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A Comparative Study Of Alternative Road Routes Based On Utility Scoring

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Abstract

This study aims to determine an alternative road alignment from Cianjur to Sindangbarang in Cianjur Regency, West Java, Indonesia, functioning as a primary collector road. The method used is Multi-Criteria Analysis (MCA), which involves selecting criteria, assigning weights, calculating utility values, and identifying the best alternative. Six criteria were used: road network hierarchy integration, spatial planning integration, economic and financial aspects, social impact, environmental impact, and physical and technical aspects. The analysis results show that Alternative 4 is the most optimal route, with the highest score (32.51) and the shortest length (119.40 km) compared to the three other alternatives and the existing 150 km route. This alignment excels in road network integration and accessibility to residential, agricultural, and plantation areas, while also offering the lowest construction cost. It has minimal social and environmental impact, affecting the fewest households and causing the least disturbance during construction. The route also crosses areas with low landslide risk and high soil bearing capacity (CBR), making it technically and physically superior. The development of this road is expected to promote economic equity in South Cianjur, increasing agricultural and plantation product value and improving the income of local communities who primarily depend on farming and plantation activities.

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Keywords: *collector street, provincial roads, multi-criteria analysis, road tracing, west java province*

Abstrak

Penelitian ini bertujuan menentukan trase jalan alternatif Cianjur–Sindangbarang di Kabupaten Cianjur, Jawa Barat, Indonesia, yang berfungsi sebagai jalan kolektor primer. Metode yang digunakan adalah Analisis Multi Kriteria (AMK), yang melibatkan penetapan kriteria, pemberian bobot, perhitungan utilitas, dan pemilihan alternatif terbaik. Enam kriteria digunakan dalam analisis: keterpaduan jaringan jalan, integrasi dengan tata ruang, ekonomi dan finansial, dampak sosial, dampak lingkungan, serta aspek fisik dan teknis. Hasil AMK menunjukkan bahwa alternatif 4 merupakan trase terbaik dengan skor tertinggi (32,51) dan panjang jalan terpendek (119,40 km), dibandingkan tiga alternatif lainnya maupun jalan eksisting (150 km). Alternatif ini unggul dalam keterpaduan jaringan jalan, akses ke kawasan permukiman, pertanian, dan perkebunan, serta memiliki biaya pembangunan terendah. Dampak sosial dan lingkungan juga paling rendah, termasuk jumlah keluarga terdampak dan gangguan selama konstruksi. Trase ini melintasi lahan dengan kerentanan gerakan tanah rendah dan nilai CBR tinggi, sehingga unggul secara fisik dan teknis. Pembangunan trase ini berpotensi mendorong pemerataan ekonomi di 15 kecamatan wilayah Cianjur Selatan melalui

peningkatan nilai produk pertanian dan pendapatan masyarakat yang mayoritas bekerja di sektor pertanian dan perkebunan

Kata kunci: *jalan kolektor, jalan provinsi, analisis multi-kriteria, penelusuran jalan, provinsi Jawa Barat*

1. INTRODUCTION

Three-way intersections on provincial roads often cause accidents. Accidents occur because of the geometric conditions of the road and the lack of public facilities on the side of the road (Lin et al., 2022). In terms of provincial road project management, the success of planning and managing highway projects in Korea is better than that of provincial road project management (Lee & Kim, 2021). The development of provincial road traffic infrastructure causes massive land use changes along transport routes and stimulates urban expansion at connecting points, leading to the degradation of ecosystem services, including soil conservation (Dai et al., 2022).

The Cianjur-Sindangbarang primary collector road route passes through hilly areas with a slightly steep to steep slope of 5% to 4%. Judging from the ground movement, several sub-districts in the Southern Cianjur Region are categorized as vulnerable to the high ground movement which is prone to landslides (Surono, 2004), disrupting traffic flow.

According to Saul A. et al, vehicle speed on collector roads should not be disturbed except on local roads, to hinder the speed of vehicles they usually placing speed bumps (Queretaro, 2020). The results of research in Poland show that vehicles will reduce their speed by 3.53 km/hour when facing pedestrian crossings on collector roads and speed by 2.60 km/hour on arterial roads (Szagała et al., 2021). Vehicle speeds on collector roads can be reduced by installing speed indicators at pedestrian crossings and can contribute to pedestrian safety (Malin & Luoma, 2020).

As a result of disruption to vehicle speeds on the Cianjur - Sindangbarang road route, the cost of transporting people and goods has become more expensive and the selling prices of agricultural products received by farmers have become cheaper. The local regional government hopes that there will be an alternative route from Cianjur to Sindangbarang. Therefore, an alternative Cianjur – Sindangbarang road route is needed which functions as a primary collector road. The map of Cianjur Regency is presented in Figure 1

Figure 1. Map of Cianjur Regency

The purpose of this study is to determine an alternative road route from Cianjur to Sindangbarang, which functions as a collector road. This article is the result of research on alternative provincial roads that function as primary collector roads.

The route selection used the Multi-Criteria Analysis method, a method for selecting alternatives using various criteria according to the topic of the alternative selection. Road alignment selection uses Multi-Criteria Analysis, namely an alternative selection method using various criteria according to the topic of alternative selection (Sulistyorini & Dwi Herianto, 2010). Multi-criteria analysis (MCA) uses stakeholder perceptions of the criteria or variables that are compared in decision-making. The Multi Criteria Analysis approach is very appropriate to use to study the optimization of the placement of electric vehicle charging stations on highways (Skaloumpakas et al., 2022). The Multi-Criteria Analysis Methodology provides a practical approach by visualizing the level of spatial suitability for integrated, advanced, and sustainable urban transportation development and provides a way for decision-makers (Çalışkan & Osman, 2023). Multi Criteria Analysis is a practical methodology for identifying the best alternative among several pedestrian routes, to achieve a sustainable transportation system (Eboli et al., 2023).

The novelty of this research is that the selected races are not only based on the lowest cost or length of road, but on a combined utility score from multi-disciplinary criteria, resulting in more comprehensive and applicable decisions for infrastructure policy.

2. RESEARCH METHOD

This study aims to select alternative road routes using multi-criteria analysis. The research location is in Cianjur Regency, West Java, Indonesia. The analysis stage consists of determining the decision maker from the stakeholders involved, determining alternative options, determining the selection criteria to be used, determining the utility value of each alternative, determining the weight of each criterion, and determining the best alternative (Sjafrudin, 2004).

2.1 Determination of Decision Maker

Decision makers or parties involved in deciding road route selection policies are regulators, users, operators, and non-users. The regulator group is the group that determines road transportation development policy, consisting of the Government and The people's representative council. The Operator Group is the group authorized to operate roads, consisting of the Highways Service and the Transportation Service. The User Group is a group of road transportation users, consisting of the general public, road users, drivers, and vehicle owners. Non-user Groups are people affected by road construction, namely farmers and traders.

2.2 Determining Alternative Options

Table 1 shows an alternative route from Cianjur to Sindangbarang in West Java province, Indonesia. This route is based on previous research and consists of four sections. Generally, this route passes through national, provincial, and district roads in Cianjur Regency.

Table 1. Alternative Road Traces

No.	Road Traces	Length (km)	Width (m)	Roads passed	Subdistrict Passed
1.	Alternative 1	138.70	6.0	District & province roads	8 sub-districts
2.	Alternative 2	133.10	6.0	District & province roads	9 sub-districts
3.	Alternative 3	125.80	6.0	District & province roads	8 sub-districts
4.	Alternative 4	119.40	6.0	District roads	8 sub-districts

2.3 Determination of Selection Criteria

Table 2 shows the criteria and sub-criteria for selecting alternative roads. The criteria for selecting alternative road routes are adjusted to the conditions of the existing road routes. The results of the study determined six criteria, namely the criteria for integrated road network hierarchy, the criteria for integration with Regional Spatial Planning, economic and financial criteria, social impact criteria, environmental impact criteria, and physical and technical aspect criteria. Furthermore, to facilitate analysis, each criterion is further broken down into several sub-criteria (Kyrylych & Povstenko, 2023).

Table 2. Criteria for selecting alternative road routes

No.	CRITERIA	SUBCRITERIA
1	Hierarchical integration of the road network	The alternative road functions as a collector road
2	Integration with Regional Spatial Planning	a. Residential area
		b. Agricultural area
		c. Plantation area
3		a. Road construction costs

	Economic and Financial Aspects	- Road construction costs
		- Land acquisition costs
		b. Benefits of road construction
		- Time Values
		- Vehicle operating costs
4	Social Impact	a. Number of families to be relocated
		b. Social disruption during construction
5	Economic Impact	a. Damage to ecosystems in protected areas
		b. Noise
6	Physical and Technical Aspects	a. Susceptibility to ground movement
		b. Soil bearing capacity

The criteria for hierarchical integration of the road network in this research are that the proposed alternative road alignment will function as a primary collector road and can provide access to primary local roads and village roads along the road alignment. Determining the hierarchy of road networks in several countries still uses a conventional approach that gives top priority to vehicle movement, resulting in a significant negative impact on cities. Improvements to the road hierarchy system must be made to improve and support sustainable modes of transportation (Tsigdinos & Vlastos, 2020). Evaluation of the road hierarchy system can also be used for an integrated urban transportation planning approach, designing entrances and roads that are community-centered and attractive for pedestrians through rearranging central areas and road network hierarchies (Paraskevopoulos, 2022).

Integrating with Regional Spatial Planning, this criterion describes the accessibility of alternative road alignments to the regional spatial planning of The Cianjur district. The priority areas for Cianjur Regency are residential, agricultural areas, and plantation areas. The development of regional spatial planning in the era of globalization and informatization has become an increasingly important interactive space and is experiencing rapid development. Regional Spatial Development has experienced major changes in population cross-border travel, and constantly changing urban spatial patterns (Pattern, 2023). In health research in Brazil, spatial planning is used by applying temporal and spatial analysis (Barbosa et al., 2023).

Economic and financial aspects, consisting of the costs and benefits of constructing the Cianjur - Sindangbarang alternative road route. Road construction costs consist of land acquisition costs and construction costs. Meanwhile, road benefits consist of the value of travel time and vehicle operating costs. Several studies of social, economic, and financial phenomena can provide a clear picture of changes in the global economy of a region (Przybytniowski et al., 2022). Economic and financial aspects, also calculate capital and operational costs for the production process, as well as activation to ensure economic sustainability and generate income (Ajien et al., 2023).

The social impact aspect in the construction of the Cianjur - Sindangbarang alternative road consists of the number of heads of families who have to be moved and social disturbances during construction. The social impact aspect is the influence that will occur during road construction. Social Impact Assessment facilitates sustainable and equitable consideration of social issues in transportation infrastructure planning (Mottee, 2022). In analyzing social impacts, many fundamental problems in the field must be addressed for future development. Handling social impacts must involve local communities and experts (Stjernborg & Stjernborg, 2023). The key factors for success in analyzing social impacts include changing the development philosophy to an approach that is more oriented towards community welfare (Chen et al., 2021).

The environmental impact aspect consists of damage to ecosystems in protected areas and noise from passing vehicles due to the construction of alternative roads. To analyze environmental impact aspects, institutions that are responsible for the environment are needed.

The final effort in environmental management is to identify policies that can encourage more sustainable strategies (Stranieri et al., 2023).

Physical and technical aspects, these aspects include the vulnerability of ground movement and the carrying capacity of the soil on alternative road alignments. Ground movement is the movement of soil/rock mass in a vertical, horizontal, or inclined direction from its original position. Meanwhile, the soil bearing capacity is the subjective California Bearing Ratio (CBR) value on alternative road sections. The influence of trees will influence variations in ground movement in analyzing ground movement susceptibility (Sun & Li, 2023). To increase the bearing capacity of the soil, dynamic compaction can be used as an economical method and can reduce soil compressibility (Ismael & Al-otaibi, 2021).

2.4 Performance Assessment for Each Criterion

The assessment of each criterion is to determine the expected performance of each criterion. Criteria assessment is carried out indirectly quantitatively through pairwise comparisons and pairwise comparisons based on input from respondents. The input is in the form of answers to questions in general form, which are expressed as follows: **"How important is criterion A relative to criterion B",** this condition states that there is a pairwise comparison. Assessment is carried out by providing a rating scale that shows the level of importance between two criteria.

2.5 Determination of Criteria Scores

Table 3 is the weighting between criteria. Criteria scores were carried out on the perceptions of respondents representing the stakeholders interviewed. The number of respondents for each type of group was 10 people, so the total number of respondents was 80 people. Determining scores to get the importance score for each criterion, namely making a pairwise comparison matrix, making an average weight of the criteria for each stakeholder group, and making an average weight of the criteria for all stakeholders. The calculation of the pairwise comparison matrix was carried out using the expert choice program, input data based on respondents representing stakeholders by providing assessments between criteria.

Table 3. Assessment between criteria

Criterion I	COMPARATIVE VALUE									Criterion II
A	9	8	7	6	5	4	3	2	1	B
A	9	8	7	6	5	4	3	2	1	C
A	9	8	7	6	5	4	3	2	1	D
A	9	8	7	6	5	4	3	2	1	E
A	9	8	7	6	5	4	3	2	1	F
B	9	8	7	6	5	4	3	2	1	C
B	9	8	7	6	5	4	3	2	1	D
B	9	8	7	6	5	4	3	2	1	E
B	9	8	7	6	5	4	3	2	1	F
C	9	8	7	6	5	4	3	2	1	D
C	9	8	7	6	5	4	3	2	1	E
C	9	8	7	6	5	4	3	2	1	F
D	9	8	7	6	5	4	3	2	1	E
D	9	8	7	6	5	4	3	2	1	F
E	9	8	7	6	5	4	3	2	1	F

Criterion I	COMPARATIVE VALUE								Criterion II
A	2	3	4	5	6	7	8	9	B
A	2	3	4	5	6	7	8	9	C
A	2	3	4	5	6	7	8	9	D
A	2	3	4	5	6	7	8	9	E
A	2	3	4	5	6	7	8	9	F
B	2	3	4	5	6	7	8	9	C
B	2	3	4	5	6	7	8	9	D
B	2	3	4	5	6	7	8	9	E
B	2	3	4	5	6	7	8	9	F
C	2	3	4	5	6	7	8	9	D
C	2	3	4	5	6	7	8	9	E
C	2	3	4	5	6	7	8	9	F
D	2	3	4	5	6	7	8	9	E
D	2	3	4	5	6	7	8	9	F
E	2	3	4	5	6	7	8	9	F

2.6 Determination of Subcriteria Scores

Sub-criteria scoring is determining the quantitative or qualitative value of each alternative from the sub-criteria used. Then carry out a weighting process for each alternative sub-criteria, and form a performance matrix for each alternative to determine the best alternative.

Quantitatively measurable sub-criterion scoring, the scoring process is calculated using the proportional method as a direct comparison of the proposed sub-criterion values. The proposal with the best variable number from a sub-criterion is given a maximum score of 10. The calculation of the weighting of the sub-criteria with the highest and lowest numbers is determined using the following formula:

For the best subcriteria is the highest number:
Criterion Score X = [(Variable X value) / (Best variable value)] * 10
For the best subcriteria is the lowest number:
X Criteria Score = [(Best variable value) / (X variable value)] * 10

3. RESULT AND DISCUSSION

3.1 Criteria Analysis

Table 4 shows the criteria weights for each alternative road route. These criteria weights are obtained from respondents' assessments of each criterion. The results of the respondent selection process were calculated using a pairwise comparison matrix. The overall criteria weights were then calculated based on the average weights across the respondent groups.

Table 4. Criteria Weights for Each Alternative Road Route

No.	Criteria	Alternative Road Trace Score			
		Alt. 1	Alt. 2	Alt. 3	Alt. 4
1.	Hierarchical integration of the road network	0.339	0.771	0.414	0.464
2.	Integration with regional spatial planning	0.339	0.817	0.399	0.343
3.	Economics and finance aspects	0.819	0.963	0.798	0.929
4.	Social impact	0.090	0.303	1.000	0.156
5.	Environmental impact	0.121	0.242	0.418	0.222
6.	Physical and technical aspects	1.000	1.000	0.691	1.000

Table 5 shows the overall criteria weights. This value is obtained by calculating the overall criteria weights based on the average weights of the respondent groups.

Table 5 Overall Criteria Score

No.	Criteria	Score
1.	Hierarchical integration of the road network	0.497
2.	Integration with regional spatial planning	0.475
3.	Economics and finance aspects	0.877
4.	Social impact	0.387
5.	Environmental impact	0.251
6.	Physical and technical aspects	0.923

3.2 Subcriteria Analysis

Table 6 is the Quantitative Value of Subcriteria. Determination of scoring for sub-criteria is calculated using the proportional method as a direct comparison of alternative sub-criteria values. Each alternative road route has different conditions so that the best sub-criteria categories are the highest and the lowest.

Table 6. Quantitative Subcriteria Values

Criteria and Subcriteria	Alt. 1	Alt. 2	Alt. 3	Alt. 4
	138.70 km	133.10 km	125.80 km	119.40 km

Hierarchical integration of the road network - The alternative road functions as a collector road	138.70	133.10	125.80	119.40
Integration with Regional Spatial Planning - Residential area - Agricultural area - Plantation area	9,706.50 19,368.80 7.097.60	10,373.20 26,759.80 10,099.60	9,877.25 18,577.10 6,827.60	11,380.45 25,968.10 9,828.60
Economic and financial aspect a. Road construction costs - Road construction costs - Land acquisition costs b. Benefits of road construction - Time Values - Vehicle operating costs	9.70 104.00 5.55 357.80	9.31 99.83 5.32 343.35	8.81 94.35 5.03 324.52	8.36 89.55 4.78 308.00
Social impact - Number of families to be relocated - Social disruption during construction	1,660 59,760	1,260 45,360	1,510 54,360	1,400 50,400
Environmental impact - Damage to ecosystems in protected areas - Noise	16,820 9,960	13,600 7,560	15,420 9,060	13,400 8,400
Physical and technical aspect - Susceptibility to ground movement - Soil Bearing Capacity	2.71 3.85	2.87 3.29	2.73 4.27	2.60 4.44

Table 7 shows the preliminary scores for the sub-criteria assessment results. The preliminary scores for the sub-criteria are calculated directly by comparing the four alternative road routes.

Table 7. Preliminary Scoring Values for Sub-criteria

Criteria and Subcriteria	Alt. 1	Alt. 2	Alt. 3	Alt. 4
	138.70 km	133.10 km	125.80 km	119.40 km
Hierarchical integration of the road network				
- The alternative road functions as a collector road	10.00	9.60	9.07	8.61
Integration with Regional Spatial Planning				
- Residential area	8.53	9.11	8.68	10.00
- Agricultural area	7.24	10.00	6.94	9.70
- Plantation area	7.03	10.00	6.76	9.73
	7.03	10.00	6.76	9.73
Economic and financial aspect				
a. Road construction costs				
- Road construction costs	8.61	8.97	9.49	10.00
- Land acquisition costs	8.61	8.97	9.49	10.00
b. Benefits of road construction				
- Time Values				
- Vehicle operating costs	8.61	8.97	9.49	10.00
	8.61	8.97	9.49	10.00
Social impact				
- Number of families to be relocated	7.59	10.00	8.34	9.00
- Social disruption during construction	7.59	10.00	8.34	9.00
Environmental impact				
- Damage to ecosystems in protected areas	8.01	9.91	8.74	10.00
- Noise	7.59	10.00	8.34	9.00
Physical and technical aspect				
- Susceptibility to ground movement	9.90	9.38	9.83	10.00
- Soil Bearing Capacity	8.68	7.40	9.62	10.00

3.3 Calculation of Criteria Scores

Table 8 is the score value for the criteria. The calculation of the criteria score is calculated from the average sub-criteria score from Table 7.

Table 8. Score Values for Criteria

Criteria and Subcriteria	Alt. 1	Alt. 2	Alt. 3	Alt. 4
	138.70 km	133.10 km	125.80 km	119.40 km

Hierarchical integration of the road network	10.00	9.60	9.07	8.61
Integration with Regional Spatial Planning	7.60	9.70	7.46	9.81
Economic and financial aspect	8.27	9.31	9.11	9.67
Social impact	7.59	10.00	8.34	9.00
Environmental impact	7.80	9.96	8.54	9.50
Physical and technical aspect	9.29	8.39	9.72	10.00

3.4 Weighted Score

Table 9 is the weighted score of all road route selection criteria. The weighted score is the final calculation of the Multi-Criteria Analysis for selecting alternative road routes. The weighted score is calculated from the result of multiplying the criteria scores from Table 8 with the criteria weights in Table 4.

Table 9. Weighted scores for all criteria

No.	Criteria and Subcriteria	Alt. 1	Alt. 2	Alt. 3	Alt. 4
		138.70 km	133.10 km	125.80 km	119.40 km
1.	Hierarchical integration of the road network	4.97	4.77	4.51	4.28
2.	Integration with Regional Spatial Planning	3.61	4.61	3.54	4.66
3.	Economic and financial aspect	7.25	8.17	7.99	8.48
4.	Social impact	2.94	3.87	3.23	3.48
5.	Environmental impact	1.96	2.50	2.14	2.38
6.	Physical and technical aspect	8.57	7.74	8.97	9.23
	Amount	29.30	31.66	30.39	32.51

3.5 Discussion of Selected Alternative Road Traces

The results of the Multi-Criteria Analysis, alternative route 4 has the highest score, namely 32.51. In Table 9, not all criteria place alternative route 4 as the highest score. For the criteria for hierarchical integration of the road network, alternative road alignment 4 is proposed to be the primary collector road. The length of alternative route 4 is the shortest route so the score is the smallest, however, the accessibility of local roads and village roads to the selected route is the highest so it is worthy of being proposed as an alternative route.

The accessibility and integration of alternative road alignment 4 with residential, agricultural, and plantation areas have the highest score so for the criteria of Integration with Regional Spatial Planning, alternative road alignment 4 is worthy of being an alternative road alignment. Alternative road route 4 has the greatest development benefits and the lowest road construction costs, so from an economic and financial aspect it is worthy of being proposed as an alternative road.

Regarding the number of families that have to be moved and disruptions during construction, alternative route 4 has the second highest score. However, because it has more accessibility to local roads and village roads, and conformity with the Regional Spatial Planning is the highest, it can overcome the social impact of constructing alternative roads. For the Environmental Impact criteria, alternative route route 4 is the route that has the least impact on damage to the ecosystem in the protected area zone. Meanwhile, the noise generated is not the best alternative but can be anticipated by installing traffic signs and adhering to road distances. Therefore, it is worthy of being proposed as an alternative route.

Alternative road route 4 has the lowest susceptibility to ground movement and has the best soil carrying capacity so from physical and technical aspects it is worthy of being proposed as the chosen alternative. The location of the existing road alignment and the selected alternative route are presented in Figure 2.

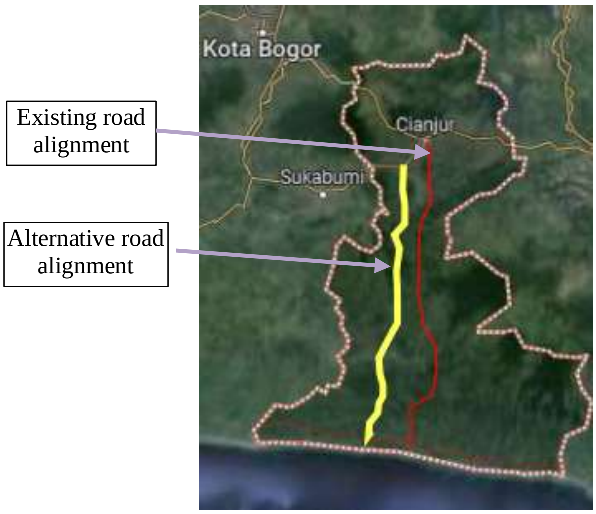

Figure 2. The location of the existing road alignment and the selected alternative rout

3. CONCLUSION

Based on the results of the Multi-Criteria Analysis, Alternative 4 was selected as the most optimal route for the development of a primary collector road between Cianjur and Sindangbarang. This alternative stands out due to its shortest length, most cost-efficient construction, and the lowest social and environmental impacts. Additionally, it demonstrates strong integration with the existing road network and regional spatial planning, while passing through areas with favorable geotechnical conditions—namely high soil bearing capacity and low landslide risk. The selection of this route not only considers technical and economic efficiency but also incorporates social and environmental sustainability. The development of this alternative road alignment is expected to improve accessibility and promote equitable economic growth in the southern region of Cianjur Regency, particularly for communities reliant on agriculture and plantation-based livelihoods.

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