3rd Malikussaleh International Conference on Multidiciplinary Studies 2022 (3rd MICoMS 2022)

IINTERNATIONAL CONFERENCE PROCEEDINGS 00009 (2022) | https://doi.org/10.29103/micoms.v3i.39
E-ISSN: 2963-2536

Analysis The Impact of The Coastal Protection Construction Development Plan On Shoreline and Estuary Changes

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ABSTRACT
This beach, which is located in Aceh Province, especially Bireuen City, Jangka District, Kuala Ceurape, is a tourism beach area, aquaculture and also a settlement. Several efforts to control sedimentation and erosion have been carried out by constructing coastal protection buildings on the coast. However, in the estuary there are no coastal protection structures such as jetties. Estuaries have quite high economic value because they function as connecting channels between sea and land. The height of the wave currents around the estuary can cause accumulation of sediment or silting of the beach by erosion which can result in decreased utilization of the coast around the estuary. Therefore, it is necessary to analyze the impact of coastal protection construction planning to determine the formation of sedimentation and erosion that occurs around the coast. This study used the Delft3D application to simulate changes in coastlines and estuaries over a period of 5 years. The data used in this study are wind data for 10 years from 2012 to 2021, depth data, tidal component data, factor morphology calculations, significant wave height calculations (*Hs*) and significant wave periods (*Ts*). This simulation uses 4 (four) wind directions, namely North, Northeast, East and Northwest directions. The results of modeling simulations over a period of 5 years show that the beach condition with the planned construction of the coastal protection has progressed along the coastline by ± 77,053 meters and progress of around ± 77.421 meters on the coast. On the contrary, it experienced a coastline retreat of ± 143.076 meters and experienced a shoreline advance of around ± 84.647 meters in the estuary. So it can be concluded that the construction of the Jetty building alone is not enough to reduce the occurrence of erosion and sedimentation problems around the coast, especially in the estuary. There is a need for the construction of other coastal protection structures.

Keywords: *Coastlines, Estuaries, Sedimentation, Erosion and Delft3D.*

1. INTRODUCTION

Muara Krueng Peusangan waters is one of the river estuaries that has experienced sedimentation and erosion, but there is no construction of coastal protection structures in the estuary. The research location is located in Kuala Ceurape, Jangka District, Bireuen City. This estuary is a wave-dominated river mouth, this is characterized by sediment transport along the coast every year and currents along the coast are more dominant in the formation of sediment in the river mouth. Excess sediment can affect the characteristics and cause related problems around the coast, such as flooding, decreasing water quality and also reducing the depth of the river.

According to Triatmodjo (1999), the problem that occurs in rivers that empties into sandy beaches is siltation or closure of the mouth of the estuary by sediments originating from the beach. The closure of the mouth of the estuary was also caused by large waves which could disrupt the flow of flood discharge and cause overflow around the river banks.[1]

2. REVIEW OF LITERATURE

2.1. Coastline

The coastline is an area that is always changing due to processes that occur around the coast, both processes originating from land and sea, where the two processes unite on the beach. Changes in the coastline around the coastal estuary are partly caused by the influence of the high and low levels of sediment from the river mouth on sediment transport along the coast. Shoreline changes that occur can be estimated in advance using a method, namely a numerical method.[2]

2.2. Estuaries

Estuaries is a mixing place of two mass of water such as the freshwater mass and seawater which is influenced by the physical characteristics of water such as seasons, tide, current, temperature, and salinity.[3]

The river mouth is the downstream part of the river which is directly related to the sea. Problems at the mouth of the river can be reviewed in the river mouth and estuaries. The river mouth is the most downstream part of the river mouth which directly meets the sea. An estuary is a part of a river that is affected by tides. The influence of tides on flow circulation (velocity/discharge, water level profile, saltwater intrusion) in an estuary can extend far upstream depending on the height of the tides, river discharge and estuary characteristics (flow section, wall roughness, etc.) (Triatmodjo, 1999).[4]

2.3. Current

Current is the horizontal movement of water caused by tides, air pressure, differences in specific gravity, salt content and temperature. Currents usually carry soil grains (mud), for heavy grains it can cause precipitation. The existence of these deposits can cause the sea to become shallow. The direction of the tides is generally opposite to the ebb. Like a harmonious tidal movement. The influence of tides is very large at the mouths of rivers.

2.4. Sedimentation dan Erosion

Sedimentation is the deposition of rock material that has been transported by water or wind power. When the erosion occurs, the water carrying the rock flows into the river towards the sea. According to Anwas (1994), when the carrying capacity is reduced or exhausted, the rock is deposited in the watershed.

Erosion is a change in the coastal plain that causes the shoreline to retreat. Factors that affect coastal erosion include: (1) climatological factors such as changes in wave climate, sea level rise, displacement of wave angles, tides, and sediment balance imbalances, (2) tectonic factors, such as: uplift and subsidence, and (3) human behavior factors that accelerate environmental changes. The imbalance in the coastal sediment balance is mainly due to human activities such as sand mining, beach embankment and dam construction which reduces sedimentation and disrupts the flow of water in the estuary.[5]

2.5. Jetties

Jetties is a building perpendicular to the beach placed on both sides of the river mouth which serves to reduce siltation of the channel by coastal sediments. In the use of river mouths as shipping lanes, sedimentation in the estuary can disrupt ship traffic. For this purpose the jetties must be long so that its end is outside the sediment along the coast which also greatly influences the formation of these deposits. The sand that passed in front of the estuary broke apart. With a long jetty the transport of sediment along the coast can be restrained and in shipping lanes the wave conditions do not break, thus allowing ships to enter the mouth of the river. In addition to protecting shipping lanes, jetties can also be used to prevent siltation in estuaries in relation to flood control.[6]

2.6. Data Analysis

2.6.1. Wind Velocity

Wind speed is measured for wave forecasting purposes using an anemometer which is expressed in units of knots. One knot is the length of one minute of equator longitude traveled in one hour, 1 knot = 1.852 km/hour. This wind data collection is the maximum daily wind data. The percentage of the dominant wind direction is used for design wave design. The wind data obtained is wind measurement data on land, so it must be converted to wind data at sea. The formula for converting wind data at sea (U_W) to wind drag speed (U_A) is as follows:

$$U_W = R_L \times U_L \quad (1)$$

$$U_A = 0.71 \times U_W^{1.23} \quad (2)$$

$$R_L = 2.760 \times U_L^{-0.305} \quad (3)$$

Information of:
U_W = wind speed predicted at sea (m/s)
R_L = speed comparison value
U_L = wind speed measured on land (m/s), z = 10 m
U_A = wind drag speed (m/s)

2.6.2. Fetch

Fetch is the length of the area where the wind blows with a constant (fixed) speed and direction. The length of the fetch is the length of the sea bounded by the islands at both ends. In view of the generation of sea waves, fetch is usually limited by the land that surrounds the sea (Triatmodjo, 1999). For forecasting wind waves, it is necessary to determine the effective fetch (F_{eff}) with the following equation:[3]

$$F_{eff} = \frac{\sum X_i \cos \alpha^\circ}{\sum \cos \alpha^\circ} \tag{4}$$

Information of:
F_{eff} = fetch effective
X_i = length of the fetch segment measured from the wave observation point to the end of the fetch (km)
α^o = deviation on both sides of the wind direction, using an increase of 6° to 42° on both sides of the wind direction

2.6.3. Significant wave height and significant wave period

Calculation of significant wave height and period uses the wave forecasting formula (CERC, 1984), which is based on fetch length (F) and wind drag speed factor (U_A). Formula equation for the height and period of significant waves is as follows:

$$\frac{g.H_s}{U_A{}^2} = 0.30\left[1 - \frac{1}{\left\{1+0.004\left(\frac{g.F}{U_A{}^2}\right)^{1/2}\right\}^2}\right] \tag{5}$$

$$\frac{g.T_s}{2\pi\, U_A} = 1.37\left[1 - \frac{1}{\left\{1+0.008\left(\frac{g.F}{U_A{}^2}\right)^{1/3}\right\}^5}\right] \tag{6}$$

Information of:
Hs = significant wave height (m)
Ts = significant wave period (m)
U_A = wind drag speed (m/s)
g = gravitation acceleration (m/s)
F = fetch length (m)

3. METHOD OF RESEARCH

The method used of the research is numerical modeling using the Delft3D software to simulation the impact of the coastal protection construction plan on shoreline and estuary changes in Kuala Ceurape, Jangka District, Bireuen City, Aceh Province (**Figure 1**). This modeling requires data such as bathymetry data and tidal components obtained from the Pengairan Aceh, wind data obtained from the Meteorology, Climatology and Geophysics Agency (Lhokseumawe BMKG) , wave data and sediment data (D_{50}) obtained from laboratorium test results.

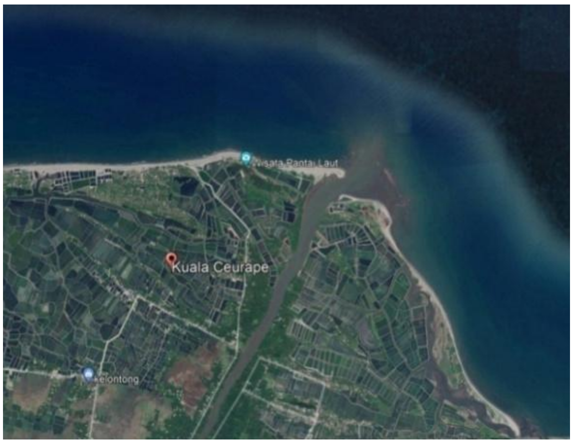

Figure 1. Location Map of the Research

Boundary conditions for hydrodynamic and morphology modeling are filled with tidal components (M_2, S_2, K_1 and O_1) and wave data (Hs and Ts) which will simulation the movement of currents, waves and sediments. The tidal data can be seen in **Table 1** below.

Table 1. Tidal Components

Wind data used for 10 years from 2012 to 2021. To make it easier to read the wind speed that occurs from various directions, it is presented in the form of a wind rose in percent as shown in **Figure 2**.

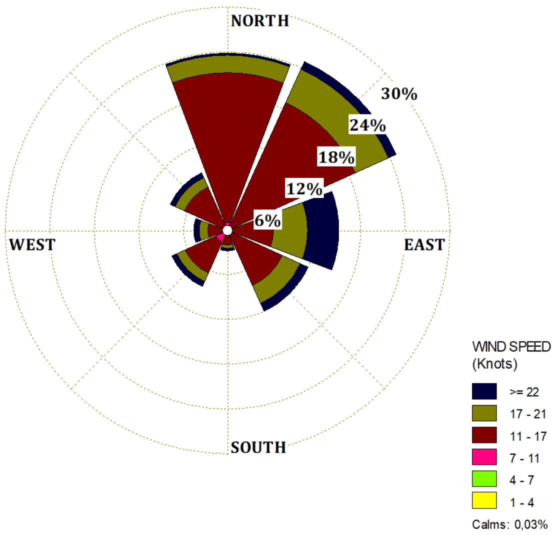

Figure 2. *Windrose* Malikussaleh BMKG (2012-2021)th

Based on the windrose in Figure 2 the most dominant maximum wind is coming from the North, North East, East and North West direction is used as a simulation model because comes from the sea. Generation of waves using the fetch method will produce an average wave that is used for the numerical modeling of the beach as input to the boundary conditions as in **Table 2.**

Table 2. Boundary Conditions

4. CONTENTS

4.1. Simulation Modeling of Flow

The impact of the jetty development plan from the results of current modeling simulations carried out in the Kuala Ceurape coastal area, Bireuen Regency, when the current moves from the east with a speed of 0.132 - 2.204 m/s towards the coast and also towards the deep sea. The current moving towards the deep sea collides with the current vector from the North where the incoming speed is 0.008 – 0.015 m/s. Then, the current moves back towards the estuary and hits the Jetty building, the current vector entering the estuary moves towards the river and enters the surrounding mines. Currents that approach the coast are very diverse, ranging from the highest speed to the lowest speed. The full results can be seen in **Figure 3** below.

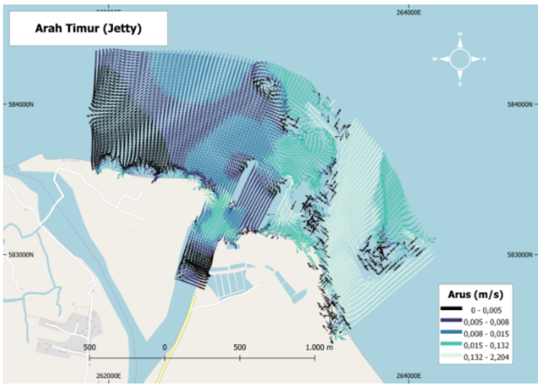

Figure 3. Current Pattern of East Wind Direction

The modeling of the North West wind direction is shown in Figure 4. At the time of the Northwest, the tides are coming at high speed towards the coast. However, the collision does not occur again in the advancing coastal sediments in the initial scenario. Instead, the ebb and flow at high speed at a speed of 0.081 – 0.562 m/s passes through the Jetty building and the low ebb current hits the Jetty walls. The low tide moves towards the East with a speed of 0.028 – 0.047 m/s. The current towards the right coast moves to the lowest speed and recedes back towards the Northeast with a speed of 0.047 – 0.081 m/s. Details are shown in **Figure 4** below.

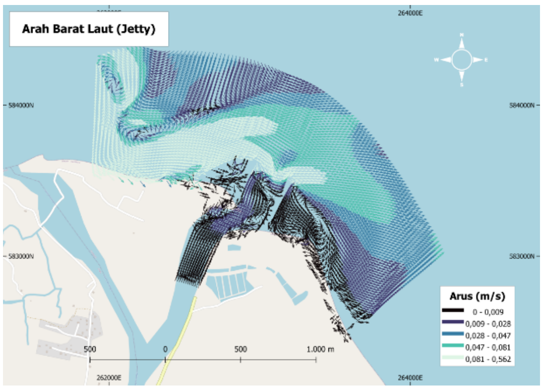

Figure 4. Current Pattern of North West Wind Direction

The condition of the current pattern from the North East moves uniformly towards the Southwest. Tidal currents that approach the coast travel at a moderate speed of 0.181 – 0.462 m/s. Then, the current recedes with a speed of 0 - 0.019 m/s to a high speed of 0.521 - 1.005 m/s moving towards the North by passing the Jetty building construction. The current entering the estuary experiences a current vector eddy because it is opposite to the river current caused by the gravity of the river flow and hits the Jetty buildings as shown in **Figure 5**. Meanwhile on the left coast the current moves at a speed of 0.019 – 0.181 m/s until low currents and ebb and flow up to medium speed.

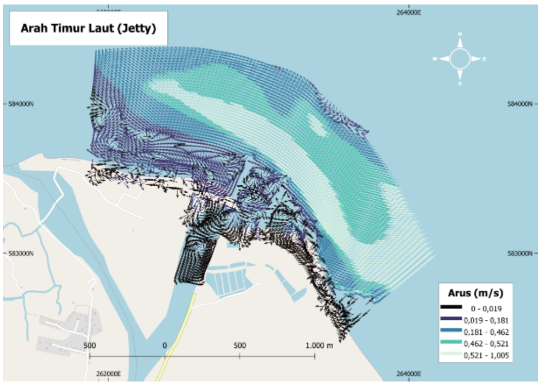

Figure 5. Current Pattern of North East Wind Direction

Then the last one is the condition of the North direction current modeling. The speed of the current moving from the North towards the Southeast with a speed of 0.126 - 0.271 m/s. The current that is heading southeast is moving at a speed of 0.072 - 0.103 m/s towards the mouth of the river estuary when it encounters a collision with coastal sediments and also the Jetty building so that some of the current vectors move back towards the coast at a speed of 0 - 0.020 m/s. However, other currents move past the Jetty building at high speed, some heading for the left coast and some entering the estuary. The current entering the estuary causes a vector vortex to the lowest speed. While the current moving to the coast hit the Jetty wall. Then the current recedes towards the North to high speed. The complete current modeling is as shown in **Figure 6**. The current towards the river collides with the estuary walls and skirts the coast at low speeds of up to 0 m/s.

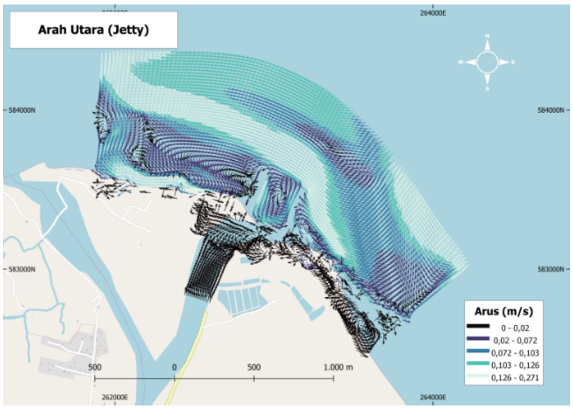

Figure 6. Current Pattern of North Wind Direction

2.2. Simulation Modeling of Wave

The wave modeling in the east direction is quite high, with a wave height of ≤ 2.749 meters with a current wave speed of 0.132 – 2.204 m/s. However, the waves only propagate in a smaller area compared to the condition before the existence of the Jetty building so that the lowest height ranges from 0 - 0.258 meters to a speed of 0.015 - 0.132 m/s. The modeling is as shown in **Figure 7**.

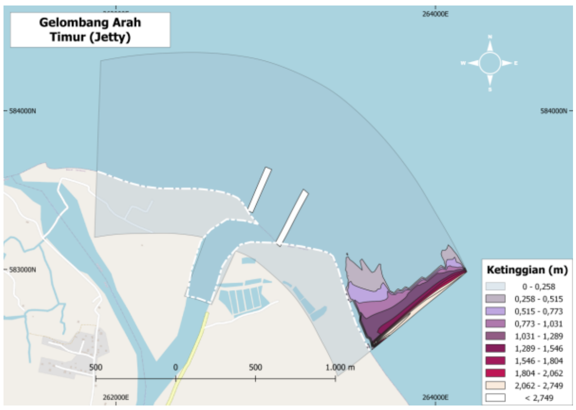

Figure 7. Wave Modeling of East Wind Direction

A simulation of the Northeast wind direction waves can be seen in **Figure 8**, where the wave heights coming from the Sea High direction start at an altitude of 1.376 – 1.634 meters with a speed of 0.521 – 1.005 m/s. Then, the waves propagate toward the coast periodically until the waves break against the coast at an altitude of 0.344 - 0.473 meters with a speed of 0.181 - 0.462 m/s, then hit the end of the Jetty building with a height of 0.860 - 1.118 meters at a speed of 0.019 - 0.181 meters. The breaking waves that enter the wavy estuary reach the lowest height, which is 0 – 0.344 meters.

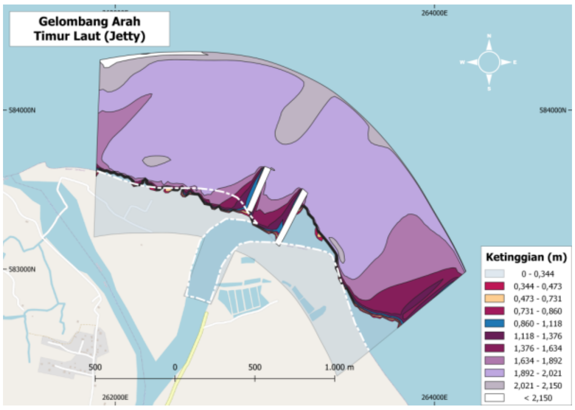

Figure 8. Wave Modeling of North East Wind Direction

North wind direction wave modeling shows that tidal waves come with a height of 1.627 – 1.748 meters with a high speed of 0.126 – 0.271 m/s. Waves coming from the north towards the coast break at 1.505 – 1.627 meters. Then, the waves headed northwest and hit the jetty building and broke at an altitude of 0.780 - 1.022 meters with a speed of 0.02 - 0.072 m/s. The waves entering the estuary hit each other with buildings and a vortex occurred from a height of 1.506 – 1.627 meters to a height of 0.296 – 0.417 meters. The receding waves propagate towards the West and turn towards the North up to a height of ≤ 1.748 meters with a speed of 0.126 – 0.271 m/s. Wave modeling as shown in **Figure 9**.

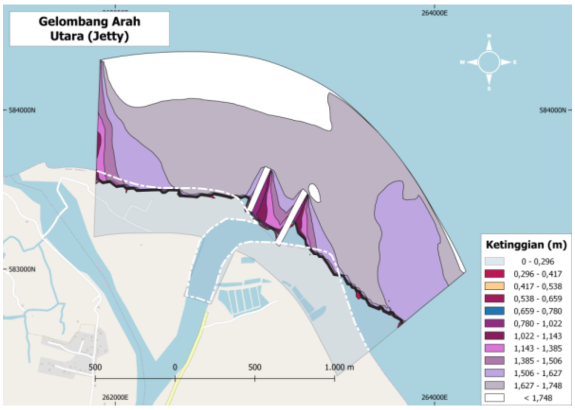

Figure 9. Wave Modeling of North East Wind Direction

Changes in coastal morphology occur due to the high and low currents and waves that hit the coastline so that a new coastline is formed which is called a change in the shape of the beach.

Conditions after numerical modeling simulations within a period of 5 years experience problems of erosion or the erosion/transportation of coastal sediments to other places. As shown in **Figure 10**.

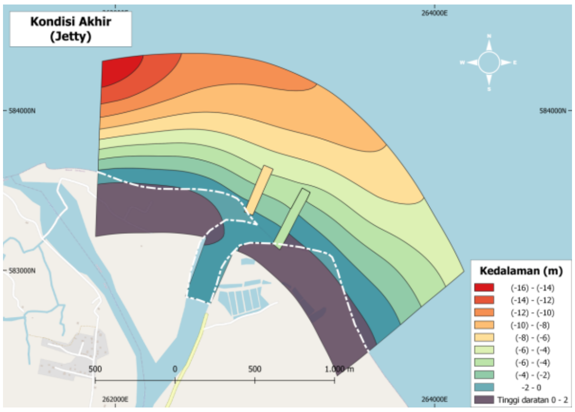

Figure 10. Beach Morphology Conditions with Modeling

The division of erosion and sedimentation modeling simulation with the construction of the Jetty building has 8 divisions, with 4 eroded sections (I, III, V, VII) and 4 sedimented sections (II, IV, VI, VIII). Part I has a coastline retreat of ± 77,053 meters with an area of ± 6,864,093 m2. Part III has a coastline retreat of ± 143.076 meters with an area of ± 35,414.163 m2. Section V experiences a coastline retreat of ± 20,556 meters with an area of ± 832,723 m2. Section VII experiences a coastline retreat of ± 61,744 meters with an area of ± 12,947,620 m2. Part II has a coastline progress of ± 22,637 meters with an area of ± 5,204,134 m2. Section IV has a coastline progress of ± 84.647 meters with an area of ± 10,360.153 m2. Section VI has a coastline progress of ± 77,421 meters with an area of ± 5,302,906 m2. Section VIII has a coastline progress of ± 72.188 meters with an area of ± 20,007.805 m2. As shown in **Figure 11**.

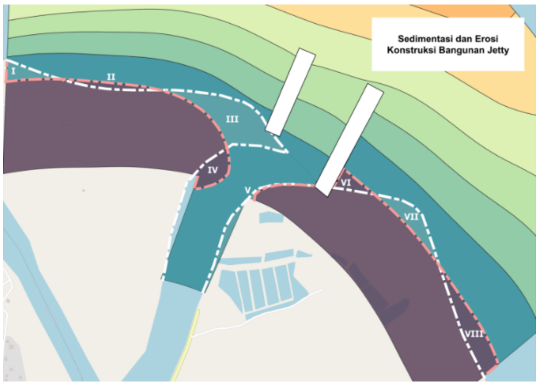

Figure 11. Erosion and Sedimentation Areas

5. CONCLUSIONS

Based on the results of numerical modeling simulations using the Delft3D application from 4 (four) dominate wind directions namely North, Northeast, East and Northwest. The results showed that the morphological conditions of the Kuala Ceurape, Jangka District, Bireuen City, Aceh Province within 5 years. The coastline is experiencing the most erosion problems, namely around ± 143.076 meters with a total area of eroded area of ± 56,058.599 m2. Meanwhile, the most distant sedimentation problem is ± 84.647 meters with a total area of sedimentation which is ± 40,874.998 m2. Therefore, the impact of the plan for the construction of a coastal protection structure (jetty) on changes in coastal morphology in Kuala Ceurape is not effective enough to reduce erosion, because the results of the modeling simulation show that the presence of the Jetty plan also causes erosion. the decline of the shoreline and the accumulation of sediment in the estuary. It is necessary to carry out periodic developments, namely by planning for Jetty buildings and other coastal protection structures that extend around the coast such as Revetments.

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