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Contents

Summary

This report is intended to give an overview of the situation of the Ribe pilot site with respect to flooding and flood protection infrastructure from a system perspective as of 2016. This work is part of the FAIR project, work package 4.

1. Pilot description

The pilot site of Ribe is located on the Danish North Sea coast approximately 7 kilometres inland and is the oldest town in Denmark. The pilot site is dependent on flood protection infrastructure. A current and future challenge is that many dike lines have to be rebuilt or renovated to uphold the required security level in the hinterland. Figure 1 shows the location of the pilot site whereas the dikes, watercourses, elevation and the extent of the town of Ribe can be seen on figure 2. The objective is to determine the best way to protect Ribe and the surrounding area from future storm surges from the sea and water rise in the local rivers, Ribe Å and Kongeåen.

Figure 1: Location of pilot area

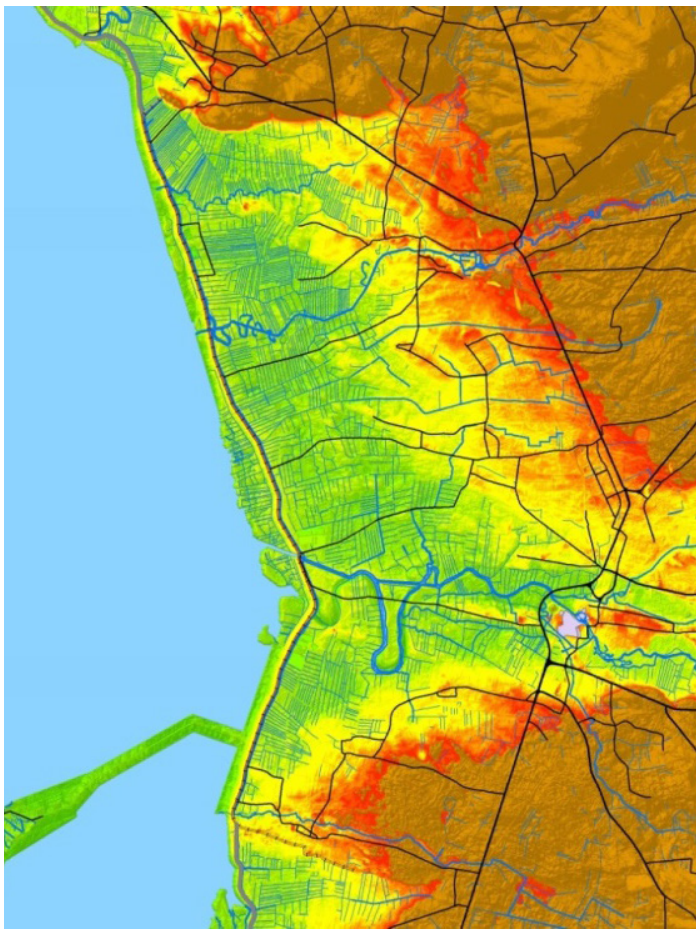


Figure 2: Height model with dikes, water courses and main roads included

The landscape between the North Sea and Ribe is a polder containing marshland and moorland. During the second to last ice age the moorland was formed. Later, sea level rise caused a change from moorland to marsh. The marsh reaches furthest inland at Ribe creek where it reaches as far as 5 km inland. As seen on map 2, dikes run along the North Sea as a barrier only interrupted by sluices. Two rivers run through the pilot site; Kongeåen and Ribe Å. The area around Ribe is a large low-lying flood plain containing mostly drained farmland, mostly lying between +1.0 to +2.0 above MSL. The area is behind the sea dikes to the Wadden Sea. The total area of the flood plain is 97 km2 and it includes the medieval town of Ribe. The ancient town centre is mostly elevated above +4.0 MSL, but the town has spread out and also occupies residential and industrial areas located down to +2,0 MSL.

Several flood protection assets are in place at the pilot site of Ribe, including dikes, sluices and pumps. Fragmented ownership of the assets poses a challenge to asset management. Maintenance and operation of the Kammerslusen is directly financed by Esbjerg Municipality. The local dike association (land and property owners) is responsible for funding maintenance of the dikes, Kongeå and other sluices, with indirect support from the municipality. The Danish Coastal Authority assists with a technical inspection twice a year, but does not contribute with funding. The pumps are owned by drainage associations, although it is worth noticing that pumping only plays a minor role in flood protection in this case. The dikes are owned by the individual owners of the properties they protect, the owners often being organized in dike associations, the roads are owned by the ministry of transport, the main sluice is owned by the municipality and the storm flood alert and contingency planning lies with the Danish Coastal Authority. Therefore, a coordination of the management of the different assets is required to minimize the risk of flooding. Dike protection is mainly financed by those, who gain from the protection. With respect to areas that would otherwise be flooded ,the value of the protection is assessed and the cost is then distributed among the involved partners such as citizens and the municipality. Table 1 gives an overview of the asset ownership and financing structure. This situation is representative of the rest of Denmark.

Table 1.

Asset	Owner	Financing
Kammerslusen	Esbjerg Municipality	Esbjerg Municipality
Other Sluices	Dike association	Dike association with support from Esbjerg Municipality
Dike	Dike association	Dike association
Pumps	Drainage associations	Drainage associations

2. Source of flooding

The flood risk in the Ribe flood plain is two-fold. One risk is flooding from the sea, caused by dike breach or overtopping during storm surges. The other risk is flooding from the local rivers, like Ribe Å or Kongeåen. Excluded from this study are floodings from groundwater and precipitation. The main sources of flooding from watercourses are two small rivers, Ribe Å and Kongeåen, and two smaller creeks, which have their outlet in the Wadden Sea, and are admitted through the dike by either lock or sluice. The river Ribe Å runs through the old town centre of Ribe, before running through the drained farmland and finally passing the dike protection through the lock, Kammerslusen, into the Wadden Sea.

During storm surges, the water level in this part of the Wadden Sea can rise upwards of 4.92 meters above MSL (100 year return period), exceeding the terrain height of most of the Ribe flood plain. During a storm on the 3rd of December 1999, at Kammerslusen water levels were measured to 5.01 meters (DVR90), before the measurement device broke. The storm surge happened to coincide with low tide, and no dike breach occurred. The regular difference between low and high tide water levels is around 2.00 metres in this part of the Wadden Sea. Had the peak of the surge coincided with high tide, the water level would have be expected to have increased to above +6.0 meters. With a dike crest of +6.88 meters, the overtopping would have been severe and would have threatened to cause a massive or total breach of the dikes.

The risk of flooding from the rivers is greatest during storm surges and winters. During storm surges, the lock and sluices in the dike line are closed, and water levels rise due to the discharge in the rivers. Water levels rising in Ribe Å can lead to flooding of the low-lying area around the town of Ribe. This occurs on a yearly basis.

The diked marshland is protected against the otherwise frequent overwash from sea water, and some of the marshlands are so dry that they can be utilized for cultivation of crops. However, the typical terrain in the marsh is only about 1.5 meter above sea level, and the marsh landscape is thus very low. The meadows around the river valley are therefore too moist for most crops and are generally used for grazing and production of hay. The river valley is dominated by Ribe Å that meanders on its path towards the Wadden Sea. Ribe Å is split into four smaller streams when running through the town, and then they gather into one west of the city. Three of these streams pass sluices in the dam, where the water level upstream is regulated.

On several locations the creek, on the stretch west of Ribe, has been lead into artificial canals that have been deepened to facilitate sailing on the creek. Within Ribe, the creek has also been impacted by human interference. The oldest part of the city is built upon a dam and in a number of places in the city, canals and watermills are established.

At high runoff from Kongeåen excess water runs into small ditches and on the surface to Ribe Å causing further pressure.

3. Pathway

As can be seen on figure 2, the pathway from the ocean to Ribe is primarily obstructed by the dike with sluices.

The first modern seawall or ocean dike was constructed in 1911-1914 and the latest enhancement was in 1978-1980. The expansion of the dike was funded by a 60/40 distribution of cost between state and local entities (municipality and county). Since the dike was built, new marshland has only emerged in front of the dike. The dike consists of the sea dikes of 15.277 metres and the southern wing dike of 2700 metres and northern wing dike of 505 metres. The ocean dike has a 2.5 meter wide crown in elevation 6.88 m at DVR90 and is grass covered. The seaside slope including the crown is clad with a 1 meter loam layer and the landside of the slope with 0.5 meter. The core of the dike contains the older ocean dike, which reportedly consists of good loam and sand. In 1978-1980 the core was enhanced with pumped-in sand. The Danish dikes are often prone to erosion of the slopes. The dike contains four sluices in total –Ribe Kammersluse and three dewatering sluices. (Kulturministeriet, 2013) The sluices only facilitate water outflow and no inflow.

There are no measures of water delay for Kongeåen that flows from Kolding Municipality. The stream overflows into its broad flood plain on its way to the Ribe area.

Several challenges exist today concerning the sluices. The gates of the Kammerslusen are 1 metre lower than the adjacent dikes, that have been raised in the late 70-ties. Kongeåslusen operates with only 2 or 3 of its 5 gates due to the accretion of sand. The latter issue is currently being addressed.

The dikes may need reinforcement or expansion due to future climate conditions with increased water levels and intensified discharge. A secondary dike line would require additional sluices or flood gates. Additional inland dikes, either riverside or as a secondary dike near the town could be considered, but none currently exists. The coast is not an erosion zone, but some sand fencing has been done in the past. In case of a dike expansion, increasing the foreshore may be beneficial to maintain a low slope of the dike. Another approach could be to allow the Wadden Sea to expand due to climate change by realigning the dikes further inland.

To address the challenge of backwater, an upstream delay might be considered. Additionally, the removal of flood receptors in the marshland, mostly farmland, would allow the river to discharge in this area while providing space for nature. The latter solution will become more compelling in the future, as increased discharge will unavoidably flood the area more frequently, making current activities non profitable and, in a longer timeframe, perhaps impossible.

4. Hinterland

The most densely populated area in the hinterland is Ribe town with approximately 8.250 inhabitants. As previously mentioned, the town is the oldest in Denmark and therefore represents important national heritage. In case of a dike breach during a storm surge, large areas including parts of the historical town centre and roads to and from Ribe could be flooded. Some of these cultural heritage sites are Ribe Cathedral, archaeological excavation sites and historical town houses. Between Ribe and the sea several smaller villages or settlements are located on the higher land within the marsh. The marsh is valued as low in the climate adaptation plan by Esbjerg municipality. The Wadden Sea was registered as a UNESCO world heritage site in 2009 and is the largest national park in Denmark covering 1459 km2. Furthermore, agricultural land is located within the polder. The bypass road, a number of wind turbines and Ribe iron industry plant are also located in the hinterland. In addition, the main road (route 24) is below +3.0 metres MSL, and in danger of being cut off in case of a major flood. On map 3 the damage extent from a potential flood is illustrated.

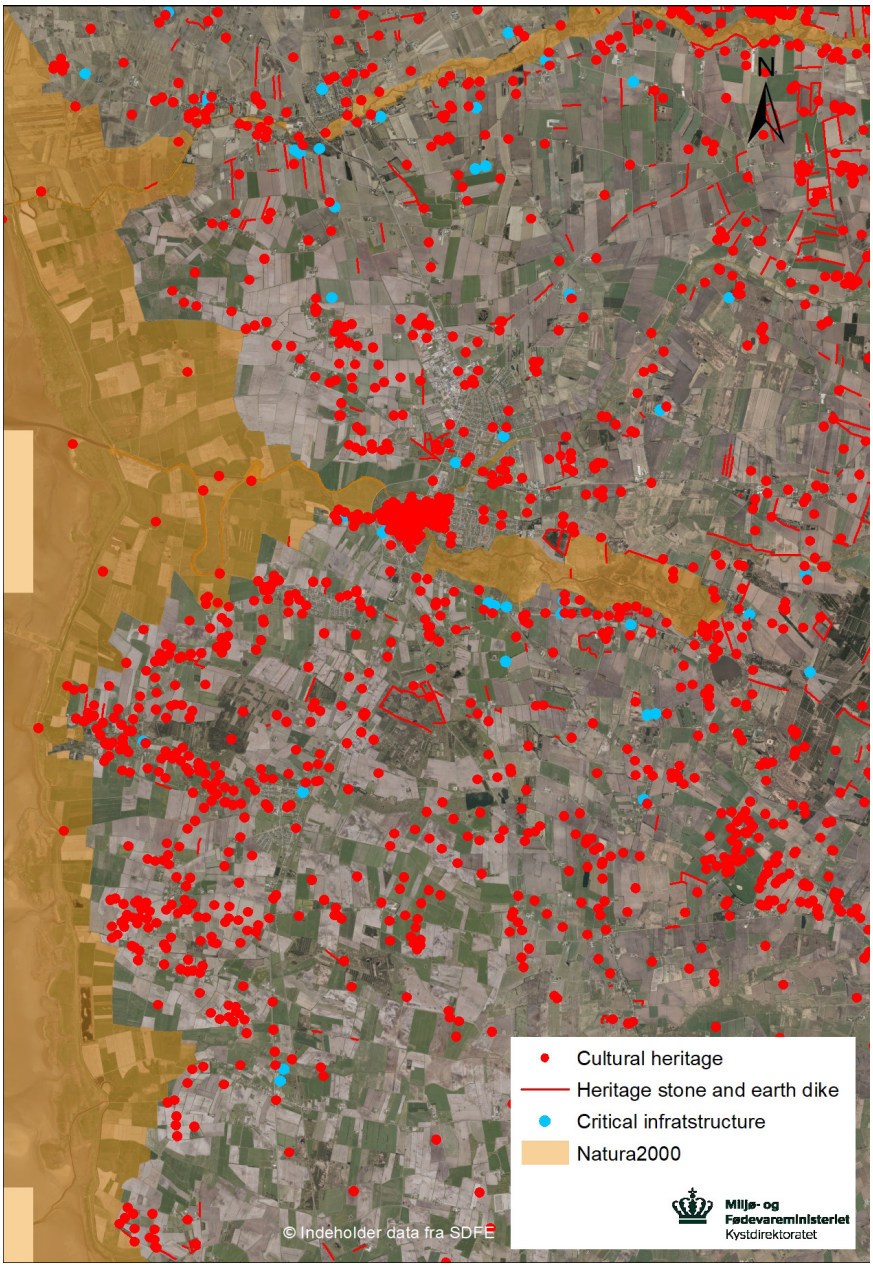


Figure 3: Damage extent from flooding in year 2115. The red dots represent cultural heritage, the blue dots critical infrastructure, the red areas protected nature and the beige areas depict Nature2000.

5. Historical storm floods

Over the centuries, Ribe and the marsh have been seen numerous storm surges. The earliest records are from 1258 but are somewhat uncertain. The first certain record of a storm surge dates back to 1362 and then 1532. From 1600 to 1613 there are records of storm surges every year. During the 1600s and the 1800s, in particular, storm surges were frequent in Ribe. The flood in 1634 was named "The Great Drowning" due to the severity of the impact and the high death toll. Storm surges occurred every year from 1818 to 1825. The floods during the 1900-s are all confirmed. There are records of floods in 1904, 1906, 1909, 1911, 1916, 1923, 1926, 1928, 1936, 1949, 1962, 1967, 1968, 1976 and 1981. The flood in 1911 was the last to reach Ribe, but the flood in 1981 was especially extensive, not only in the Ribe polder, but along the entire Danish North Sea coast. The storm in 1999 is the most severe hurricane measured in the southwest part of Denmark, reaching water levels over 5 meters above normal water (Klaus Melbye, Vadehavscentret & Anne-Marie Overgaard, Museum Sønderjylland).

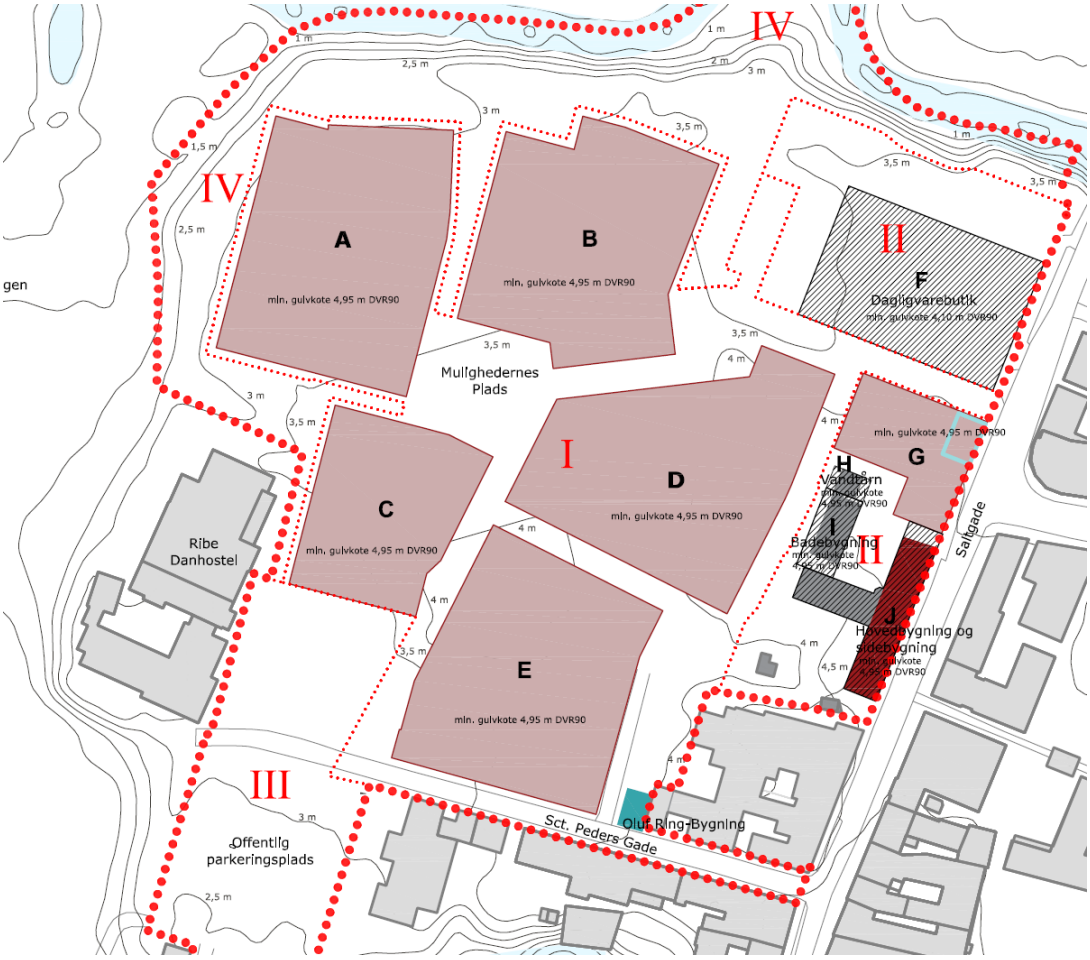
Flooding of the marsh lands from the overflow of Ribe Å is typical during winter storms, when the sluice gates are closed. This is also true for Kongeåen, mainly in the case of strong westerly winds. However, most of the infrastructure and residential areas are usually unaffected. Since the construction of the modern dikes in the early 20th century, no breach of the dikes at Ribe and no major flooding incidents of residential areas have occurred (Gram-Jensen, 1991).

The Flood Column in Ribe, with metal markers showing historical floods

6. Development plans for the area

New construction is planned where the iron plant is currently located in Ribe. This plant will be relocated and instead a residential area of 3-4 meters' elevation is planned. Existing buildings have been raised to elevation 1. 5 metres to reduce the risk of flooding. Other parcelled lands in the municipality that are exposed to flooding have been taken out of local planning to prevent construction. This is part of the climate adaptation plan to prevent future flooding. (Esbjerg Kommune, 2016)

Furthermore, a renewal of the bypass road around Ribe is underway as of 2019. The road is not intended to be climate proofed in regards to flooding. It was previously discussed to raise the new road to a higher level than the existing one but this is not part of the final plans. The road is an evacuation road that is exposed to heavy transport on a daily basis. In case of severe flooding, viable alternative routes do not exist. No extreme flooding of the road has been experienced, although the municipality reports winter water levels approaching the level of the road surface and water damage to its foundations.



Development plans for Ribe Jernstøberi. © Courtesy of Esbjerg Municipality

7. Implementation of flood protection

No total scheme of protection has been implemented during the last couple of years. The municipality is experiencing challenges as to the level of acceptable risk, both now and in the future. So far the storage of large quantities of water in the marsh lands has not been accepted, since this has not previously been an issue, but now it is a recurrent yearly event that is predicted to become more severe in the future, spurred by climate change. If the dikes are raised, storage of water in the marsh over a longer period of time must be accepted. This will be a concern in scenarios when the water level in the ocean is high, the sluice is closed and runoff from the water courses will end up in the polder. These are major concerns of the municipal authorities with regards to implementation of flood protection in the marshlands that constitute a protected area.

Changing the flood plain both west and east of the town of Ribe may harm the marsh-like habitat used by native and migrating birds. Changing of the mean water level in Ribe Å may have impact on nature types. Most of the areas along Ribe Å and are protected wildlife areas, as shown in Figure 4.

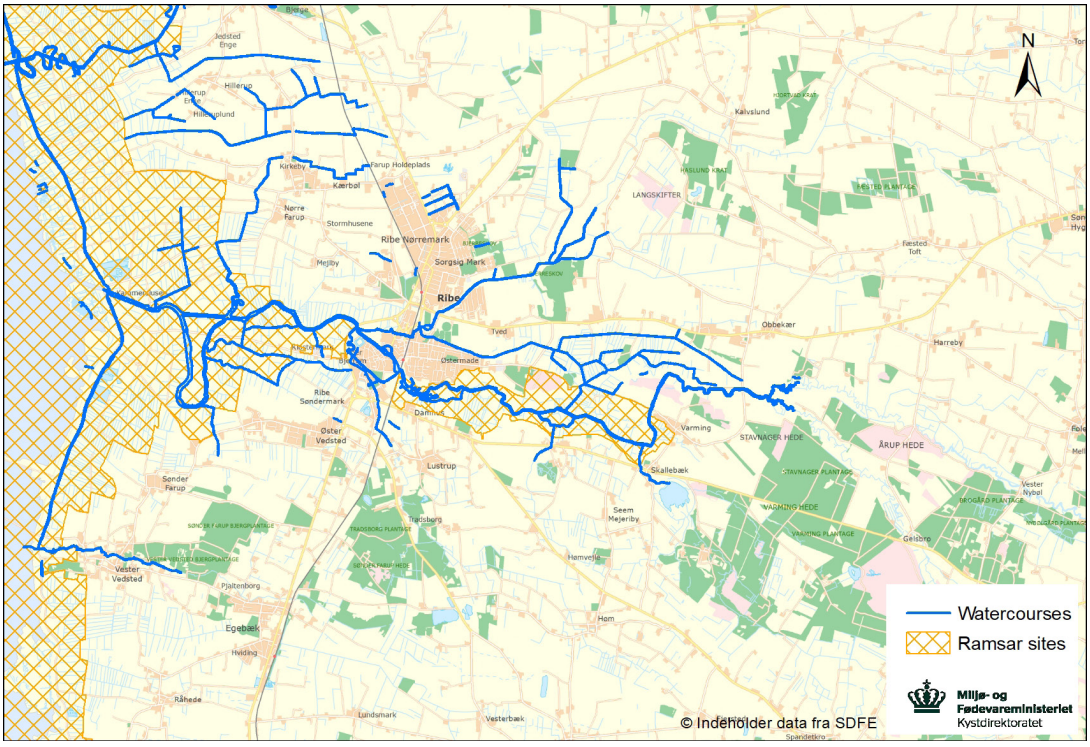


Figure 4: Ramsar areas are shown by the yellow grid and protected watercourses are highlighted by the blue lines.

Currently, no projects implemented in the pilot area encompass any interaction between flood protection and tourism or recreational activities. However, a project at the Ribe iron plant, which will be relocated to make room for housing, is looking to incorporate a recreational area into the climate adaptation plan for the area.

Several of the locals have expressed an interest in having more recreational pathways in the marsh and near the dikes but such paths will not be accessible year round.

8. Projects in the pilot

In Varde, a town relatively close to Ribe, an EU-interReg project is focusing on precipitation. The results from this project may be applicable for Esbjerg municipality, too.

Calculations and basic work for an EU-life project has been carried out for the area between the Kammersluse and Ribe. The focus of this project was meant to be meandering of creeks but ultimately the project was never realized. A challenge was to involve the farmers who had no interest in the land becoming wetter.

Several municipalities in Denmark have expressed an interest in guidance and maintenance of sluices in particular. A main focus of this pilot site is the operation and maintenance of the sluices within the sea dike. Knowledge gained will be transferable to similar sluices in Denmark.

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