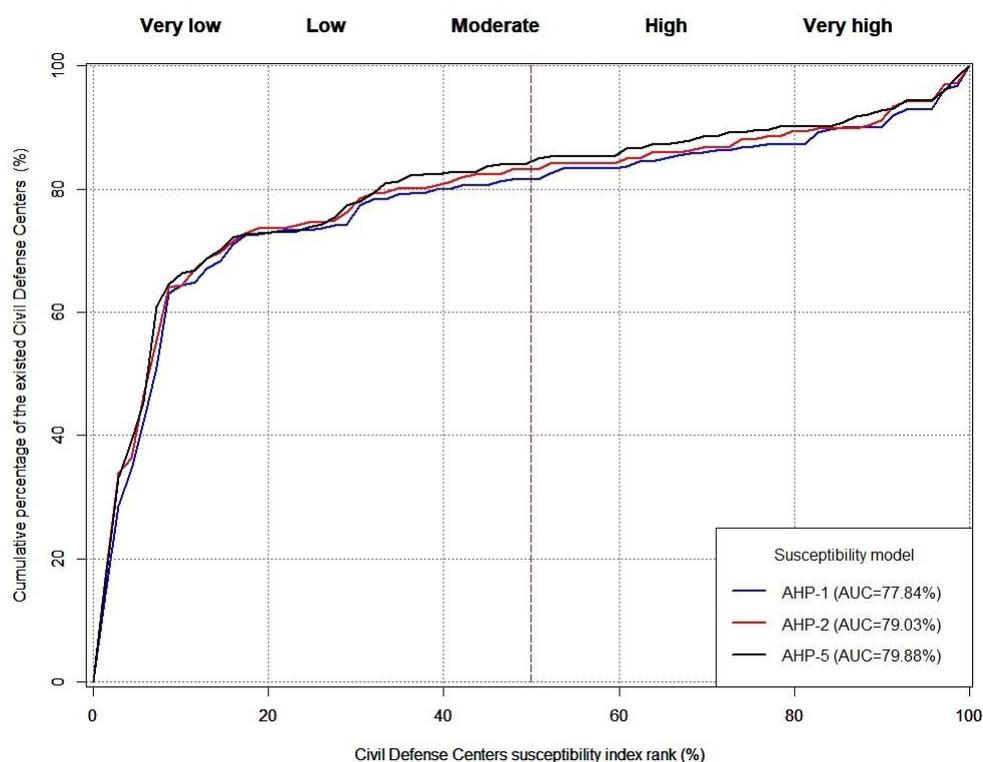
**Figure 7.** Bar graph showing the spatial suitability categories for CDCs in Al-Riyadh City.

**Table 6.** The weights of the predictive factors suggested for the best three AHP models.

Weight	C1	C2	C3	C4	C5	C6	C7	C8
AHP-1	0.434	0.016	0.030	0.152	0.046	0.107	0.052	0.163
AHP-2	0.474	0.077	0.253	0.043	0.037	0.039	0.039	0.039
AHP-5	0.411	0.022	0.021	0.164	0.070	0.082	0.027	0.202

We used the eight effective factors (i.e., C1–C8) that allow for the selection of proposed locations of CDCs in Al-Riyadh City. The use of these factors is satisfactory considering the distribution of weights (Appendix B).

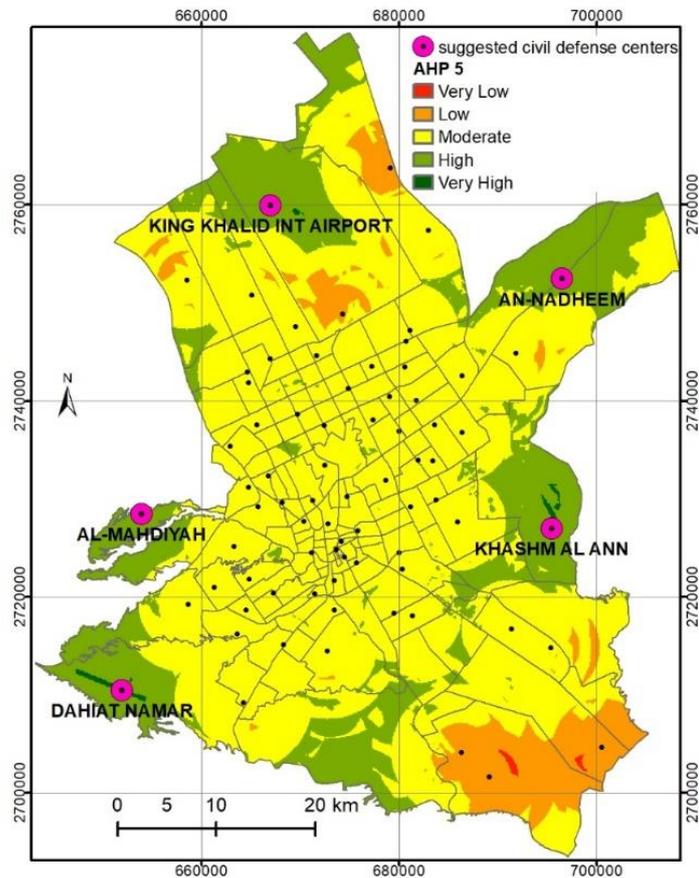
The AUC of the PRC for the best three tested models, after adding the existing CDC factor (i.e., AHP-1, AHP-2, and AHP-5; Figure 8), show lower values than the three models before adding the existing CDC factor (Figure 4). The main reason is that the existing CDCs were established on the basis of two main factors, which are distance from residential areas (C8) and distance from the road (C4). Other factors were disregarded. Therefore, the distribution of the CDCs is random. The decision-makers did not constrain their choices using the other affecting factors (i.e., distance from the civil defense center, accident density, population density, distance from the road, distance from commercial centers, distance from educational services, and distance from industrial areas). The reason is that the CDCs were established in multiple stages. For example, in the year 2000 five CDCs were established [63]. Moreover, the growth of Al-Riyadh City occurred in five stages (Figure 2).

**Figure 8.** PRC plot evaluation of the three best CDC models after adding the existing CDC factor.

The distance from the existing CDC factor did not improve the CDC maps obtained from models AHP-1, AHP-2, and AHP-5. On the contrary, adding this layer degraded the results of these three models (Figures 4 and 8).

Based on the best CDC distribution map (i.e., AHP-5), we suggest establishing five new CDCs in Al-Riyadh City (Figure 9 and Appendix C). These new suggested CDCs are on the outskirts of the city. All the areas are characterized by high rates of accidents and a high population density. For example, 18,255 people live in Dahiat Namar, in the southwest

of Al-Riyadh City, which suffers from 186 accidents per year. It includes several commercial, residential, and governmental buildings, hotels, water sewage treatment plants, police stations, and schools.

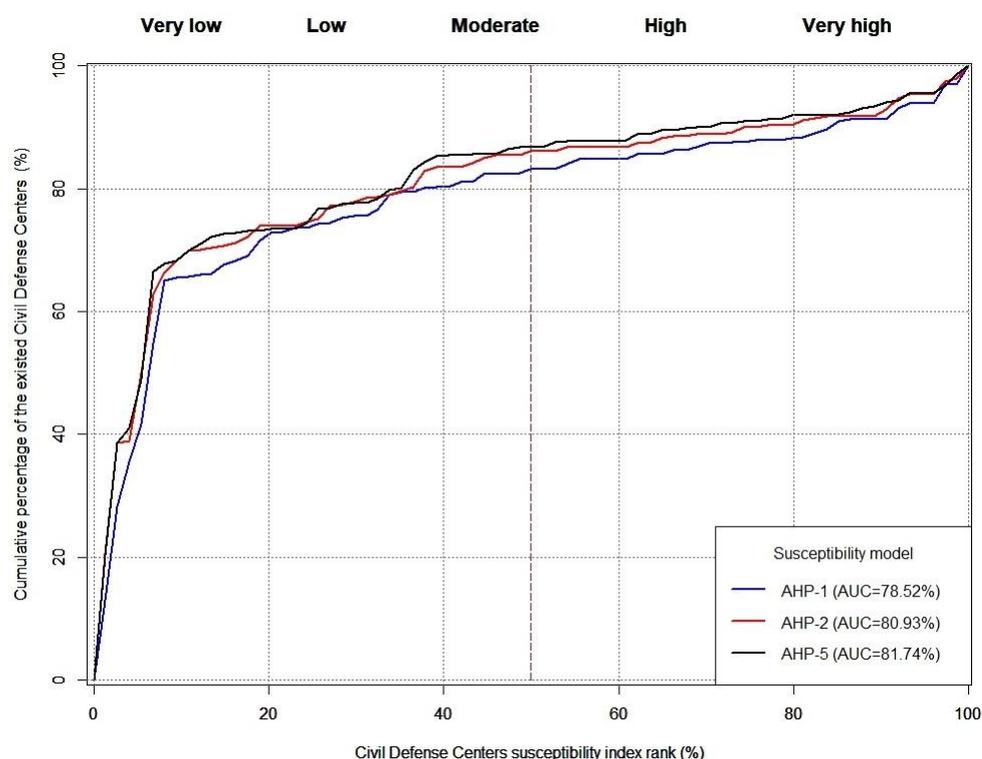


**Figure 9.** The best spatial distribution of the AHP-5 model overlain by the suggested new five CDCs.

The highest correlation was found between layers C6 and C5, which represent the distance from commercial and educational centers, respectively (Tables 5 and 6). This pair of layers had similar influences on the determination of the validity of the existing and proposed new defense centers. This allowed us to reduce the weight used by neglecting one of these layers as they act as one layer. Thus, layer C5 can be neglected as it has a strong correlation with the other layers and will depend on layer C6 (Table 3). Similarly, the layers accident density (C2) and population density (C3) have a moderate correlation (Table 3). This is logical because accidents have a direct relationship with population density. Additionally, there is a moderate correlation between distance from educational services (C6) and distance from residential areas (C8; Table 3), which is also logical because educational services are close to residential areas.

The PRC plots show that the AUC of all models increased after adding the five suggested CDCs, where AHP-1, AHP-2, and AHP-5 increased by  $\sim 0.68$ , 1.9, and 1.86, respectively (Figures 8 and 10).

This work is in agreement with [22] that the AHP method is more robust than WSM in spite of the complexity of AHP. We agreed with [53,54,64–66] that the population density is the most effective criterion to determine the CDCs' location.



**Figure 10.** PRC plot evaluation of the three best CDC models after adding the existing and proposed CDCs.

#### 4. Conclusions

An integrated approach using AHP and GIS was used in this study to provide the best model for optimally locating new civil defense centers (CDCs) in Al-Riyadh City. After evaluating the existing CDCs, it was found that they were established based on two main factors, which are distance from residential areas and distance from the road. Other factors were neglected. We tested eight factors within six models to select new proposed CDCs. Our results indicate that models AHP-1, AHP-2, and AHP-5 are acceptable estimators of the optimal localities of CDCs and the best one is model AHP-5. Adding the existing civil defense center factor led to deterioration of the results of models AHP-1, AHP-2, and AHP-5. This study recommends redistributing the CDC centers in Al-Riyadh City. Adding new CDCs is important to overcome the negative impact of the growth of Al-Riyadh City and to save the lives and property of civilians. In addition, there is a need for a clear scientific strategy for regularly locating new CDCs consistent with the rapid expansion of Al-Riyadh City. Our methods are applicable to other cities within the Kingdom of Saudi Arabia to select the best CDC sites. Including other factors, such as distance from the water supply network, is possible for future studies. In addition, to obtain better results, we recommended analyzing different types of hazards separately using multiple effective factors. The results can then be integrated in a single map.

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**Appendix A**

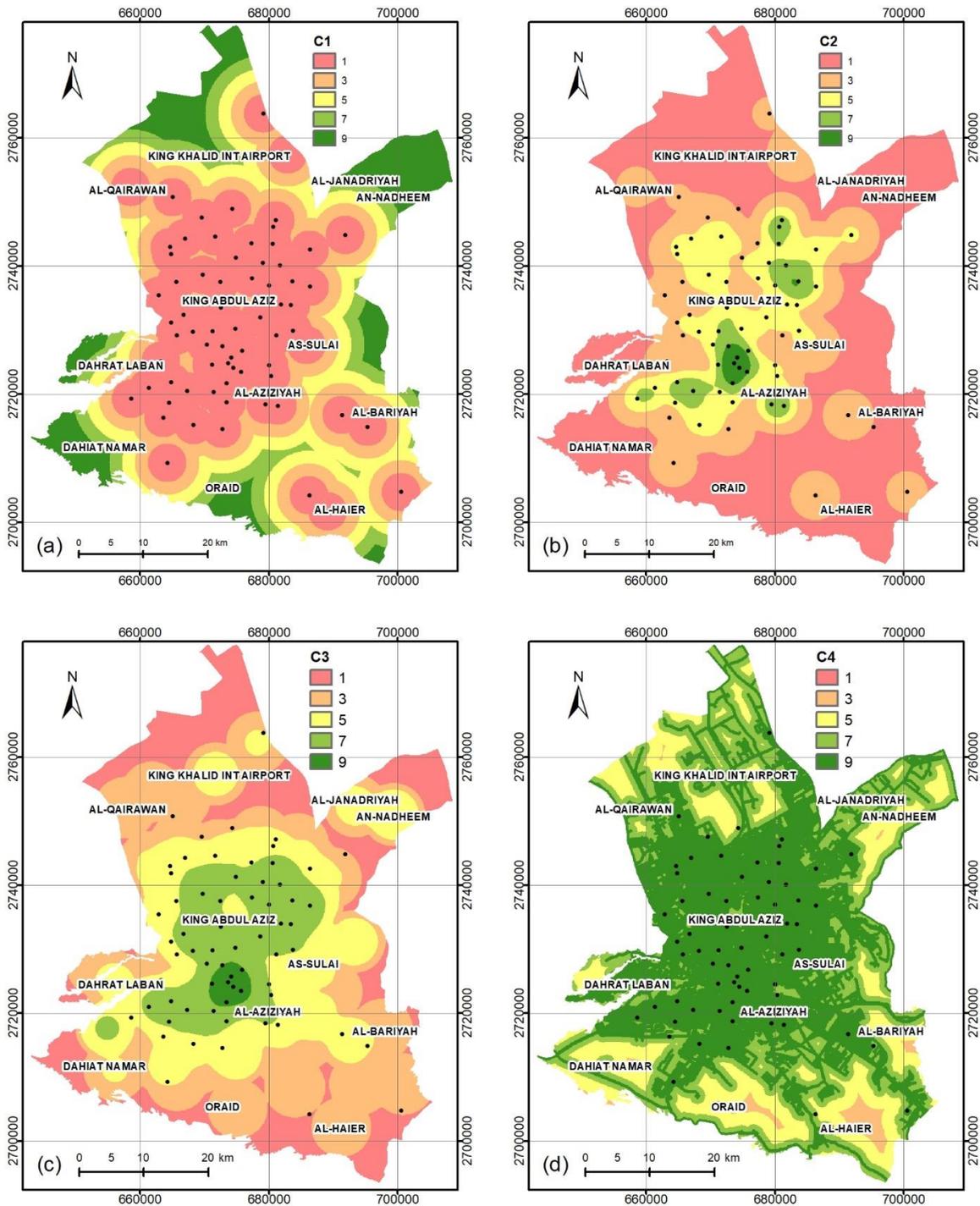
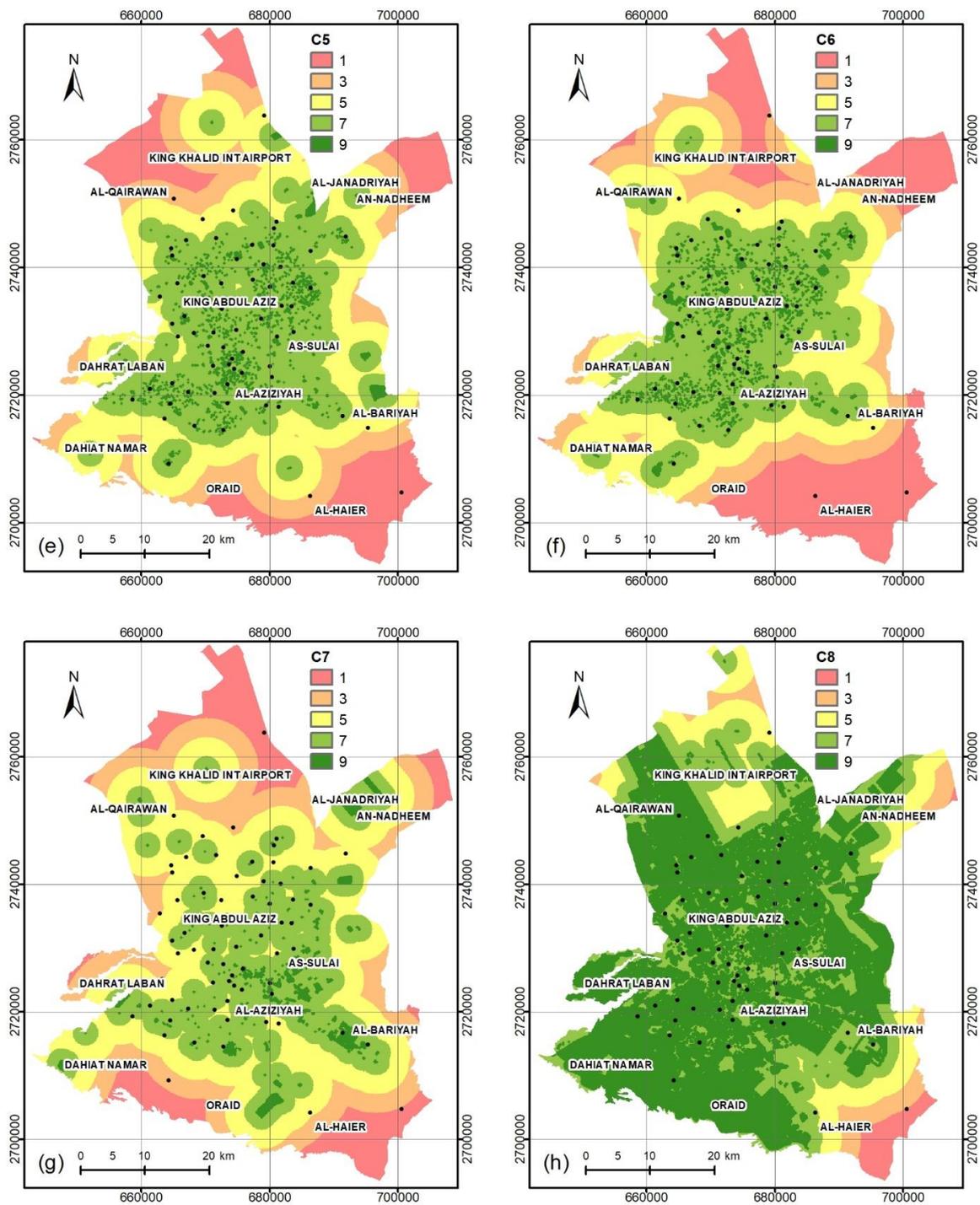


Figure A1. Cont.



**Figure A1.** The eight criteria layers: (a) distance from the civil defense center; (b) accident density; (c) population density; (d) distance from the road; (e) distance from commercial centers; (f) distance from educational services; (g) distance from industrial areas; (h) distance from residential areas.

## Appendix B. AHP Weights of the Eight Selected Factors

WSM	WSM							AHP 1	AHP 1						
	C2	C3	C4	C5	C6	C7	C8		C2	C3	C4	C5	C6	C7	C8
C2	1	1	1	1	1	1	1	C2	1	1/5	1/9	1/5	1/7	1/5	1/7
C3	1	1	1	1	1	1	1	C3	5	1	1/7	1/5	1/9	1/3	1/7
C4	1	1	1	1	1	1	1	C4	9	7	1	5	3	5	3
C5	1	1	1	1	1	1	1	C5	5	5	1/5	1	1/7	1/3	1/5
C6	1	1	1	1	1	1	1	C6	7	9	1/3	7	1	3	1/7
C7	1	1	1	1	1	1	1	C7	5	3	1/5	3	1/3	1	1/9
C8	1	1	1	1	1	1	1	C8	7	7	1/3	5	7	9	1

AHP 2	AHP 2							AHP 3	AHP 3						
	C2	C3	C4	C5	C6	C7	C8		C2	C3	C4	C5	C6	C7	C8
C2	1	1	1/7	1/9	1/9	1/9	1/9	C2	1	1	1	3	2	2	2
C3	1	1	1/7	1/9	1/9	1/9	1/9	C3	1	1	9	9	9	9	9
C4	7	7	1	7	7	7	1/3	C4	1	1/9	1	7	7	7	7
C5	9	9	1/7	1	1/9	7	1/9	C5	1/3	1/9	1/7	1	1	1	1
C6	9	9	1/7	9	1	5	1/9	C6	1/2	1/9	1/7	1	1	1	5
C7	9	9	1/7	1/7	1/5	1	1/9	C7	1/2	1/9	1/7	1	1	1	1
C8	9	9	3	9	9	9	1	C8	1/2	1/9	1/7	1	1/5	1	1

AHP 4	AHP 4							AHP 5	AHP 5						
	C2	C3	C4	C5	C6	C7	C8		C2	C3	C4	C5	C6	C7	C8
C2	1	1	1	3	2	2	2	C2	1	1	1/7	1/9	1/3	1	1/9
C3	1	1	9	9	9	9	9	C3	1	1	1/7	1/9	1/9	1	1/9
C4	1	1/9	1	1	1	1	1	C4	7	7	1	9	9	9	1/3
C5	1/3	1/9	1	1	1	1	1	C5	9	9	1/9	1	1/9	1	1/9
C6	1/2	1/9	1	1	1	1	1	C6	3	9	1/9	9	1	1	1/9
C7	1/2	1/9	1	1	1	1	1	C7	1	1	1/9	1	1	1	1/9
C8	1/2	1/9	1	1	1	1	1	C8	9	9	3	9	9	9	1

## Appendix C. The Coordinates of the Five Proposed New CDCs

No.	Location (UTM Z38N)		District Name
	X(m)	Y(m)	
1	652,000	2,710,500	Dahiat Namar
2	695,500	2,727,000	Khashm Al Ann
3	667,000	2,760,000	King Khalid Int Airport
4	696,500	2,752,500	An-Nadheem
5	654,000	2,728,500	Al-Mahdiyah

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