Analysis of Earthquake-Priority Cities in Iran Based On Clustering Methods and Evaluation of Transformation to Seismic-Resistant Cities

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ABSTRACT

Iran is an earthquake country. Large parts of the country, important industrial areas, and densely populated large cities are at risk of earthquakes. In the last century, Iran has suffered major earthquakes, with tens of thousands of people killed and hundreds of thousand buildings destroyed and damaged. The earthquake has caused massive loss of life and property to the country. Iran is not yet at the level of earthquake preparedness of a country. Millions of people are at risk in dozens of cities awaiting major urban transformations. In this article, an aggregate analysis of Iran's territories is done in the R Studio program according to the relevant parameters. Accordingly, earthquake priority cities have been identified. A road map has been unveiled for the transformation of earthquake-resistant cities into priority cities.

Index Terms— Earthquake risk, disaster management, priority cities, resilient cites, population, clustering analysis

I. INTRODUCTION

Iran is one of the oldest nations in the world, and is among the world's largest countries by population and population. The country has a population of 87,92 million and a total area of 1.648.000 km^2 [1]. In the emerging-class of Iran, the process of infrastructure development, technological breakthroughs, industrial advances, and economic development continues almost uninterrupted. Iran is in the middle of the world. This line is the nucleus of the world's oldest civilizations, and is also the line with the most livable and reasonable climate characteristics and natural riches on a global scale. Iran, Turkey, Egypt, the European Union, Russia, Pakistan, India and China are neighbors and an important juncture in their conflict.

The land of Iran, which is often deserted and mountainous, has large deserts as well as fertile agricultural land. Iran also has a rich fauna in terms of animal and plant populations. Nonetheless, Iran is an

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earthquake country, and much of its territory is located in the 1st and 2nd quake zones. Table 1 below shows the largest earthquakes recorded in Iran's history.

TABLE I

IMPORTANT EARTHQUAKES IN IRAN [2]

Date	**Center**	**Magnitude**	**Death**
12.Kas.17	Kirmanşah	7.3	620
20.Haz.90	(Manjil-Rudbar)	7.4	>40000
28.Tem.81	South Iran	7.3	1500
11.Haz.81	South Iran	6.9	300
16.Eyl.78	Tabas	7.8	15000
10.Nis.72		7.1	5054
31.Ağu.68	Daşt-e Bayaz	7.3	>7000
1.Eyl.62	Buyin Zehra	7.1	12225
13.Ara.57	Sahneh	7.1	1130
2.Tem.57	Mazenderan	7.1	1200
5.Ağu.47	Pasni	7.3	
6.May.30	Salmas	7.2	2500
1.May.29	Kopet Dağları	7.4	3800
23.Oca.09	Silakhor	7.3	6000
7 Haziran 1755	Kaşan	x	40
18 Kasım 1727	Tebriz	x	77
23 Mart 893	Erdebil	x	150
22 Aralık 856	Damgan	x	200

As shown in Table 1, more than 10 earthquakes have occurred in Iran, most of them with a magnitude of 7.0 or higher in the last century. According to official records, the number of deaths in the earthquakes was 10,000 and 4 more. Fai mobility is active in Iran and the risk of major earthquakes continues.

Figure 1 below shows a map of earthquake risk in the region of Pre-Asia, including Iran. Much of Iran, Turkey, Afghanistan, and Pakistan have similar seismic characteristics, and the risk of earthquakes is high or even high. Iraq's eastern border with Iran, along with the mountainous sections on the north-south axis, and Syria's Mediterranean coastline, are at high risk of earthquakes [3].

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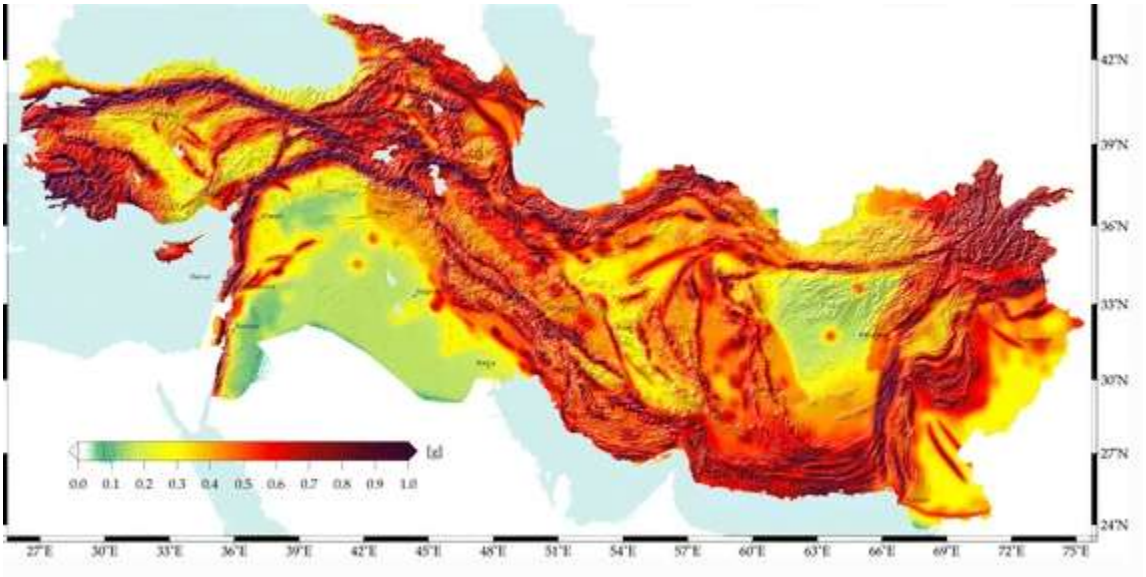

Fig. 1. South West Asia Seismic Map [3]

Iran consists of many provinces and cities with a large population and population. The shapes of the trees can show serious differences between each other. As the population density increases, the provinces tend to decrease, and the density of the population increases.

The population density in Iran's north, especially in the northwest and north-central part, is generally rising considerably. Again, Iran's western, southwestern and south-central, and relatively north-eastern areas have high population densities. However, in the interior and eastern regions, especially in the southeast, the population density can be significantly reduced. In recent years, internal migration has resulted in migration from the country's northwest and relatively inland areas, especially to the country Basra gulf coastal cities and coastal areas of the Khazarian coast and the Basra Gulf. Figure 2 below shows a map of Iran's administrative regions [4].

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Fig. 2. Iran State Map [4]

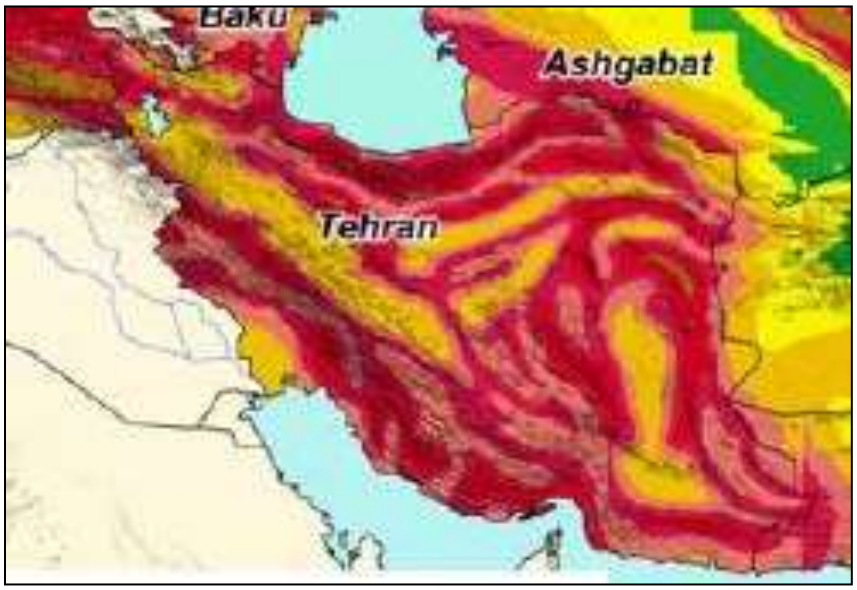

Fig. 3. Iran Seismic Map [5]

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Figure 3 above shows an earthquake risk map of Iran. It is understood that most of the country is in the 1st and 2nd-degree earthquake zone. The entire Hazar coast, much of the country's northeast, part of its northwest, a very large part of the Bara coastline, almost all of its eastern line, are at risk of major earthquakes. Some of the northwestern part of the country, inland areas adjacent to the Khazarian coast, land areas adjoining the country's southeast, the coast of Basra on the Iraqi border, the western neighborhood of the capital Tehran and, in part, the southeastern neighborhood, are relatively safe areas [5].

Prof. Dr. Naci Görür said that Turkey urgently needs to identify "earthquake-priority cities" and make scientific plans to turn them into "earthly-resistant cities". The same view applies to Iran in a similar emergency. Because Iran's risky, unsustainable, rotting structural stock, metropolis and big cities, above all, have a lot of land in the countryside. Figure 4 below shows the distribution of the Iranian earthquake risk map by province and city boundaries.

Fig. 4. Iran State Based Seismic Risk Map

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TABLE II

RISK ASSESSMENT LEGEND

E.R.	EEP	CASE
1	8	URGENT
2	6	UNSAFE
3	4	MODERATE
4	2	SAFE

Table 2 shows the risk case, earthquake emergency parameters and risk zones (ER) equalities in one list. Within this range, most of Iran's villages and cities are in the 1st and 2nd-degree earthquake zone. The central population is based on the earthquake zone in the districts where more than half of the province's population is centered. The earthquake zone with more than half of the province's landscape is at greater risk than the earthquakes zone with the city's center, but it is classified as a high-risk zone. This method has been used to obtain an Iranian provincial earthquake risk map as shown above.

Priorities should be identified for the identification of 'earthquake-priority cities' in the countries concerned, based on a number of criteria. The province's population, employment, its strategic value for the country, and population density (also a factor that increases the risk of an earthquake and its potential for destruction) make it a priority in the assessment of the country's seismic risk.

In this article, an aggregate analysis is carried out in the R program by taking into account these parameters under a specific weighting. Firstly, a road map for the regions determined by the clusters, a cost calculation has been carried out using a scientific approach.

Iran is a country with an ongoing population growth. There are many metropolises and major cities. In Iran, the population has been growing steadily over the past 50 years, and the size of the household has tended to decrease generally, including all the cities. These trends are expected to continue in the coming years, which means millions of additional demand for new housing, mainly in major cities, in Iran over the next decade, in addition to the mandatory urban transformation of existing housing. Figure 5 shows the important cities distribution of Iran [6].

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Fig. 5. Important Cities of Iran [6]

TABLE III

IRAN CITY BASED POPULATION (DENSITY), LIVABILITY AND SEISMİC RISK RATINGS [7]

City	Pop	EWM	SWM	POP DENS	EEP
Tehran	7153309	3,054	2,744	6	8
Sari	255396	2,385	2,361	5	6
Tabriz	1424641	1,243	1,482	4	6
Isfahan	1547164	0,794	0,681	2	4
Yazd	477905	0,558	0,489	1	6
Shiraz	1249942	0,53	0,856	2	6
Ahvaz	841145	0,529	0,618	3	4
Qazvin	333635	0,445	0,549	4	8
Semnan	124826	0,433	0,541	1	6
Rasht	594590	0,256	0,321	5	6
Karaj	1448075	0,187	0,105	6	8
Gorgan	244937	0,043	0,217	4	6
Ardabil	410753	0,005	-0,184	3	6
Mashhad	2307177	-0,095	-0,083	1	8
Ilam	140940	-0,115	0,278	2	4
Birjand	196982	-0,133	0,072	1	8

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Bandar Abbas	352173	-0,185	-0,352	2	6
Qom	900000	-0,258	-0,346	4	8
Bushehr	165377	-0,291	-0,439	2	6
Zanjan	357471	-0,293	-0,456	2	6
Orumiyeh	577307	-0,387	-0,666	4	8
Arak	503647	-0,426	-0,461	2	4
Sanandaj	349176	-0,475	-0,539	3	6
Hamadan	528256	-0,51	-0,385	4	4
Shahr-e Kord	129153	-0,523	-0,542	3	6
Yasuj	96786	-0,591	-0,674	2	6
Kermanshah	621100	-0,713	-0,627	4	6
Kerman	577514	-0,772	-0,882	2	4
Bojnurd	192041	-0,977	-0,866	2	8
Khorramabad	329825	-1,262	-1,512	3	6
Zahedan	551980	-2,456	-2,301	2	6

Table 3 shows city based population, population density, livability and seismic risk ratings of Iran cities [8]. Iran's population continues to grow, but at the same time its households continue to decrease steadily. Even if a household population grew in parallel with population growth, there would be a need for new housing for the country as a whole in the coming years. However, as the population increases, the need for new housing that will emerge with the decrease of the household population is even greater. This does not mean the need for new housing that will emerge with urban transformation. It's already a necessity. But, with the demographic dynamics in question, zero demand for housing, which Iran will face in the coming years, at least in the context of an increasing population and a declining household population, is a matter of its own [9].

II. MATERIALS AND METHODS

The aggregate analysis methods in the R programme will be used to select priority cities to create earthquake-resistant cities. A road map for preference of steel structures and wooden structures for earthquake priority cities, as proposed by Görür (2023), should also be established [10]. A significant portion of structures in Iran are still concrete. While steel structures have been on the market since the 2000s, the way to build housing is insufficient. The concrete material consists of concrete and iron (steel). The concrete has a high pressure resistance, while the steel has high pull resistance. With the acquisition of concrete material in the world, the construction sector has crossed a rather critical edge. It was possible to cross high openings and reach high floors during construction, along with concrete materials with high

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resistance to both the pulling and the pushing forces. In today's developing countries, skyscrapers (multi-storey structures) and wide-ranging structures (shopping centers, etc.) are quite common. It's basically not an indicator of progress. Developed countries are not the countries where skyscrapers and large structures are most common. However, it may be more appropriate for these structures to be limited to specific areas, numbers and purposes, and for large-scale buildings to be given priority to public and infrastructure buildings. The durability of the steel material is also high in both pulling and pressing strength. Steel structures and wooden structures are lighter than concrete structures. This is also prominent as a reduction in loss of life and property during an earthquake and as a facilitation in emergency search and rescue operations. It would also be much more effective to dismantle steel and wood profiles during recovery than to work on concrete debris. This could mean more efficient activity in terms of both time and workforce. Construction costs for steel structures and wooden structures are partly higher than for concrete. However, in building earthquake-resistant cities, this cost difference is a negligible difference. Because the loss of life and property in the aftermath of the earthquake means much more than that cost difference. Wooden structures can be constructed in two-storey profiles in limited areas of the city. Steel structures can also be preferred as a residential construction basis according to certain priorities.

A. Identifying Earthquake Priority Cities with Clustering Analyze in The R Program

The R analysis program incorporates the parameters given in the chart of cities in Iran. At the same time, an aggregate analysis of Iranian cities has been carried out based on these parameters.

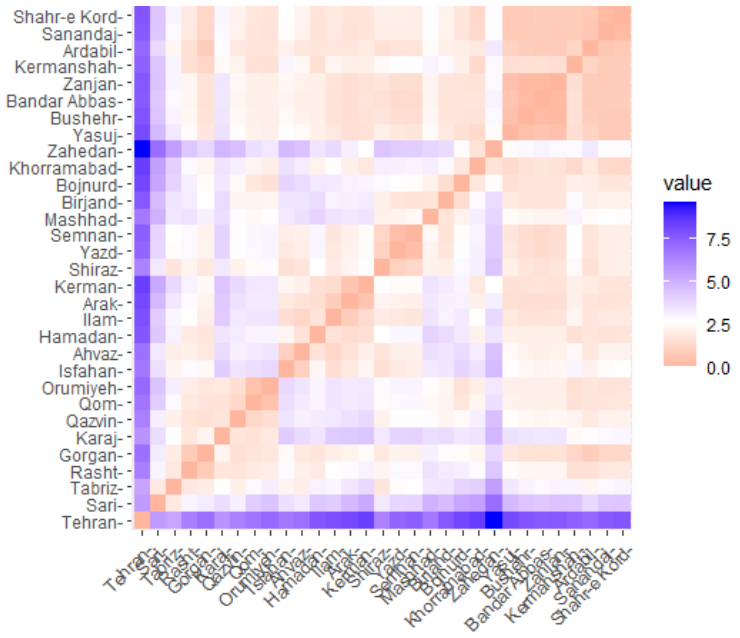

Fig. 6. Correlation Between Cities

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Figure 6 shows the correlations between the cities of Iran according to the specified parameters.

Three statistical methods are used in cumulative analysis. The K-means are the PAM and Clara methods.

K Means Method

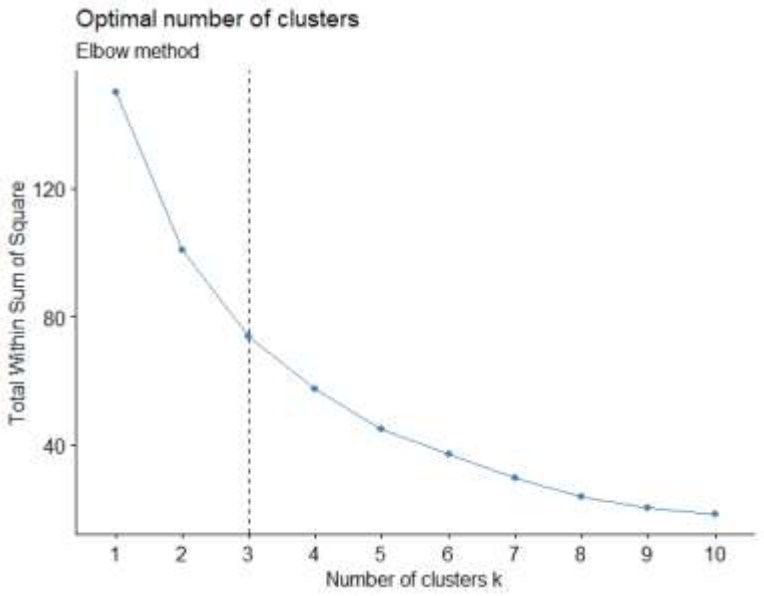

Fig. 7. Optimal Cluster Number for K Means Method

The optimum number of clusters for the K means method is shown graphically in Figure 7 above.

Cluster Visulation

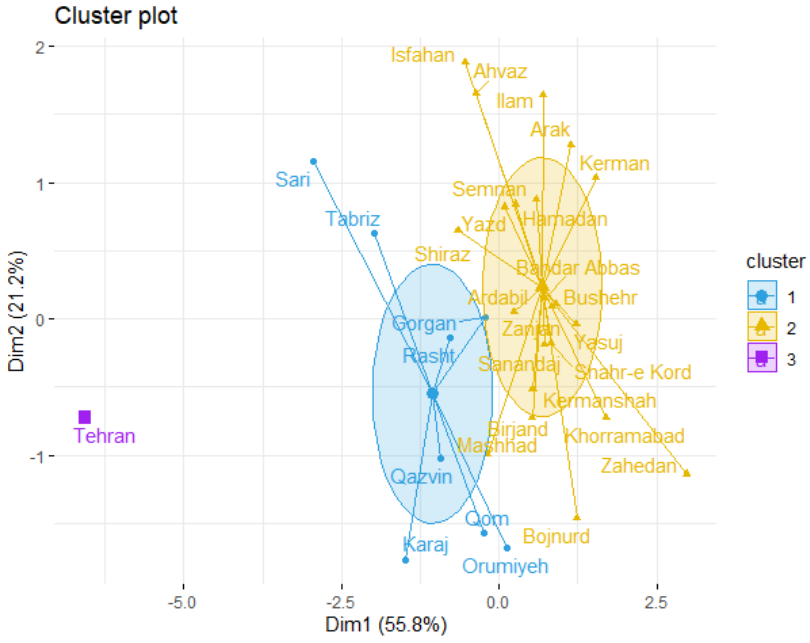

Fig. 8. Visulation of Clusters for K Means

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The cluster distribution of cities for the K means method is shown in Figure 8 above.

PAM Method

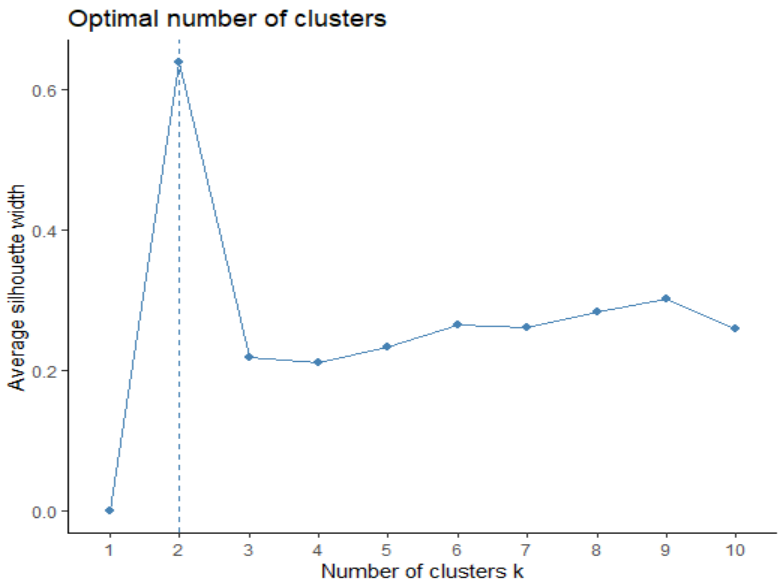

Fig. 9. Optimal Cluster Number for PAM

The optimum number of clusters for PAM method is shown graphically in Figure 9 above.

Cluster Visulation

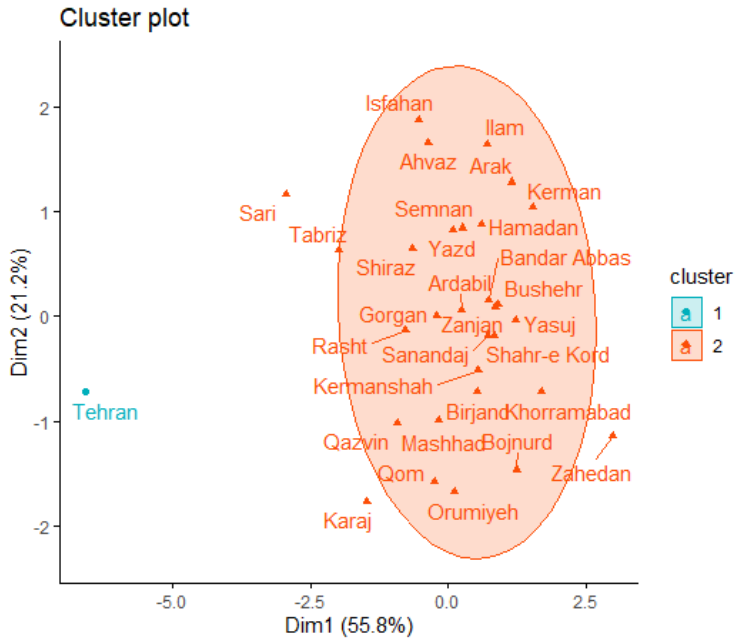

Fig. 10. Visulation of Clusters for PAM

The cluster distribution of cities for PAM method is shown in Figure 10 above.

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Clara Method

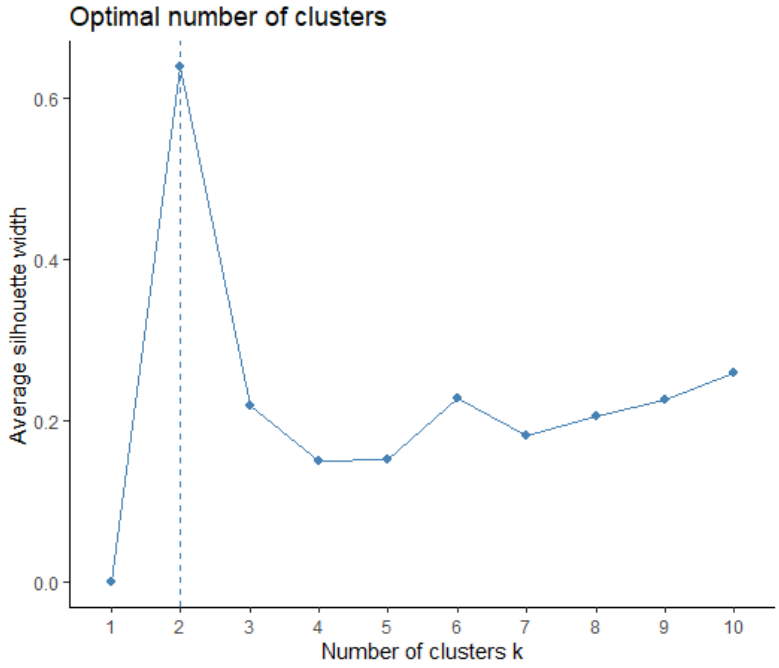

Fig. 11. Optimal Cluster Number for Clara Method

The optimum number of clusters for Clara method is shown graphically in Figure 11 above.

Cluster Visulation

Fig. 12. Visulation of Clusters for Clara Method

The cluster distribution of cities for Clara method is shown in Figure 12 above.

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III. RESULTS AND DISCUSSION

As a result of the aggregate analysis, the three-digit cluster based on the K average method is progressing in the next steps. The list of clusters is shown in the Table 4 below.

TABLE IV

LIST OF CLUSTERS AND CITY PARAMETERS

City	Population	Pop. Den.	Cluster
Tehran	7153309	6	3
Sari	255396	5	1
Tabriz	1424641	4	1
Isfahan	1547164	2	2
Yazd	477905	1	2
Shiraz	1249942	2	2
Ahvaz	841145	3	2
Qazvin	333635	4	1
Semnan	124826	1	2
Rasht	594590	5	1
Karaj	1448075	6	1
Gorgan	244937	4	1
Ardabil	410753	3	2
Mashhad	2307177	1	2
Ilam	140940	2	2
Birjand	196982	1	2
Bandar Abbas	352173	2	2
Qom	900000	4	1
Bushehr	165377	2	2
Zanjan	357471	2	2
Orumiyeh	577307	4	1
Arak	503647	2	2
Sanandaj	349176	3	2
Hamadan	528256	4	2
Shahr-e Kord	129153	3	2
Yasuj	96786	2	2
Kermanshah	621100	4	2
Kerman	577514	2	2
Bojnurd	192041	2	2
Khorramabad	329825	3	2
Zahedan	551980	2	2

Assessments conducted to determine which urban clusters are prioritized in terms of earthquake prevention according to the relevant parameters have shown that Tehran, which alone constitutes a top

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priority cluster (number three) in the terms of population, population density and earthquakes risk, as well as the number one cluster clearly stands ahead of the number two cluster in the area of population and seismic risk, while neither cluster has a clear priority to each other in the population context. Accordingly, the number 3 cluster (Tahran) and number 1 cluster should be identified as earthquake priority cities in the total of the regions assessed. Accordingly, as a result of aggregate analysis, the cities selected as earthquake priority cities are listed in the Table 5.

TABLE V

EARTHQUAKE PRIORITY URBAN AREAS

City	Population	Pop. Den.	Cluster	EEP
Tehran	7153309	6	3	8
Karaj	1448075	6	1	8
Tabriz	1424641	4	1	6
Qom	900000	4	1	8
Rasht	594590	5	1	6
Orumiyeh	577307	4	1	8
Qazvin	333635	4	1	8
Sari	255396	5	1	6
Gorgan	244937	4	1	6

Figure 13 shows Iran Eartquake Action Regions.

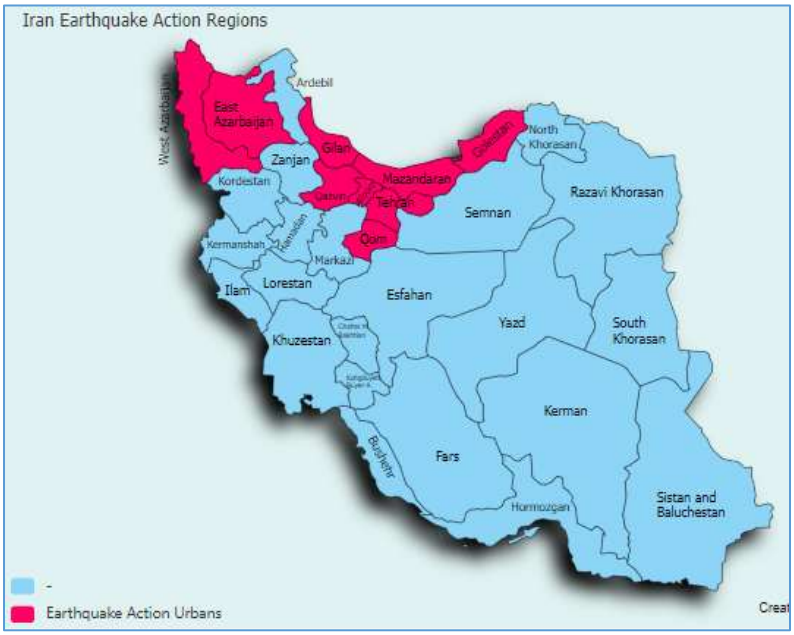

Fig. 13. Iran Earthquake Action Regions

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IV. CONCLUSIONS

In this study, a group analysis of the provinces, based on population, population density, earthquake emergency ratio and per capita GDP values, was carried out in the R programme, which included nine cities ranked 3rd (Tahran) and 1st and identified as priority cities for earthquakes. These districts are located in the northern half of the country. Together with Iran's large valleys in the northwest, the fast-growing and migratory waters off the coast of the Khazarian Sea, together with the northeastern city of Gürgan, form an area of earthquake priority cities up to the capital Tehran in the south and the surrounding area.

- To transform priority cities into earthquake-resistant cities, the existing structural stockpile should be reviewed to identify low-risk and resistant buildings, and the urban transformation process should be initiated gradually [11].
- In these cities, a detailed review and action plan should be launched for structures of strategic importance in the context of infrastructure, defence, economy, security, military, education, health, technology, or which are frequently used by people in everyday life.
- If there is an urgent need for a population relocation in these cities, new cities should be established in solid places in the war zone so as to overlap with other strategic objectives.
- In the cities concerned, taking into account population growth, birth, marriage and divorce data, domestic and external migration, changes in household size, and other socio-economic data, the additional housing needs for the target years should be calculated and the established number of housing premises should be constructed in such a way as to make the land of the properties and districts, within the framework of earthquake-oriented construction design, including steel and wooden structures, if necessary. This requires comprehensive planning.
- The identified earthquake priority cities refer to the first stage. A phased process should be carried out and other earthquake-oriented urban clusters identified for target years to be identified in further time frames. Isfahan, Shiraz, Mehed, Sanandaj could be candidate cities [12].

As a result:

- Earthquake priority cities will be transformed into earthquake-resistant cities
- solid foundations will be laid for less destruction
- a target for a significant reduction in post-earthquake loss of life and property will be decided
- a more effective search and rescue operation will be carried out in the first 3 days after the earthquakes

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- diversity and expertise in the construction sector will be expanded.
- Increased confidence in civil engineers and earthquake experts in the community
- New employment spaces for urban and transport planners will be created to make this process more effective;
- Spread of steel and timber construction
- Employment of Steel and Wood construction professionals and staff
- Legislative arrangements to facilitate and facilitate the construction of steels and wood structures
- Redistribution of the supply chain for steel & wood construction across the country from cutting-edge to logistics and the final product could be possible in the short and medium-term coverage.

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