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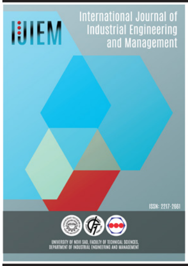

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The Impact of Climate Change on Sustainable Development: The Case of Vojvodina

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ABSTRACT

Sustainability Development Goals require each country and region to adjust their environmental and social policies to ensure a timely global response, stabilization of climate, and social equality. Vojvodina's area has unique challenges due to its political status and significant dependence on environmental resources to ensure its economy, energy supply and food security. The researchers reviewed potential challenges to Vojvodina's sustainable development based on analysis of long-term trend changes of temperature and water flow. To support sustainable development, Vojvodina region needs to strive for the integral concept of flood protection, which includes harmonization of “human” demands component and “environmental” demands components.

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1. Introduction

To design an adequate response to the socio-environmental global crisis, Vojvodina's leaders need to enhance its environmental awareness and actions. Based on analyses of climate parameters trend change, we review potential challenges to policy makers regarding establishing reachable sustainability goals under given socio-environmental circumstances. The ecological crisis results from significant civilizational changes recorded in production, consumption and growth models and fundamental human values. Effective outcomes are the misbalance in the natural, demographic, technological and social systems. Several aspects of human actions are direct culprits in intensified environmental degradation and climate change emission of greenhouse gases (GHG), ozone-depleting substances (ODS), industrial pollutants such as heavy metals and other chemicals, overexploitation of forest and mineral resources, water and soil pollution and degradation. A prominent GHG is carbon dioxide (CO2). The research of Marceda Bach et al. [1] has shown that there are long-term and causal relationships between economic growth and CO2 emissions. Activities, such as transport and industrial agriculture, contrib-

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ute the most to total greenhouse gas emissions.

Humans are intrinsically connected to the environment, and as such, their activities inevitably affect natural processes and environmental sustainability [2]. Local climate change trends could compromise improvements and accomplishments of current manufacturing technologies as variability in environmental impacts increases [3]. As stated by Halsnæs et al. [4], there is a dual relationship between sustainable development and climate change. Recognition of that relationship requires adaptation of laws, industrial practices, and social traditions. Many international studies and papers [5]-[13] address the importance of adopting and respecting the relationship between climate change and sustainable development. The major challenge for lawmakers is to balance the economic and environmental aspects of actions required to achieve Sustainable Development Goals (SDG). Keeping the balance is especially hard in countries and regions that do not accumulate enough financial capital for domestic investments. The only opportunity for economic growth is attracting foreign capital. Attracting foreign capital comes with the price of lowering environmental and social standards in the shape of a cheap workforce or lack of pollution restrictions, monitoring or enforcement. Such actions are endangering the long-term sustainability of the environment and economy. Design of regulatory response to ever-growing economic and social needs for natural resources must be based on scientific estimates of their future availability and sustainability.

This paper is structured into four sections. Section 2 gives a general overview of sustainability, sustainable development imperatives, and climate change of the Autonomous Province of Serbia, Vojvodina. Section 3 explains used materials and methods. Its first subsection provides data and sources. The second subsection describes research methods. The third subsection summarizes the results of trends analyses of selected climate variables in Vojvodina. Sections 4 and 5 provide discussion and conclusions.

2. Climate Change and Sustainable Development

The term sustainable development came into force when the World Commission on Environment and Development (WCED) was formed for the first time by the United Nations in 1987. The term is most often used to denote practices that are more environmentally friendly than others [14]. Commission members [15] defined sustainable development as meeting the needs of the present generation without compromising the needs of future generations. Responsible behavior towards future generations is fundamental because they do not have the "right to vote" and therefore cannot influence policymaking at present. Thus, the principle of intergenerational equality must be respected. Economic growth is desirable and acceptable only if it does not lead to the degradation of natural resources that are limited and scarce, i.e., they are not in abundance. Required fields for defining sustainability and sustainable development are economics, politics, sociology, ecology, and sciences explaining environmental processes. Due to the diversity of social-economic-environmental systems and national interests, there is a discrepancy in methods and implementation of appropriate strategies between global and local perspectives. All human activities are associated with consumption and production, resulting in resource depletion and pollution of the environment.

Applying climate change policies influences the environment and changes the course of natural changes. Deliberative public-private partnerships work most effectively when investors, local governments and citizen groups are willing to work together to implement new technologies and produce arenas to discuss these technologies that are locally inclusive [16]. There is growing awareness that climate change, extreme climate events, non-linear impacts and tipping points should play a significant role in sustainable development strategies [17]. Many of the methods and activities designed to adapt to climate change are integrated into measures taken to achieve national development goals, poverty alleviation, disaster risk reduction, and other sustainable development and resilience (e.g., the green economy, green jobs and green growth). Simultaneously, efforts to mitigate climate change are gathering momentum and generating changes within human society [18].

Sustainable development considers all population issues, politics, economic, industrial development, and climate change issues [2]. Vojvodina, as an autonomous province of Serbia, located in the northern part of the country, is a territory with more stable climate parameters than other regions [19]. Vojvodina area has a history of the negative rate of population change, which influences social planning and population vulnerability rate. To ensure sustainable development Vojvodina region needs to overcome challenges and develop hazard resistant society [20]. The sustainable development strategy of the Republic of Serbia, in which Vojvodina is the northern Province, identifies the Vojvodina region as crucial in ensuring the sustainable economy of the country. At the same time, it is noticeable degradation of life quality in the Vojvodina region. The Autonomous Province of Vojvodina (APV) economy constitutes almost a third of the gross domestic product of the Republic of Serbia. In contrast, the gross domestic product per capita exceeds the national average. The most developed sectors of the industry include manufacturing, wholesale and retail trade and repair of motor vehicles and motorcycles, agriculture, forestry and fishing, mining, and professional, scientific, innovative, and technical activities.

Vojvodina is the most important agricultural region of Serbia due to its high-quality soil types with high production values, the wealth of water and regulated water regime [19]. It covers around 1.75 million hectares of farmland, accounting for about 34% of the agricultural area in Serbia, while cultivated fields and gardens encompass nearly half of arable land in Serbia [19]. Vojvodina provides over 90% of the total production of sugar beet, sunflower and soybean in Serbia and is famous for its production of grain and industrial crops [19]. As an agricultural area, Vojvodina's economy is more than dependent on climate variables and climate change. Regulatory actions require scientific input of climate change and environmental degradation trends. Studies have pointed out that global trends can be but are not necessarily accompanied by the same local trends [13]. Thus, to mitigate the effects of climate change in Vojvodina, it was essential to review the trends of selected climate parameters.

3. Materials and Methods

3.1 Source

The original study of climate change trends [13] used monthly temperature and rainfall data over 50 years from 1950 to 2006 from seven Vojvodina stations. For a better overview of the hydrological regime, six hydrological stations in the system of the Republic Hydro-meteorological Service of Serbia were considered. The hydrological network of Vojvodina consists of three large rivers Danube, Sava and Tisza and an extended network of streams and channels. Sava and Tisza, together with other streams in Vojvodina, are part of the Danube River Basin. The Tisza, with its tributaries, provides a significant contribution to the hydrological regime of Vojvodina. Stations covered in analyses are Bezdan, Bogojevo, Novi Sad – Slankamen (Danube), Novi Kneževac, Senta – Novi Bečej (Tisza), Sremska Mitrovica (Sava). For all six profiles, equations of rating curves were provided based on observed rating curves. Hydrometeorological data came from the Republic Hydrometeorological Service of Serbia.

3.2 Research Methods

The research summarizes the 50-year annual and monthly air temperature and rainfall variations in Vojvodina's Province with the help of a linear tendency estimation and a climate trends statistical method. In modern systems, temperature monitoring via various temperature data loggers is of great importance for the normal functioning of these systems [21]. Analyses of the trend of change of the relative air temperature, extreme air temperatures, precipitation regime and rain factor were conducted. Based on this, the intensity of climate change in Vojvodina's Province was evaluated. A meteorological drought index SPI6 was used to estimate the long-term effect on water resources. Trends of four selected hydrological parameters were assessed with the help of calculated rating curves. The specific calculation methods used are as follows:

Linear trend, based on a sequence of pairs of values

$$X : X_1, X_2, X_3, X_4, \dots, X_N$$
$$Y : Y_1, Y_2, Y_3, Y_4, \dots, Y_N$$

where X represents the time variable and Y presents the changes to some phenomena in time, then such a series of pairs of $\{X_i, Y_i\}$, represents a time series.

Time series analysis observes tendency or trend [22].

$$Y = f(x) \qquad (1)$$

Relevant to the research presented in this paper was the linear trend.

The linear trend model shows the observed time series's linear movement (positive or negative) values. The line of a linear trend model is made using the method of least squares regression. The essence of the least-squares process is that it minimizes the sum of squared deviations of all points of a given line to get the best line adapted to the series. Of all the lines $y = ax + b$, the most likely direction of regression is the one for which the sum of squares of deviations

$$f(a,b) = \sum_{i=1}^{n}\left[y_i - (ax_i + b)\right]^2 = \sum_{i=1}^{n}\varepsilon_i^2 \text{ is minimum.} \qquad (2)$$

The sum of squares of deviation is minimal when at the same time $\frac{\partial f(a,b)}{\partial a} = 0 \quad i \quad \frac{\partial f(a,b)}{\partial b} = 0$

and $\frac{\partial f(a,b)}{\partial a} = 0 \quad i \quad \frac{\partial f(a,b)}{\partial b} = 0$ are valid.

The final expression of the linear trend model is:

$$\hat{y} = ax + b \qquad (3)$$

where b is the constant, or the expected value of a time series for the observed period when the independent variable x equals 0, $b = y$. Coefficient a shows the average change of dependent variable y when independent variable x goes up for a time unit.

Relative temperature is of great importance in the analyses of the annual behavior of air temperature. It is crucial for defining how close to continental climate is the climate of the region. The relative temperature is calculated from the expression [13]:

$$t_r = \left(\frac{(t_i - t_I)}{A}\right) \cdot 100 \qquad (4)$$

where: tr is relative air temperature for a particular month of the year and is expressed in percentage; ti mean temperature of the month; t_I mean temperature in the coldest month of the year; A is the mean annual fluctuation of air temperature.

In this statement, the coldest month will have a relative temperature of 0% and the hottest 100%. For other months of the year, the relative air temperature is derived from the relationship of the two differences: differences of the temperature of the observed and the coldest month and the temperature difference of the hottest and coldest months [23].

Precipitation regime (distribution within the year) usually is represented with relative annual variations of precipitation [23]:

$$r = \left[(R_x - R_n)/R_g\right] \cdot 100\ \% \qquad (5)$$

where: r is precipitation regime; R_x is the amount of precipitation in the month with the most recorded precipitation; R_n is the amount of precipitation in the driest month; R_g is the annual sum of precipitation. Less fluctuation we have the distribution of the precipitation is more balanced over the year, and otherwise.

Lang's Rain factor presents the proportion between the annual precipitation (mm) and the mean air temperature (°C). Based on this ratio, Lang classified three humidity climate zones. He pointed out types of natural vegetation, as shown in Table 1.

McKee et al. developed the Standardized Precipitation Index (SPI) [24]. Computation of the SPI involves fitting a gamma probability density function to a given frequency distribution of precipitation totals for a station. The alpha and beta parameters of the gamma probability density function are estimated for each station for six months' time scale. The SPI represents the number of standard deviations above or below that an event is from the mean. Table 2 describes the adopted scale of SPI.

Table 1. Raw data set from the real-time location sensors

Climate		Rain Factor
Arid	Deserts	0-20
	Semi deserts	20-40
Humid	Steppe	40-60
	Savanna	60-100
	Bush and deciduous forest	100-160
Wet	Rain forest	> 160

Rating curve or the functional dependence of Q=f (H) provides an unambiguous relation between the discharge and water level. A functional dependency is often in the polynomial form [25]:

$$y = a + bx + cx^2 + \ldots + kx^n \qquad (6)$$

The parameters a, b, c, to k are determined by the least-squares method. Rating curves presented in the paper were obtained from analysis of the experimentally established curves of dependence between discharge and the stage, whereby the dependence equations were determined using the ORIGIN 5.0 program through functional analysis of polynomial fit. The coefficient of determination determines the measure of the adequacy of the obtained functions.

Tables 3 through 7 depict the rating curves for selected hydrological profiles.

4. Results and discussion

Tables 8 and 9 summarize the results of trends analyses of selected climate variables in APV. As seen from the presented, there can be expected a significant local variability in climate change trends.

The changes that are listed have already taken place. An increase of average annual temperature from over 0.5ºC to 1ºC during the last fifty years on Vojvodina's territory indicates that it follows global trends and locally has a more significant impact. Vojvodina's natural features are already significantly altered, but we need to be one step ahead of them to continue to keep pace with the changes. Research results in this paper are based on the period 1950–

Table 2. Adopted SPI values

Category	SPI
Extremely wet	> +2
Very wet	from 1.50 to 1.99
Moderately wet	from 1.00 to 1.49
Near normal	from 0.99 to -0.99
Moderately dry	from -1.00 to -1.40
Severely dry	from -1.50 to -1.99
Extremely dry	< -2

Table 3. Functional dependency of discharge from the stage (water level) (equations)

Station	Functional dependency Q=f(H) (rating curves)
Bezdan	$y = 1062{,}28711 + 2{,}1838\ x + 0{,}00827\ x^2$
Bogojevo	$y = 203275{,}930.43 - 5708{,}57387\ x + 40{,}00368\ x^2$
Sremska Mitrovica	$y = 1{,}44821 \cdot 10^8 - 7{,}69973 \cdot 10^6\ x + 153468{,}561.04\ x^2 - 1359{,}18186\ x^3 + 4{,}51331\ x^4$

Table 4. Value of coefficient of determination for modelled functional dependencies

Station	The value of the coefficient of determination R 2 for the resulting functional dependence Q=f(H)
Bezdan	1
Bogojevo	0.99981
Sremska Mitrovica	0.99703

Table 5. The functional dependence of discharge at Novi Sad profile from the stage at Slankamen profile based on parameter curve

The stage at Slankamen	Functional dependence of Q = a + b1H + b2H2 for Novi Sad (approximate values of coefficients)			Coefficient of determination
Absolute value	a	b_1	b_2	R^2
69	391356.82	-11497.3485	-11497.3485	1
70	352945.15	-10494.1342	77.9221	0.9984
71	269770.54	-8340.7738	63.9881	0.99843
72	100414.28	-3964.2857	35.7143	0.99843
73	-201010.00	3798.5714	-14.2857	0.99674
74	-476443.78	10613.9786	-56.3864	0.99534
75	-1187730.00	28550.6701	-169.4949	0.99668
76	-2919360.00	-2919360.00	-446.7219	0.99653
77	-5139760	124588.2961	-790.0920	0.99613
78	-9929120	246438.4991	-1527.4499	0.99485

Table 6. Equations were obtained based on parameter curves for discharge for the River Tisza at the hydrological s tations Novi Kneževac

Stage at profile Novi Bečej [1] absolute	Functional dependencies Q=f(H) for the Tisza at Novi Kneževac (approximate values of coefficients)	Coefficient of determination R^2
71	$y = 184617.433 – 5237.429\ x + 37.143\ x^2$	0.99933
72	$y = 109449.999 – 3200.031\ x + 23.334\ x^2$	0.99972
73	$y = 43640.2023 – 1477.617\ x + 12.058\ x^2$	0.99941
74	$y = -1.337 \cdot 10^6 + 51387.826\ x – 662.456\ x2 + 2.869\ x^3$	0.99982
75	$y = -4.177 \cdot 10^7 + 2.085 \cdot 10^6\ x – 39004.015\ x^2 + 324.154\ x^3 – 1.01\ x^4$	0.99951
76	$y = -1.268 \cdot 10^8 + 6.336 \cdot 10^6\ x – 118707.06\ x^2 + 988.155\ x^3 – 3.084\ x^4$	0.99873
77	$y = -2.625 \cdot 10^8 + 1.302 \cdot 10^7\ x – 242108.574\ x^2 + 2000.674\ x^3 – 6.198\ x^4$	0.99922
78	$y = -2.360 \cdot 10^7 + 877191.057\ x – 10871.91\ x^2 + 44.945\ x^3$	0.99794
79	$y = -3.814 \cdot 10^7 + 1.405 \cdot 10^6\ x – 17261.42\ x^2 + 70.723\ x^3$	0.9977
80	$y = -9.518 \cdot 10^7 + 3.487 \cdot 10^6\ x – 42580.496\ x^2 + 173.378\ x^3$	0.99834

[1] Referent station is Novi Bečej G.V., due to inhomogenity and missing data for period 1950 –1981 hydrological profile Novi Bečej was adopted as referent one.

Table 7. Equations were obtained based on parameter curves for discharge for the River Tisza at the hydrological stations Senta

Stage at profile Novi Bečej [2] absolute	Functional dependencies Q=f(H) for the Tisza at Senta (approximate values of coefficients)	Coefficient of determination R^2
71	$y = 224278862 - 6404.572\ x + 45.714\ x^2$	0.99862
72	$y = 78407.999 - 2441.636\ x + 18.788\ x^2$	0.99976
73	$y = 16783.626 - 850.764\ x + 8.516\ x^2$	0.99926
74	$y = -7.717 \cdot 10^7 + 3.959 \cdot 10^6\ x - 76175.443\ x^2 + 651.145\ x^3 - 2.086\ x^4$	0.99952
75	$y = -1.71028 \cdot 10^8 + 8.705 \cdot 10^6\ x - 166150.08\ x^2 + 1409.11\ x^3 - 4.48\ x^4$	0.99892
76	$y = -1.214 \cdot 10^7 + 460000.91\ x - 5817.265\ x^2 + 24.552\ x^3$	0.99796
77	$y = -2.242 \cdot 10^7 + 842744.462\ x - 10566.617\ x^2 + 44.195\ x^3$	0.99723
78	$y = -5.537 \cdot 10^7 + 2071510\ x - 25838.156\ x^2 + 107.463\ x^3$	0.99793
79	$y = -9.394 \cdot 10^7 + 3485900\ x - 43126.731\ x^2 + 177.896\ x^3$	0.996
80	$y = -2.45985 \cdot 10^8 + 9065820\ x - 111387.136\ x^2 + 456.2433\ x^3$	0.99942

[2] Referent station is Novi Bečej G.V., due to inhomogenity and missing data for period 1950 –1981 hydrological profile Novi Bečej was adopted as referent one.

Table 8. Trend and intensity of direction of change of the precipitation, annual precipitation regime, rain factor and SPI6 in 50 years, on seven major meteorological stations in Vojvodina

	Precipitation [mm]		Annual precipitation regime [%]		Rain factor [mm/°C]		SPI6	
Novi Sad	56.65	↗	-0.49	↘	-0.54	↘	0.00073	↗
Palić	31.75	↗	-0.65	↘	0.15	↗	-0.00216	↘
Sombor	25.28	↗	-0.80	↘	2.37	↗	-0.00814	↘
Bačka	37.89	↗	-0.64	↘	0.66	↗	-0.00319	↘
Zrenjanin	-6.75	↘	2.16	↗	2.83	↗	0.00615	↗
Kikinda	-19.82	↘	0.35	↗	4.12	↗	0.00035	↗
Vršac	-2.93	↘	1.49	↗	0.87	↗	0.00235	↗
Banat	-9.83	↘	1.33	↗	2.61	↗	0.00295	↗
Sremska Mitrovica	-40.32	↘	-0.62	↘	6.03	↗	-0.00500	↘
Vojvodina	7.99	↗	0.24	↗	2.12	↗	-0.00066	↘

Table 9. The mean annual discharge trend, maximum and minimum yearly stage and minimum monthly stages in 50 years, on six major hydrological profiles in Vojvodina

River hydrological profile	Mean annual discharge [m3/s]		Maximum annual stage	Minimum annual stage	
Danube	warm season	cold season	absolute units	annual	monthly
Bezdan	↘	↘	⇢	↘	↘
Bogojevo	↘	↘	↗	↘	↘
Novi Sad	↘	↘	↗	↘	↘
Tisza					
Novi Knezevac	↗	↘	↗	↗	↗
Senta	↗	↘	↗	↗	↗
Sava					
Sremska Mitrovica	↘	↘	↘	↘	↘

2006. A recent analysis [26]-[28] indicates that the region's growing urbanization will only further intensify environmental degradation and climate change.

The regional government of APV relies on Vojvodina resources for future development, especially in the energy sector. The goals of the energy policy of the Republic of Serbia, as well as APV, are to construct new facilities satisfying the requirements in terms of energy efficiency and use of Renewable Energy Sources (RES), to replace fossil fuel with biomass and other RES such as hydro and wind [24]. All renewable energy resources are highly vulnerable to climate change effects and impacts [29]. The rise of temperature does not only mean a shorter heating season, but the disturbance of the entire course of the current energy and heat supply methods that were based on stable temperature trends and well-established seasons. Different RES competes for the same resources – water and soil, with other industries such as agriculture and fishery. A detailed study on how the diverse function of RES is affected by different users and the availability of RES for all stakeholders is required [30].

As trend analysis indicates, the region would not be equally affected by upcoming changes; thus, regional plans would have to consider local deviances and incorporate them into development strategies for sustainable energy supply. Based on the examination of average annual flow trends, it can be concluded that the territory of Vojvodina is under the influence of climate changes that are significantly affecting and changing socio-economic strategy in the Province.

Due to the significant agricultural character of Vojvodina, it is required to consider the changes made in the meteorological and hydrological developments while budgeting and planning. Also, it is necessary to carry out studies of prevention and early warning, as it is to expect intensification in hazard weather and more frequent hazard events. As biomass energy supply depends on regular supply and production, it is intrinsically connected with future agriculture strategies.

In terms of social and economic development in Vojvodina, constant increase in the need for land use in flood zones can be expected, followed by a progressive increase in the value of goods and increasing concentration of population. In case of further use of old approaches, protecting coastal areas would require a permanent and substantial investment in facilities. Even with high economic investments, the risk of flooding could not be eliminated. Therefore, to support sustainable development, it is necessary to strive for the integral concept of flood protection, which includes harmonization of "human" demands component (protection of property and human life) and "environmental" demands components (the preservation or restoration of the natural features and resources within the floodplain) [30].

Besides agriculture, impacts of observed climate change that are mandatory to consider are on the groundwater and the consequences for the population, mainly through availability and quality of drinking water. It would be essential to conduct a feasibility study on the available amount of water in river basins and its impact on coastal cities and their industry. Vojvodina's regulators could

Rural Tourism is one of the industry branches that can be significantly affected by changing climate. Rural tourism is recognized as essential for future stabilization and sustainable growth of Vojvodina. It supports local production and enhances the coping capacities of small and medium villages to resist urbanization or loss of residents due to migration to urban centers [31]. The current greatest challenge for the rural Vojvodina is ensuring sustainable water supply for the communities and protection of water resources from overuse of pesticides and industrial chemicals [32]–[34].

The industrial development of Vojvodina must rely on the utilization of circular economy principles, green chemistry, and RES [34]. Vojvodina's chemical and oil industry must seek alternatives and ensure sustainability and growing employment opportunities in the sectors. Recycling industries and new building materials, currently underutilized and without regulatory incentives, are opportunities that Vojvodina's regulator must inbuild in sustainability strategy [35]–[36].

5. Conclusions

This study provides challenges to Vojvodina's sustainable development based on analysis of long-term trend changes of temperature and water flow. Vojvodina's political-social-environmental position within Serbia and the European Union must clarify before establishing any detailed sustainability strategy. There is a general lack of ongoing systematic long-term regional climate studies and their incorporation in the regulatory framework. A review of published literature noted a lack of integrated studies addressing the circular economy, sustainable development, green chemistry, social equality for the Vojvodina region. As Vojvodina's economy heavily relies on natural resources, it is essential to design local strategies that reflect the locals' climate change tendencies and socio-economic characteristics. The great cultural diversity of Vojvodina presents the opportunity to assimilate diverse, sustainable solutions into local structures while protecting cultural heritage and the environment. Empowering and strengthening rural communities will ensure a sustainable supply of food and energy supply to the urban areas.

This study is not without limitations that require future research. Results are based on municipalities within the whole region. Further investigation should consider the interconnectedness of sustainability of rural communities and urban areas is required. Other limitation includes the impact of social policy on the future of industry and employment. Future studies are necessary to understand the implications and pressures on natural resources.

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