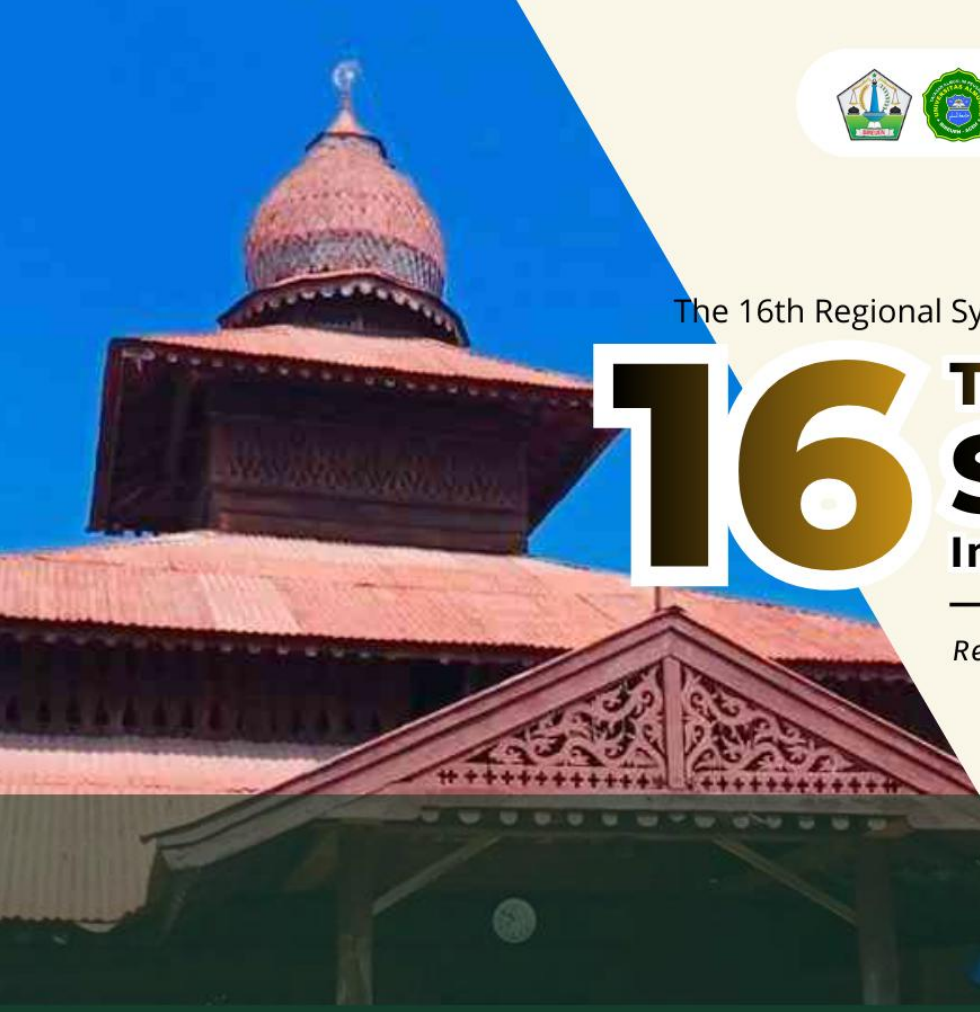

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IDENTIFICATION AND CLASSIFICATION OF CLIMATE CHANGE RISK VARIABLES ON ROAD INFRASTRUCTURE PROJECT PERFORMANCE IN ACEH PROVINCE

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Abstract: *Climate change is a real threat to the performance of road infrastructure projects, especially in tropical regions like Aceh Province, which is vulnerable to extreme weather. This study aims to identify and classify climate change risk variables affecting the performance of road infrastructure projects in Aceh Province. Through a mixed methods approach encompassing literature study, Focus Group Discussion (FGD), and questionnaires targeting medium and large qualified contractors, 42 risk variables were identified and classified into seven main categories: (1) weather, (2) hydrological changes, (3) temperature and humidity, (4) health and safety, (5) infrastructure risk, (6) financial risk, and (7) operational and productivity. Each category consists of specific indicators that directly impact project time, cost, and quality aspects. The results of this identification and classification provide a systematic framework for understanding the climate risk profile in Aceh's road infrastructure sector and serve as a basis for formulating targeted mitigation strategies.*

Keywords: *risk, climate change, roads, Aceh.*

1. INTRODUCTION

Climate change has become a global threat with significant impacts on various sectors, including road infrastructure construction (Gido et al., 2018). Aceh Province, as a tropical region with unique geographical characteristics, experiences high vulnerability to the impacts of climate change, particularly in the form of increased rainfall intensity, floods, and landslides (Heagney, J. 2016; Deubelli & Mechler, 2021; Morioka et al., 2019). This phenomenon directly affects the performance of road infrastructure projects, which are inherently open and highly dependent on weather conditions (Rahardian, 2020; Hidayat, 2023; Charan et al., 2017). Based on field observations, many road infrastructure projects in Aceh Province experience delays in completion and cost overruns due to unexpected weather disruptions (Deubelli & Mechler, 2021; Morioka et al., 2019).

Rainfall fluctuations can extend project duration by up to 21% and cause unexpected cost increases (Marzoughi et al., 2018; Dolamore, 2023; Deubelli & Mechler, 2021). Furthermore, climate change also impacts work quality due to challenges such as material damage, logistical disruptions, and decreased worker productivity (Charan et al., 2017; Wibowo et al., 2023). Climate change risks in construction projects can occur at every project stage, from planning and design to implementation and completion (Moi & Purnawirati, 2021; Yudhaningsh, K., et al., 2022). In the context of Aceh, this challenge is increasingly complex given the region's

frequent high rainfall and susceptibility to natural disasters like floods and landslides (Deubelli & Mechler, 2021; Morioka et al., 2019). These conditions indicate the need for a systematic approach to understanding and managing climate change risks. Risk management has become an important step in mitigating the impact of climate change on construction projects (Yu et al., 2020; Muflihah & Pudjihardjo, 2019). Risk identification, analysis, and mitigation are essential steps to ensure the success of road infrastructure projects, especially in facing weather uncertainties due to climate change (Muflihah & Pudjihardjo, 2019; Yu et al., 2020; Herawati, N., & Kartikasari, D., 2021). However, an effective risk management approach requires a comprehensive understanding of risk variables specific to the local context.

Several previous studies have examined the impact of climate change on construction projects, but few have focused specifically on road infrastructure projects in tropical regions like Aceh (Ballesteros-Pérez et al., 2017; Gaarder et al., 2024; Dolamore, 2023). The study by Ballesteros-Pérez et al. (2017) explored the impact of weather on construction productivity but focused on temperate countries whose climate conditions differ from Aceh. Meanwhile, research by Gaarder et al. (2024) focused more on humidity aspects and company preparedness for extreme weather in England. This study aims to fill this literature gap by focusing on identifying and classifying climate change risk variables specific to road infrastructure projects in Aceh Province. Using a mixed methods approach integrating qualitative and quantitative analysis, this study successfully identified 42 risk variables classified into seven main categories. The results of this study are expected to form the basis for developing more targeted and effective risk mitigation strategies in managing road infrastructure projects in Aceh. These findings are also expected to provide practical contributions for stakeholders, including contractors, consultants, and local governments, in formulating risk mitigation policies relevant to Aceh's local conditions (Yu et al., 2020; Muflihah & Pudjihardjo, 2019). Furthermore, from an academic perspective, this study enriches the literature on construction project risk management with a holistic perspective on the characteristics of climate change risks in tropical regions (Rashid, 2020; Zhang et al., 2020).

2. METHODOLOGY

This study was designed to identify and classify climate change risk variables affecting the performance of road infrastructure projects covering 23 districts/cities in Aceh Province. The research stages involved identifying risk variables through a comprehensive literature study. This was followed by a Focus Group Discussion (FGD) using the nominal group technique involving academics and experienced contractor practitioners in Aceh Province. The process of identifying and classifying variables was validated through triangulation by comparing the results of qualitative (FGD) and quantitative (survey) analysis. Variables that consistently appeared in both methods were considered core variables forming the climate change risk framework for road infrastructure projects.

The variable classification stage was conducted through quantitative analysis based on a survey of 278 registered contractors in Aceh Province. Classification used the Risk Importance Index (RII) with the formula RII = FI × SI, where FI measures the frequency of occurrence and SI measures the severity of impact. Variables were then grouped into seven main categories based on characteristics through thematic content analysis. Validation of the identification and classification results was carried out through method triangulation by comparing the

consistency of findings from the FGD and survey results. Variables that consistently appeared in both methods were considered core variables forming the climate change risk framework for road infrastructure projects in Aceh Province.

Table 1. Risk Classification Criteria Based on RII

Risk Category	RII Value	Priority Level
Very Low	0.00-0.20	Not a priority
Low	0.21-0.40	Routine monitoring
Moderate	0.41-0.60	Requires attention
High	0.61-0.80	Medium priority
Very High	0.81-1.00	Top priority

3. RESULTS AND DISCUSSION

Results: Based on comprehensive analysis through literature study and FGD, this study successfully identified 42 climate change risk variables grouped into 7 main categories. The identification results show that the variables with the highest frequency of occurrence came from the temperature and humidity category (28.6%), followed by hydrological changes (23.8%) and weather (21.4%).

Table 2. Distribution of Risk Variables by Category

Risk Category	Number of Variables	Percentage	Dominant Variables
Weather	9	21.4%	High rainfall (A1), Heavy rain (A4)
Hydrological Changes	10	23.8%	Flood (B2), Erosion (B4)
Temperature and Humidity	12	28.6%	Temperature increase (C2), Metal corrosion (C1)
Health and Safety	5	11.9%	Decreased productivity (D3)
Infrastructure Risk	3	7.1%	Road structure damage (E1)
Financial Risk	2	4.8%	Project cost increase (F1)
Operational & Productivity	1	2.4%	Delivery delays (G2)
Total	**42**	**100%**	

Based on the Risk Importance Index (RII) calculation from contractor respondents, the risk variables were classified as follows:

Table 3. Variable Classification Based on RII Value

Risk Level	RII Range	Number of Variables	Percentage
Very High	0.81-1.00	12	28.6%
High	0.61-0.80	15	35.7%
Moderate	0.41-0.60	8	19.0%
Low	0.21-0.40	5	11.9%
Very Low	0.00-0.20	2	4.8%
Total	**42**		**100%**

The analysis results show 12 variables in the very high-risk category (RII > 0.81) which are the top priorities, namely:

Table 4. Risk Variables with the Highest RII Values

Variable Code	Variable Description	RII Value	Category
F1	Project cost increase due to schedule and weather changes	0.89	Financial Risk
B2	Flood hindering access to the project site	0.88	Hydrological Changes
E2	Drainage system failure due to heavy rain	0.86	Infrastructure Risk
A4	Heavy rain affecting concrete work stability	0.85	Weather
E1	Road structure damage due to sudden temperature changes	0.84	Infrastructure Risk
F2	Financial loss due to work delays caused by flood	0.83	Financial Risk
A1	High rainfall causing work area inundation	0.82	Weather
C2	Temperature increase affecting asphalt material strength	0.81	Temperature and Humidity
G2	Material delivery delays due to weather	0.80	Operational & Productivity
A5	Bad weather disrupting road asphalting activities	0.79	Weather
F3	Financial loss due to decreased productivity	0.78	Financial Risk
D3	Decreased labor productivity	0.77	Health and Safety

Discussion: The research findings reveal that financial factors constitute the category with the highest RII values, even though it consists of only 2 variables. This indicates that the impact of climate change on project cost aspects is considered most critical by contractors in Aceh. This result aligns with the study by Zhang et al. (2020), which states that climate change can increase construction project costs by up to 25%. The variables flood (B2) and drainage system failure (E2) occupy the second and third highest positions, reflecting the vulnerability of the Aceh region to hydrological impacts. This finding is consistent with the BMKG report (2023), which recorded a 20% increase in flood frequency in the last decade in Aceh. The distribution of risk variables dominated by the temperature and humidity category (28.6%) indicates that micro-climatological impacts have the broadest scope, although not always the most critical. This is in line with Gaarder et al.'s (2024) research on the impact of humidity on construction projects in tropical regions. The consistency of identification results through FGD and quantitative survey (85% conformity rate) strengthens the validity of the 42 identified variables as a comprehensive climate change risk framework for road infrastructure projects in Aceh.

4. CONCLUSION

Based on the identification and classification results conducted, this study concludes that:

1) Variable identification successfully revealed 42 climate change risk variables grouped into 7 main categories, with the highest distribution in the temperature and humidity category (12 variables, 28.6%), followed by hydrological changes (10 variables, 23.8%) and weather (9 variables, 21.4%).
2) Risk classification based on RII shows 12 variables (28.6%) fall into the very high category (RII > 0.81), with financial (F1: project cost increase, RII 0.89) and hydrological (B2: flood, RII 0.88) variables being the most dominant.

3) Aceh's local context is reflected in the high risks related to floods, extreme rainfall, and drainage system failures, which correspond to Aceh's geographical characteristics as a tropical area with high hydrometeorological vulnerability.

5. Suggestions

Based on the research findings, it is recommended that stakeholders prioritize handling the 12 risk variables in the very high category (RII > 0.81), especially the most dominant financial and hydrological aspects. Local governments need to integrate this framework of 42 risk variables into road infrastructure planning guidelines, while contractors are advised to develop specific early warning systems and contingency plans.

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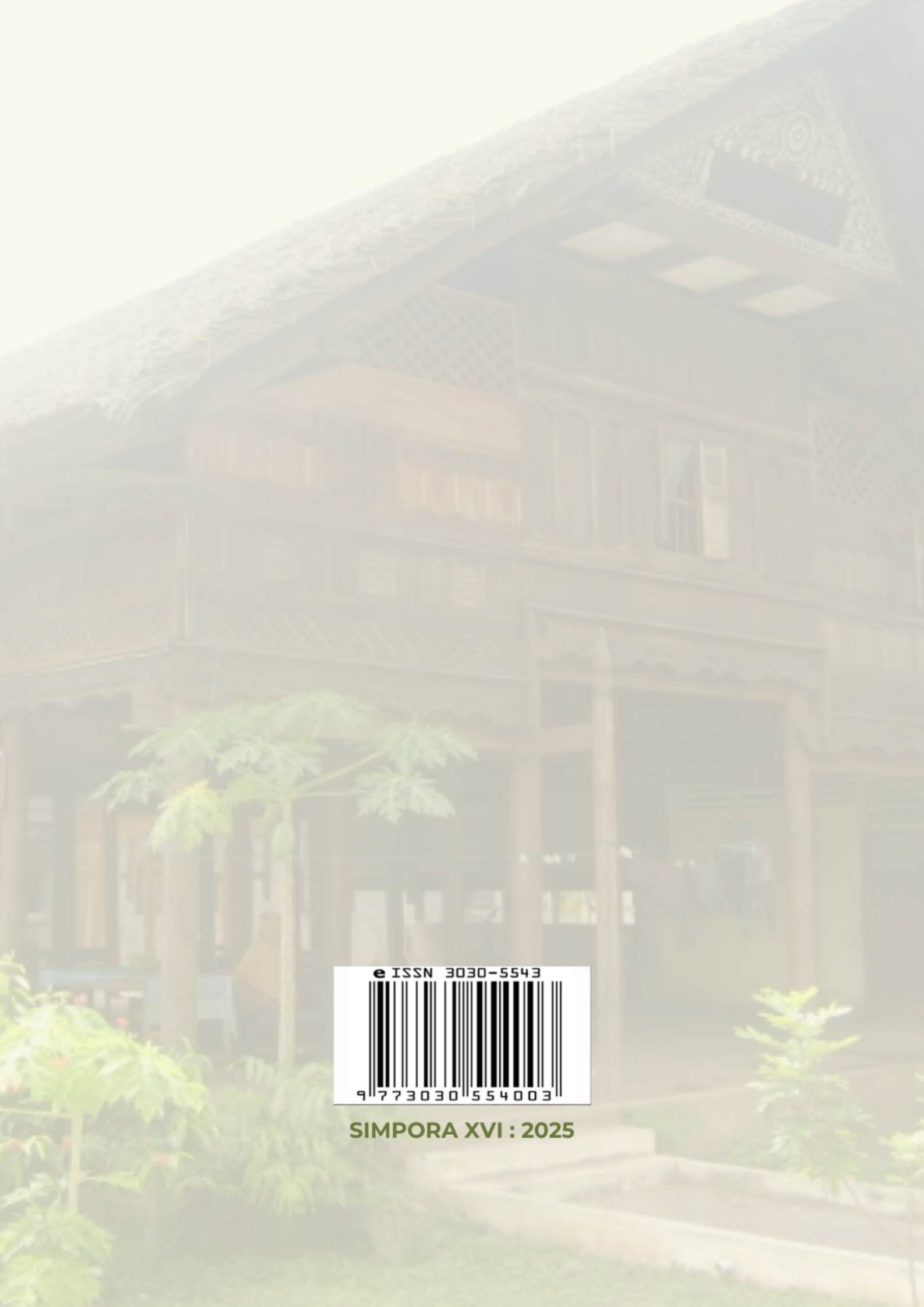

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