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APPLICATION OF GIS AND AHP TECHNIQUE IN EVALUATION OF EXPOSURE INDEX FOR COMMON NATURE DISASTERS ASSESSMENT. A CASE STUDY IN VU GIA - THU BON RIVER BASIN

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Abstract

Vietnam is one of the most affected countries from natural disasters and climate change. In this context, frequent natural disasters are flooding, tropical depression, drought, saline intrusion, and others. With the influent of climate change, the impact of natural disaster is higher and increase the losses of social - economics. To prevent and reduce the risk of disaster, the International Panel of Climate Change [1] issued a framework of disaster risk assessment, which includes 3 components: Hazard, Exposure, and Vulnerability. Exposure evaluation is complicated, with many socio - economic and human factors. To overcome the difficulty, this research using GIS combined with multi - criteria analysis in Exposure evaluation. The study area is Vu Gia - Thu Bon, one of the largest river basins in the Central Coast of Vietnam. The result of the research is the maps of the Exposure index, which are very useful in natural disaster risk assessment. Three aspects of components combine the Exposure index are: Human live, Economic and Social. Each component has been evaluated independently from 5 indicators, which described the exposure of 5 types of the natural disaster which frequently occur in the study area. The study area is Vu Gia - Thu Bon river basin, which stayed in between Da Nang and Quang Nam provinces. The AHP technique is applied in 3 levels. The results show the exciting and reasonable of the Exposure index and its components. That given a strongly basic to applying GIS and AHP in Disaster Risk assessment in general and particularly in Exposure evaluation.

Keywords: Hazard; Exposure; Vulnerability; GIS and AHP technique.

1. Introduction

Vietnam is one of the most affected countries by climate change in the world. The natural disasters occurred with increasing frequency year by year, and the consequence is the increasing of disaster risks. Therefore, disaster risk management is essential to provide risk reduction and prevention. In [1, 2] defined risk should be assessed from 3 components: Hazard, Vulnerability, and Exposure. The assessment of those components is complicated with the multi-factor relationship. In various researches about the Exposure index in Vietnam, the index is assessed by the qualitative method. This method is quite easy to apply, and the data requirement is not very high. The previous researches in Vietnam focused on social factors but not economic and human. In our research, we use the multicriteria analysis with AHP to evaluate the Exposure index with social, economic, and human life aspects.

2. Background

2.1. The Exposure index.

The disaster risk is a combination of three components R = f(Hazard, Exposure, Vulnerability) [1]. The exposure index of natural hazard is used to present the location of people, livelihood, environmental service and resources, the infrastructure of economic, social, cultural assets in places that could be adversely affected by physical events and which, thereby, are subject to potential future harm, loss, or damage [1]. The Exposure is needed but not enough to define the risk.

The time and scale are critical factors to assess disaster risk exposure. If people present in the exposure area, the people's exposure index increases. In the case of the early alarm system worked, the people in hazard areas are evacuated, the exposure index is lowered [1]. For example, in Ketsana tropical storm, 2009, the evacuation of 60.000 people in Quang Nam province is the primary factor in reducing the damage on people and economic [3].

In Vietnam, the resident's relocation program in floodplain and bank erosion areas in Mekong delta is one of the best examples to reduce the Exposure of people in hazard zone [4]. The relocation is reducing the Exposure but not the Vulnerability of the community. If the flood is higher than the relocated areas, the flood risk still occurred. Therefore, to reduce the risk, it needs to reduce both Exposure and Vulnerability.

In many types of research on disaster risk assessment in Vietnam, the exposure index is quite an unfamiliar concept in disaster risk assessment study. Many types of research are based on Vulnerability - capacity assessment [5 - 7] rather than the newer system from IPCC 2012 [1]. But recently, there are several kinds of research adopted the concept of Exposure in risk assessments [8, 9].

2.2. GIS and AHP technique

The GIS application is using in various fields of studies, especially in earth sciences and related topics. In nature disaster risk assessment, GIS has been widely using in the estimation of risk components (Hazard, Exposure, and Vulnerability) [10 - 15]. It also used in disaster damage estimation such as flooding damages [16, 17, 18, 19]. GIS has become an integrated approach to disaster risk management [20].

Thomas develops the AHP technique Saaty [21]. The technique is using in Multi - criteria analysis, which helps to solve the complex problem in social and economic studies [22 - 24]. The GIS analytical and spatial decision - makers quickly found the use of AHP and multicriteria analysis in solving complex spatial decision problems [25]. This technique also applied in several kinds of research related to natural disaster risk assessment [26, 27, 28, 29].

2.3. Study area

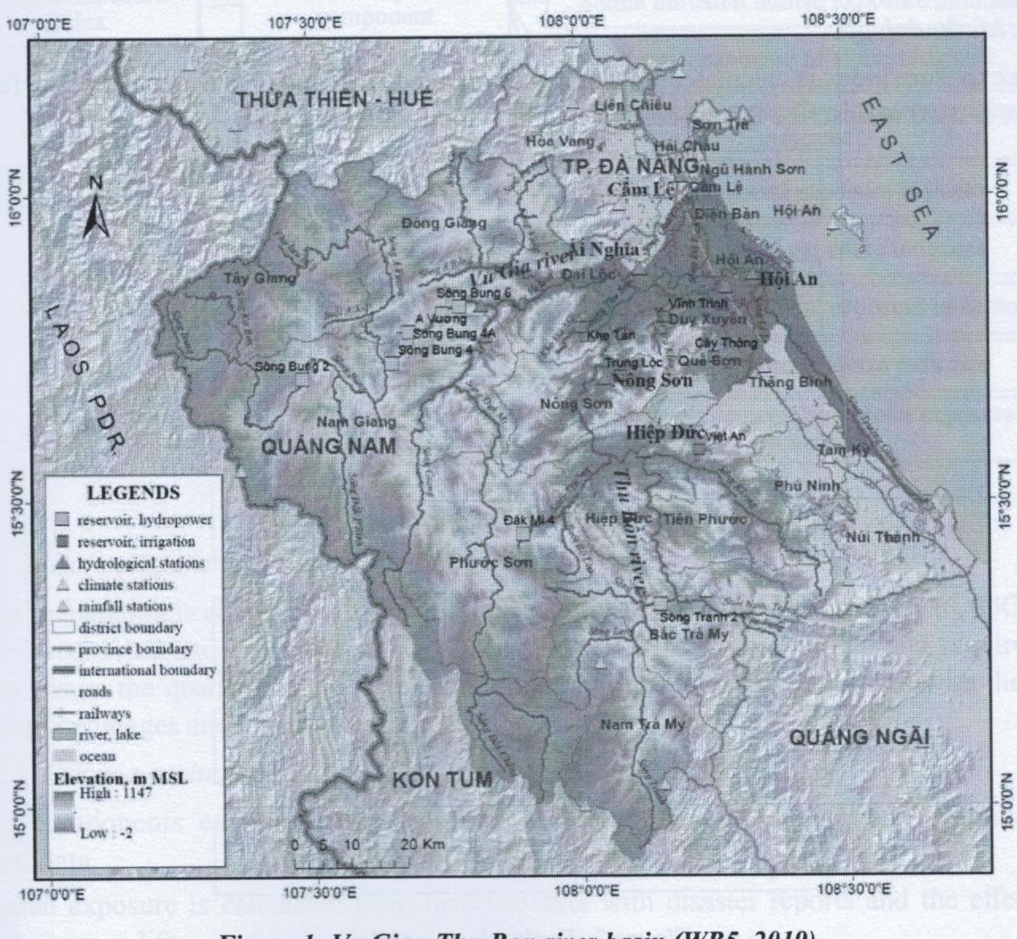

Figure 1: Vu Gia - Thu Bon river basin (WB5, 2019)

The Vu Gia - Thu Bon (VGTB) river basin has an area of 10,350 km^2. Approximately 9,000 km^2 (87%) of the watershed falls is in Quang Nam Province, 790 km^2 (8%) is in Da Nang City, and the remaining 560 km^2 (5%) is in Kon Tum Province. The total length of rivers in the VGTB basin is 900 km. There are two main rivers: the Vu Gia and the Thu Bon. The rivers originate near the border of the Lao Peoples Democratic Republic and flow into the Eastern Sea via the Dai and Han Rivers located near Hoi An and Da Nang. The primary river system data are summarized in the next table. The watershed is characterized as "short and steep". The riverbeds in upstream areas are steep and narrow, while the midland areas have wide and shallow riverbeds.

3. Data and methodology

3.1. Data

In this research, we have collected data from several sources, mostly from the Ministry of Nature Resources and Environment. There are two categories of data are using in the research.

Spatial data:

- Land use maps of Quang Nam and Da Nang, date 2015 from MONRE.
- Transportation, residential and hydrological system collected from Open Street Maps.
- Landsat ortho images.

Non - Spatial data

- Statistical data of commune level: socio - economic, population, labor,…
- The statistical of disaster damage of the river basin from 2009 - 2017.

3.2. Methodology

The exposure index is calculated by using an integrated AHP and GIS techniques. The following workflow is used to describe the process to calculate the Exposure index.

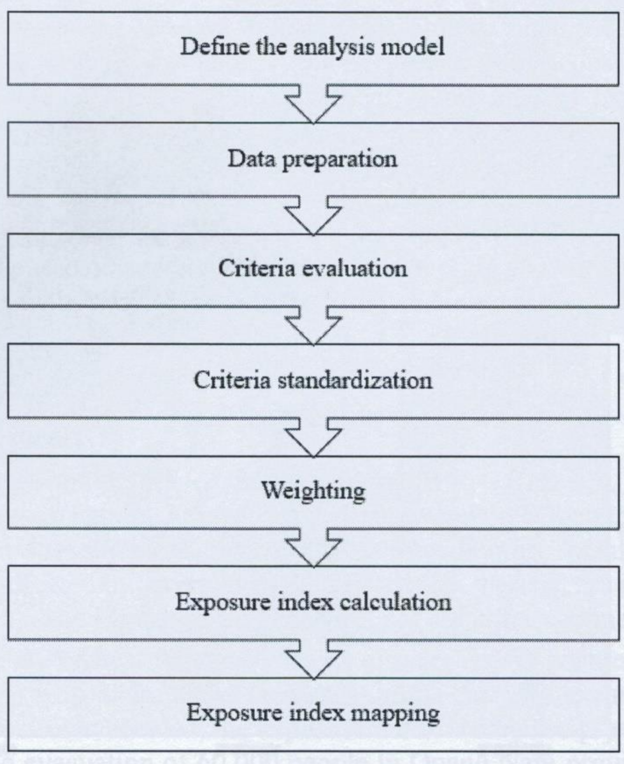

Figure 2: Evaluation workflow

3.2.1. Define the analysis model

The Analysis model is defined by evaluating the disaster risk in the study area. The evaluation based on the disaster risk reports is collected from the local authorities. Those reports and data are filtered, classified, and using statistical tools to calculate the frequency of each type of disaster. Based on this result, the most affected disasters are selected and put in the research. There are 5 types of disaster selected and calculated the exposure: Storm, Flooding, Drought, Saline intrusion, and Extremely temperature.

The AHP model is defined base on three types of disaster damages: human, social, and economic damages. The AHP tree is described in the following figure.

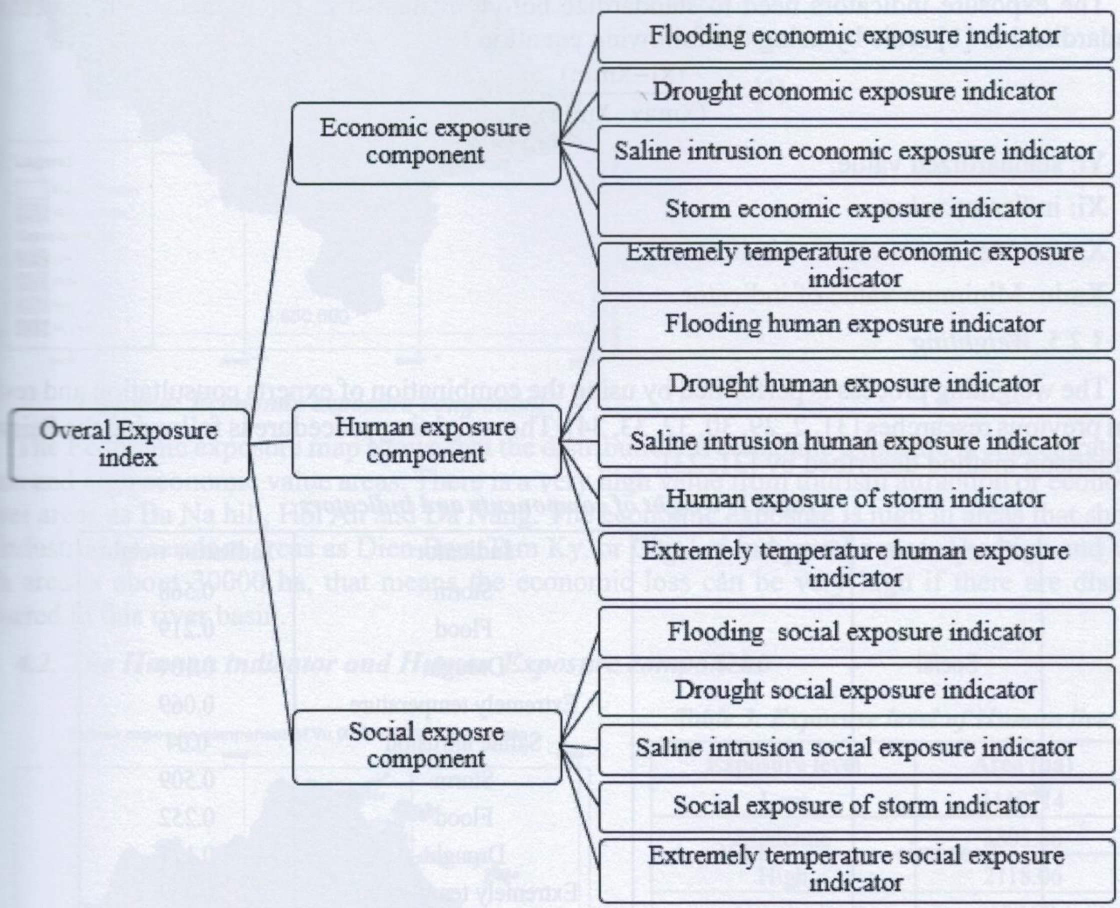

Figure 3: AHP tree of Exposure index evaluation

3.2.2. Data preparation

Data preparation is conduct by using GIS packages. The data with various formats (DGN, SHP, OSM) are converted and organized in ESRI geodatabase. This step is critical and required many efforts to ensure the quality of data. The data editing and updating are performed with the help of online satellite images and Landsat orthoimages.

3.2.3. Criteria evaluation

The components exposure include Human, Economic, and Social, are evaluated from statistical data.

Human exposure is calculated from land-use data with disaster reports and the effect of the disaster on human life.

Economic exposure is calculated from economic value, which can be affected by disasters. The value of damageable is evaluated from statistical data and disaster reports.

The last exposure components are Social is evaluated by the ranking method using [30] system.

Those exposure components are combined by using a simple weighting sum as the following equation.

$$Ej = E_1 x W_1 + E_2 x W_2 + E_3 x W_3 + E_4 x W_4 + E_5 x\ W_5 \qquad \text{(E.q 1)}$$

Ej: Exposure components (Human, Economic, Social)

Ei: Exposre indicators.

3.2.4. Standardization

The exposure indicators need to standardize before evaluated in the model. Each indicator is standardized to [1] scale by using the following equation.

$$Yi = \frac{(Xi - Xmin)}{(Xmax - Xmin)} \qquad \text{(E.q 2)}$$

Yi: standardized value.

Xi: indicator value

Xmax: Maximum value of indicator

Xmin: Minimum value of indicator

3.2.5. Weighting

The weighting process is performed by using the combination of experts consultation and review from previous researches [31, 2, 29, 30, 32, 33, 34]. The weighting procedure is following the Pairwise comparison method described by [21, 23].

Table 1. Weight of components and indicators

Components	Component weight	Indicator	Indicator weight
		Storm	0.568
		Flood	0.219
Social	0.238	Drought	0.104
		Extremely temperature	0.069
		Saline intrusion	0.04
		Storm	0.509
		Flood	0.252
Economic	0.136	Drought	0.121
		Extremely temperature	0.079
		Saline intrusion	0.039
		Storm	0.423
		Flood	0.307
Human	0.625	Drought	0.174
		Extremely temperature	0.039
		Saline intrusion	0.057

3.2.6. Exposure index calculation

The Exposure index is calculated by applying the simple weighted sum method, which is using the following equation.

$$E = E_{j1} x W_{j1} + E_{j2} x W_{j2} + E_{j3} x W_{j3} \qquad \text{(E.q 3)}$$

E: Exposure index

Eij: Exposure components (Human, Economic, Social)

4. Result and discussion

4.1. The Economic indicator and Economic exposure component

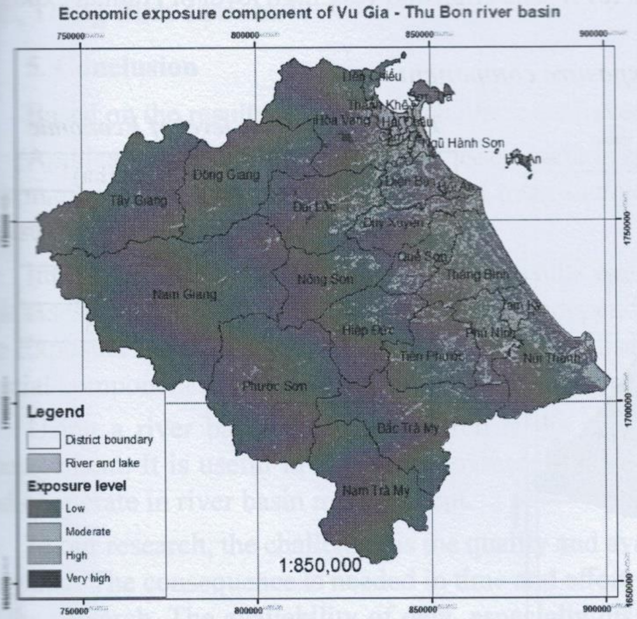

Figure 4: Economic exposure component

Table 2. Exposure level of Economic

Exposure level	Area (ha)
Low	1074286
Moderate	54470
High	25877.28
Very high	3853.93

The Economic exposure map shows that the distribution of economic exposure is concentrated in urban and high economic value areas. There is a very high value from tourism attraction or economic center areas as Ba Na hill, Hoi An and Da Nang. The economic exposure is high in areas that should be industrial or services areas as Dien Ban, Tam Ky, or Chu Lai industrial zones. The high and very high area is about 30000 ha, that means the economic loss can be very high if there are disaster occurred in this river basin.

4.2. The Human indicator and Human Exposure component

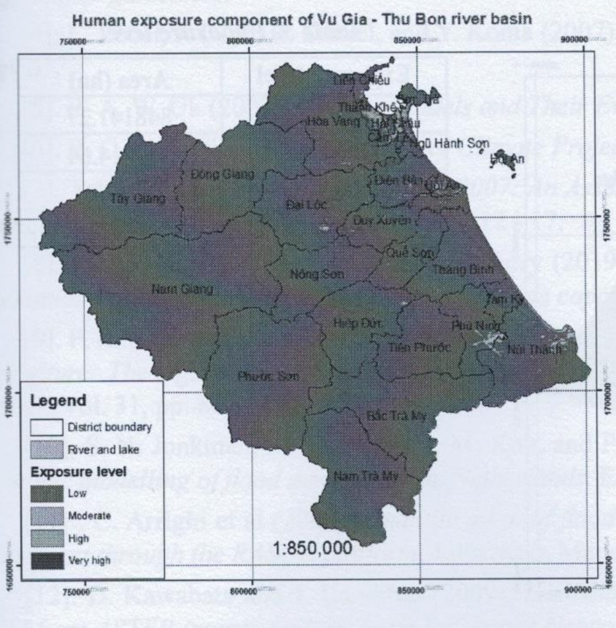

Figure 5: Human exposure component

Table 3. Exposure level of Human live

Exposure level	Area (ha)
Low	1149714
Moderate	3803.86
High	2118.06
Very high	509.73

The Human map presents an overview of the human exposure component of the river basin. As indicated in the map, the highest level of exposure areas in Da Nang and the Hoi An city, which have a higher population density. In the rural area, human exposure is low, but the urban area, this exposure component shows the moderate to a very high level. The High and very high level of Human exposure is about 2600 ha.

4.3. The Social indicator and Social Exposure component

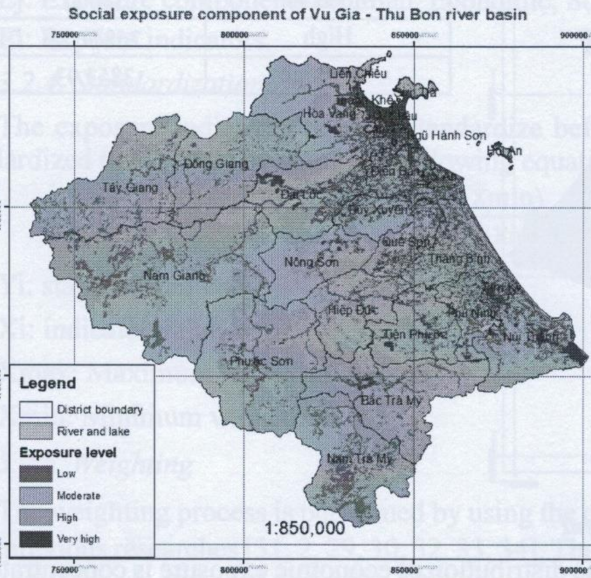

Figure 6: Social exposure component

Table 4. Exposure level of Economic

Exposure level	Area (ha)
Low	68439.34
Moderate	462751.63
High	535518.16
Very high	91778.3

Based on the map, Social exposure is distributed higher in urban and lowland of the river basin. But overall, the Exposure level is moderate to very high in almost of the river basin area. The high and very high-level area combined is about 660000 ha, concentrated in urban areas, which have the number of significant construction, infrastructure for social activities.

4.4. The Exposure index

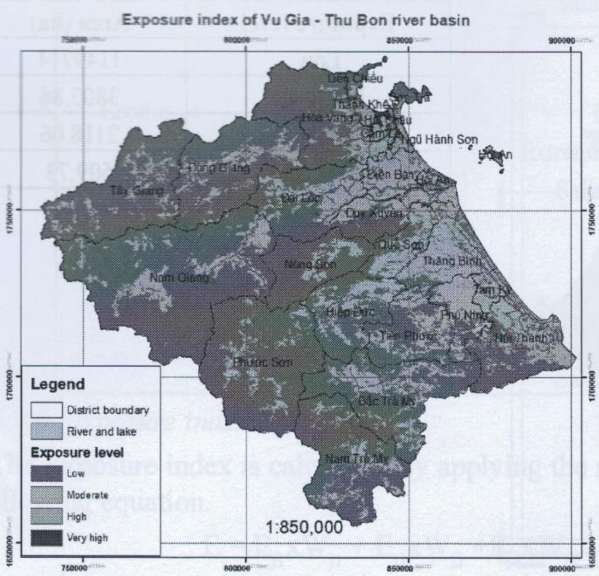

Figure 7: Exposure index

Table 5. Exposure level

Exposure level	Area (ha)
Low	848141.27
Moderate	267714.64
High	38718.01
Very high	1500.26

The Exposure index map shows the increase of exposure from the rural area to the urban area. The very high exposure area is 1500 ha, mostly in urban districts of Da Nang and part of Hoi An. The high-level area is 38718 ha in the sub-urban area of Da Nang, Tam Ky ad industrial zones of Dien Ban, Thang Binh districts.

5. Conclusion

Based on the results of the research, there are several conclusions drawn.

Application of GIS in disaster risk assessment is beneficial and giving a better view of disaster risk management. The standardization and quantification ability of GIS is beneficial in the field of disaster risk prevention and reduction.

Integrated GIS and AHP show excellent results in the evaluation of complex problems as disaster risk assessment. Each component can be used independently in a different assessment. In the case of the Exposure index, the overall result is needed in disaster risk management and assessment. It is a crucial component of risk assessment in the framework of risk assessment [1]

Using a river basin scale in research is the new approach that gives benefit to disaster risk management. It is useful in the inter-provinces river basin. It can help both provinces an overview and cooperate in river basin management.

In our research, the challenger is the quality and availability of data. The quality of spatial data is very bad. The consequence is needed in time and effort to improve the quality to warranty the quality of the research. The availability of data, especially disaster damage data, is very limit, which gives difficulties in disaster types selection as well as indicator evaluation processes.

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