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Application of Spatial Multi-Criteria Evaluation (SMCE) in Classification of earthquake hazard (Case study: Amol county)

Mohsen Ali zadeh[1], Ibrahim Bin Ngah Designation[1], Esmaeil Alizadeh[2], and Himan Shahabi*[3]

[1] *Department of Urban and Regional Planning, Faculty of Built Environment, Universiti Teknologi Malaysia (UTM), 81310, UTM Johor Bahru, Johor, Malaysia*

[2] *M.Sc. Student of Urban Planning, Shiraz University, Iran*

[3]*Remote Sensing Department, Faculty of Geo Information and Real estate, Universiti Teknologi Malaysia (UTM), 81310, UTM Johor Bahru, Johor, Malaysia*

Abstract

A comprehensive and reliable analysis of hazardous processes and their consequences are always required for the sustainable development of mountainous areas, and the safety of the citizens. Movement of faults caused to release the potential energy and so caused to earthquake, death, and financial damages to property of people especially in urban regions. In this way, Spatial Multi-Criteria Evaluation (SMCE) which has site evaluation structure can be evaluated earthquake events variables unlimitedly with presenting intra groups and among groups. This model has been created on the base of multivariate evaluation which is used in mathematical and statistics sciences for analyzing between different variables. While, different elements and factors are effective on estimating of capability of earthquake of a place and also the role of each factor is Spatial Multi-Criteria Evaluation has potential for assessment of all elements and effective factors of earth quaking jointly with good and rational results. In this research with using this model theories about the potential of earthquakes have been classified in Amol county, Mazandaran Province, Iran. Overall, from all area of Amol county 27.13% is lie down in high risk area and 71% is stand down in low risk area. Parameters in this classification is included fault, direction of fault, foci of earthquakes, and all recorded data from earthquake foci like magnitude of earthquake, depth, compaction, lithologic structures. The results suggest that the proposed methodology may provide a new approach for analyzing vulnerability that can add to our understanding of human/hazards interaction.

Keyword: Amol county; earthquake; Natural Hazard; Urbanism; Spatial Multi-Criteria Evaluation (SMCE).

1. Introduction

Risk is a part of life. Therefore, there is a strong need for defining a systematic framework containing the risk parameters and the urbanism parameters. As planning is a discipline, regulating the societal transformation and space formation-reformation, a risk management perspective should be added [1]. Seismic hazard, in a broad perspective, refers to any kind of phenomena related to earthquakes capable of imparting potential damages to the built and social environment. Although it is generally defined as a specified level of ground shaking, several other hazard entities such as landslides, liquefaction, and tsunamis are often associated. The hazard is significantly controlled by changes in geotechnical material properties during the earthquake. In fact, site-specific attributes related to surface geologic conditions can induce considerable alterations of the seismic motions [2, 3 and 4].

Over the past two decades, vulnerability has come to represent an essential concept in hazards research and in the development of mitigation strategies at the local, national, and international levels [5, 6, 7 and

8]. Several models of urban vulnerability have been proposed to address the various ways by which society becomes subject to hazard impacts [9, 10 and 11].

Geo-hazards cause huge loss of lives and infrastructure every year in the world and are dramatically increasing since last few decades in Iran. Several damaging Geohazards (earthquakes and landslides) that have occurred in Iran during the last two decades have clearly demonstrated their catastrophic consequences. The disastrous impact of earthquakes and landslides in Iran has been starkly illustrated in Bam (2003), Ardabil (1998) Ghaenat (1996), Manjil (1990) where thousands of people lost their lives. Many settlement areas (urban & rural) as well as Tehran, the capital city of Iran are located in the hazardous area. The present area of study, a part of northern Alborz located in North of Iran, is a high risk area with several settlements and establishments. Disastrous earthquake and landslides have been recorded in this high geo-hazard potential area. Remote sensing and GIS techniques, with other available different geological data are essential tools in detecting geo-hazards of different types and to check their activities and define their potential areas. Their effect on nearby sites could also be estimated and mitigated by certain precautions. The main objective of this research is to assess the geo-hazard and make a large scale geo-hazard map for the study area, based on recent Remote Sensing information on a GIS platform.

The value of GIS in supporting urban vulnerability analysis arises directly from the benefit of integrating a technology designed to support spatial decision making into a field with a strong need to address numerous critical spatial decisions [12]. For this reason, there has been a growing interest in applying GIS and spatial analytical models to vulnerability and risk analyses. This is evidenced by an increasing number of published articles on this topic [13, 14, 15, 16, 17, 18 and 19].

One of the major deficiencies in current GIS approaches to vulnerability analysis is that many models apply deductive, well-structured problem-solving methodologies to the inherently ill structured problem of vulnerability.

Iran is among the countries where the majority of cities and facility location selection, regardless of the medium seismicity can be taken. Given this understanding of Iran, Amol as a case study has been analyzed in this research. In this study, tried to separate the earthquake hazard zones with aid of several factors to be ranked zones and it is important to examine. Combining elements of effective parameters on events in the city by multivariate spatial method has been mentioned the seismic zonation maps of the city.

2. Study area

Amol is a city in and the capital of Amol County, Mazandaran Province, Iran. The Amol city located in 36°23'N latitude and 52°20'E longitude. At the 2006 census, its population was 197,470, in 55,183 families [20]. Amol and the old part of town is the first of the four towns that populate the world in which there is Nzamyh. Amol is a city of strategic accounts from beginning to end. Amol is located on the Haraz river bank. It is less than 20 kilometres (12 mi) south of the Caspian Sea and less than 10 kilometres (6.2 mi) north of the Alborz mountains (Fig. 1).

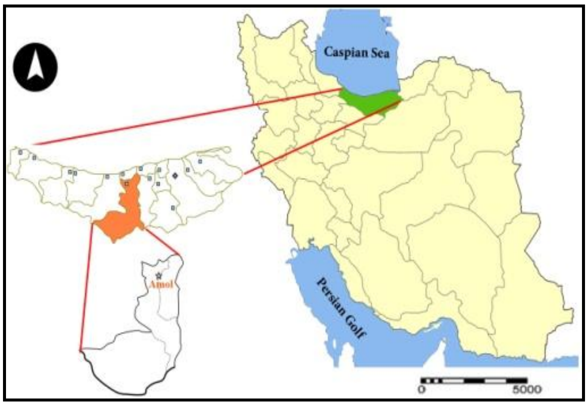

Fig. 1. Geographical position of study area

3. Material and Methods

In this study, base maps, and other information related to the various provinces is used including topographic and geological map 1:250,000 scale, manage Spatial Multi-Criteria Evaluation model in a series of software structures of GIS. The sample program spatial multi-criteria evaluation is performed in ILWIS 3.3 software. In order to establish this model, the data were first collected geo-referenced digital data related to the environment are effective in identifying possible seismicity. The geo-referenced digital data and data layers include:

- **Lineaments**
- **earthquake magnitude**
- **earthquake density**
- **shallow earthquakes**
- **lithologic structure** (Geology series are classified according to withstand seismic waves) [21].

The fifth parameter, the main parameters according to the availability of data for spatial multi-criteria evaluation model for seismic zonation used in the city of Amol. The second phase of data identification is a conceptual model in order to reach the target. The conceptual model used in this study was based on previous studies on the use of seismic parameters and using top earthquake experts, is provided. Software used to prepare a conceptual model, is Rational Rose software and power transmission models are designed to meet the GIS program (Fig. 2).

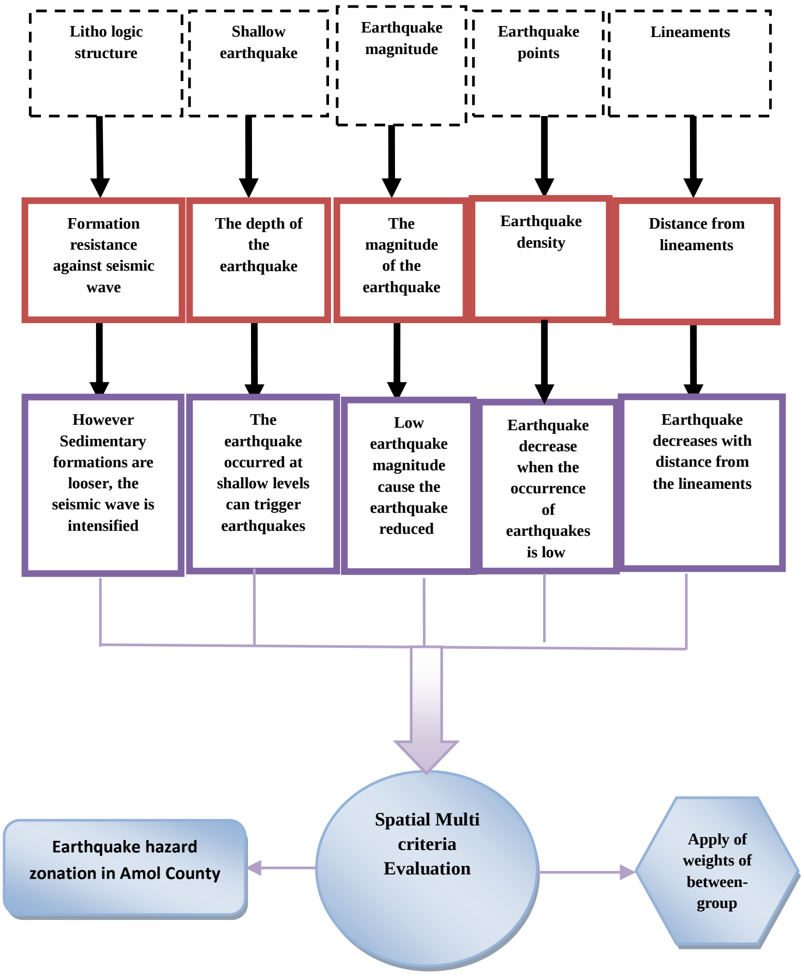

Fig.2. Overview of the conceptual model of spatial multi-criteria evaluation for earthquake zonation of Amol County

Based on this model, layer structure model fits the data and application environment and software were analyzed. The third step is to analyze impacts and alternatives. To analyze the effects of each of the options as active components in the environment of geographical information system was crossed and maps each item in the map for each of the components of the environment, were crossed. The crosses were made as raster maps in GIS. A new map is obtained by performing a cross with a table that shows the location and description of the development. The importance of values and qualities shows in Table 1.

Table 1: Significance levels for earthquake hazard zonation [21]

Cost	The value of importance	Benefit
Very damaging effect	5	Very beneficial effect
Damaging effect	4	The beneficial effects
Damaging effect of moderate	3	The beneficial effects of moderate
Negative effect of poor	2	The beneficial effects of poor
Negative effect of poor	1	The beneficial effects of slight
No effect	0	No effect

Then create two columns and values between 0 and 5 are identified useful or harmful effects on the environment. The two columns under the column titles and column advantage is cost.

This column is used for two-way SMCE or negative sign of each layer in the overall planning of different dimensions cannot be involved. But positive effects and negative effects in the form of layers or strata benefit costs are considered. Then, based on the values of these two columns, the final plan will be drawn.

The fourth step is to standardize the parameters given in the paper. Sign ILWIS-SMCE maps with different features are contained. So they need to be standardized. The system maps all properties to have values between zero and a standard. There are three standard methods in ILWIS-SMCE:

A) Standard quantitative map B) standard Boolean maps C) maps with quality standards [22].

In this study, A method used because input map was numeric. In the standard method, by a linear function of the minimum and maximum values of the map uses occur. Positive values are costs and benefits of this standard. Standard values are between zero and one. Inputs to the system are the costs and benefits of the standard maps. Ties used in this way benefit plans are as follows:

Benefit impact = (value – minimum input value) / (maximum input value – minimum input value)
Cost impact = 1- (value – minimum input value) / (maximum input value – minimum input value)

The fifth stage is the weighting parameters used in the study. Criteria for prioritizing between different zones earthquake hazard criteria are assigned a weight. The relative weighting is the criteria for prioritizing. In this compared with dual weighting system was ILWIS-SMCE. Weight values are between zero and one that normally are applied in the calculations. In this research used the AHP method for weighting of parameters.

In Analytical hierarchy process (AHP) all criteria and factors are doubled up and are compared and result are registered in a weighting index matrix. There are nine scales ranging from 1 to 9 that gradually show priority factors. One means equal values while 9 mean the maximum priority (Table 2).

Table 2: Pair-wise comparison 9-point rating scale [23]

Importance	Definition	Explanation
1	Equal importance	Contribution to objective is equal
3	Moderate importance	Attribute is slightly favored over another
5	Strong importance	Attribute is strongly favored over another
7	Very strong importance	Attribute is very strongly favored over another
9	Extreme importance	Evidence favoring one attribute is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values	When compromise is needed

This study will make use of the AHP method because of its precision, ease of use, and because of its ready availability as a built-in tool within Expert Choice software. Factor weights for each criterion are determined by a pair-wise comparison matrix as described by Saaty (1977) and Saaty and Vargas (2001) [23, 24]. The method employs an underlying 9-point recording scale to rate the relative preference on a one-to-one basis of each criteria [25].

4. Results and Discussion

Today's location of residence and establishment of new centers, the economic factors are considered. And against the land of cheap natural forces are ignored. It said that more than 90% damage to buildings and architectural alternatives is not relevant. But incorrect positioning or lack of environmental planning and performing financial and human make-up will cause severe damage [26].

Most engineers are completely unaware of the consequences of natural hazards such as earthquakes and more attention to building strength in knowing if the land on which the city is built. Zoning earthquake-prone areas of useful measures to reduce the severity of the damages is considered, it is hereby be limited use of high-risk areas. Construction of some buildings in these zones can prevent by identifying risk zones in cities in low-risk areas of vital arteries decided. Lineaments as seismic sources, including plate movements and withdrawal are major factors, thus, away from the faults could be considered as one of the main parameters of seismicity. Location of faults in Amol county and weighting based on distance from the fault; the county is considered a moderate seismicity (Fig. 3 and Table 3).

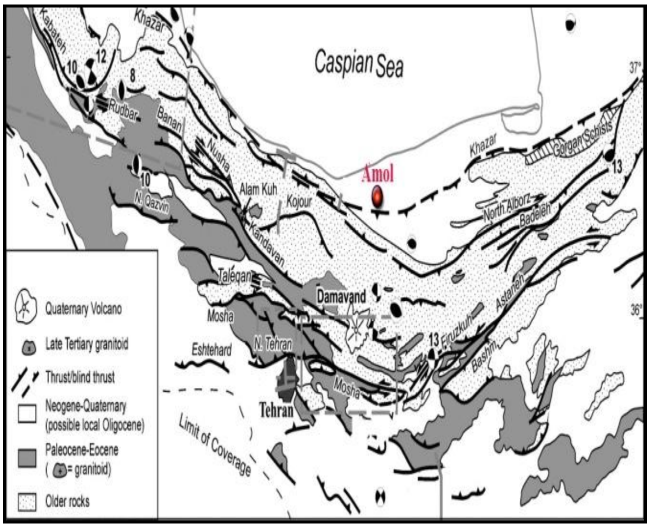

Fig. 3. Geology of the Alborz and, inset, its location within the Arabia–Eurasia collision. Geology derived from the National Iranian Oil Company (1977, 1978) [27, 28], and location of Amol in northern Alborz.

Table 3: Value weighted according to the distance from fault lines.

Factor	Fault		
Distance to Fault (km)	0-30	30-50	50<
The value of weight	3	2	1

Assessment centers and spatial distribution of seismic units as well as the density of the earthquake happening in the Amol county, indicating that this is a 29.5% of the province's total area is high densely and 35% of the county area in the event of an earthquake zone, with less density. Evaluation of earthquake magnitude and intensity of earthquakes occurred in the Amol County, indicating moderate earthquakes during the period. Magnitude of earthquake in the Amol County shows that low intensity earthquake zones in southern and south-western areas of the province have been broadcast sporadically (Table 3 and Figure 3). The depth of the seismic event, including important elements of earthquake severely damaged. It is closer to the surface, the intensity and destructive power of earthquakes occurred in the lower levels are higher. Geologic and litho logic conditions, in terms of the behavior of seismic waves, the most important environmental parameters on the occurrence of an earthquake [29].

4.1. Geologic and lithologic conditions

Overall structural relief from the Alborz Mountains to the southernmost Caspian basement is ~25 km. It is a part of the Alpine-Himalayan organic belt in Western Asia, which is bounded by Caspian Sea on the north and Central Iran on the south [30]. The study area is a small part of the central Alborz Mountain consisting of dolomite, limestone, shale and sandstone. It is marked by a number of thrusts that are oriented in east-west and northeast-southwest direction. The major structures such as thrust and faults that have been considered as important parameters for the earthquake studies have been discussed. The area of investigation is traversed by number of thrust of regional extent, which generally shows NW-SE with northeasterly dips varying 30-59 degree. The various litho-units of area have been displaced by a number of faults. Most of these faults are transverse with reference of the thrusts. It is observed that geology, geomorphology and geo-structure condition in area causing the vulnerable zone for earthquake and landslide hazard risk [31]. Further any change in this condition had brought about adverse environmental implications (Table.4).

Table 4: The weight of the litho logy of study area

Strength level earthquake (according to Richter)	Terraces and alluvial	Dolomite	Shale	Phyllite	Limestone	Sandstone
The value of weight	2	2	2	1	1	1

The Alborz Mountains range from the southern end of the Talesh to its junction with the Kopeh Dagat. The overall trend of the mountains changes from N110°E in the western Alborz to N80°E in the eastern Alborz, and a marked hinge occurs near longitude 52.5°E. According to Jackson et al. [30], most of the focal mechanisms in this mountain belt show either reverse faulting or left-lateral strike-slip on faults parallel to the regional strike of the belt [32] (Fig. 4).

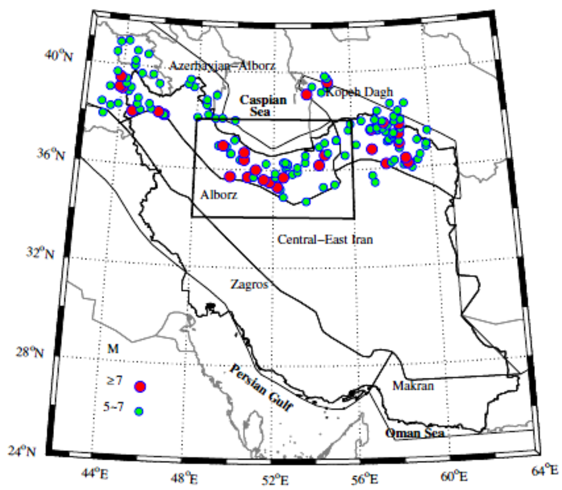

Fig. 4. Five different tectonic zones of Iran suggested by Mirzaei et al. [33] and the seismicity of Northern Iran region (M>5.0).

Almost all significant earthquakes in the region were analyzed considering the events occurred in a long period of time, form 1990 to 2009. These earthquakes were recorded at different stations; located in the Alborz region, Northern Iran and covered a wide range of hypo central distances (Fig. 5).

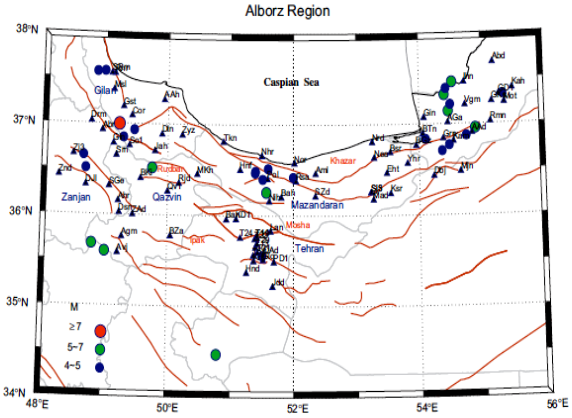

Fig. 5. Epicenter location of the earthquakes analyzed for the present study (circles), strong-motion stations (triangles) and active faults in each part (red solid-line). Light gray lines show the province boundaries [32].

In other words, some parameters such as distance from the fault, a high number indicates the environmental benefits and low numbers indicate the loss (cost) and high environmental risk, the seismic (Figures 6 and 7). In the next stage of development, therefore, must be applied between the parameters and weights between groups. This weighting is based on the data collection is done by the software [21].

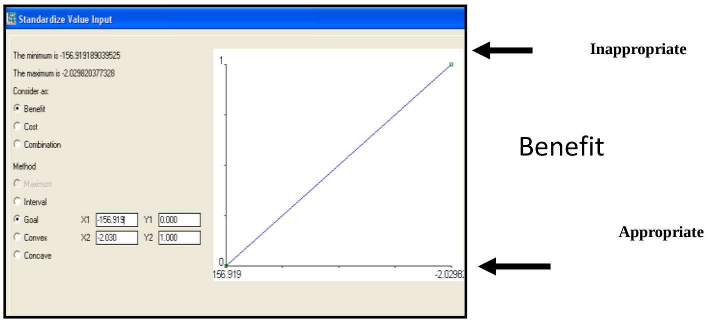

Fig. 6. The weighting of each parameter to study the seismic zonation by using Benefit method

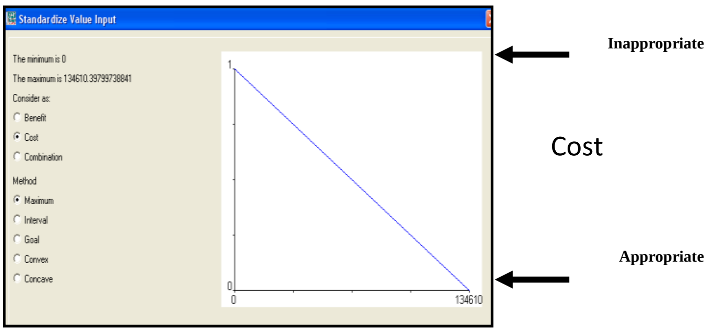

Fig. 7. The weighting of each parameter to study the seismic zonation by using Cost method

The next step should be applied weights between the parameters of groups. (Table. 5).

Table 5: The weighting of the layers

The name of Layer	Distance from active faults and seismic	Lithologic structure	The depth of the earthquake	The magnitude earthquakes	Density based on the severity of earthquake ground motion
Weight	8	4	3	7	4

❖ The numbers are normalized based on the number 1

Final map, map of earthquake hazard maps as summarizing the effects of cost and benefit plans may be affected in all groups. Map values are between zero and one and areas closer to the one that has the most benefit for programs and practices (Fig. 8).

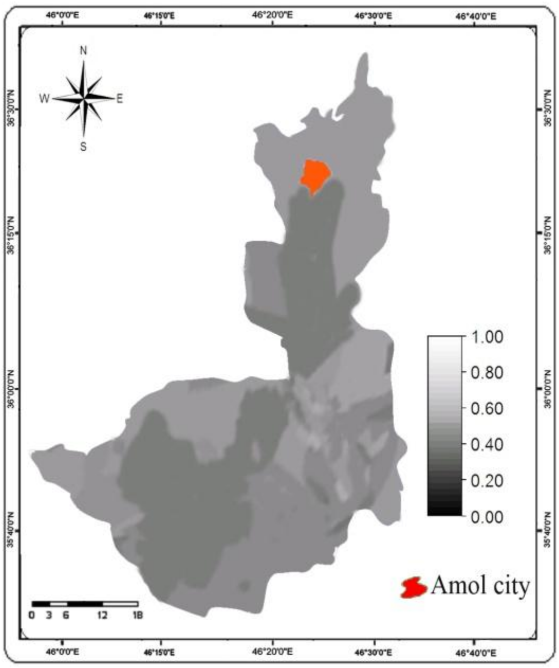

Fig. 8. Seismic zoning map of the Amol county using spatial multi-criteria evaluation

5. Conclusion

Based on the brief statistical analysis of historical earthquake damages and building types, Iran was ranked as one of the highest seismic vulnerable countries in the world. Analyses of spatial multi-criteria problems are designed based on geographic information system in decision-making and evaluation criteria. Multivariate assessment model can integrate spatial information because the different structures in order to achieve a goal, the seismic zonation of Amol county was used for the result of this research. Amol county earthquake seismicity can be divided into two regions, North and South. In total, 27.13% county is in the high-risk zone, 71% in the low-risk zone. County can be divided into three parallel bar include South Strip area covering high risk, Bar area in the county center area is moderate in earthquake hazard and northern area is low seismic risk and from south to north and from west to east of the county will be reduced relative risk of earthquakes. Young Arbors thrust zone earthquakes compliance with the above, it is suggested that the most important earthquakes associated with this fault occurs. Based on this research, GIS ILWIS-SMCE by multiple criteria analysis techniques are able to make decisions and choices of spatial data such as maps that this ability is important in science, planning and evaluation.

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