

ROAD-RAT - REGIONAL RISK ASSESSMENT TOOL FOR FLOODING, EROSION, AND OVERTOPPING OF COASTAL ROADS

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INTRODUCTION

In many places, coastal roads are the first line of infrastructure impacted by coastal processes. Failure mechanisms for coastal roads include, e.g., undermining due to wave erosion, inundation, and erosion due to the weir-flow mechanism (Douglass, 2020). The damage and associated disruption can be either temporary or permanent and are, in principle, caused by the processes of erosion, flooding, and overtopping. The damages and disruptions are often costly and may have long-term effects for local residents, business, and rescue service access. Still, the knowledge about coastal risks on the road infrastructure is limited and risk analyses typically apply simplified approaches where only the still water level is taken into account. In this study, we develop a tool to assess the probability of impact from flooding, storm erosion, and overtopping on coastal roads, taking into account the long-term coastal evolution and the impact of sea level rise.

RISK ASSESSMENT TOOL

The risk assessment tool (ROAD-RAT) calculates the probability of road failure due to flooding, erosion, and overtopping in computation points distributed along the investigated road network. The tool is designed to be used for screening risks at a regional scale over coastal stretches of 100s of kilometres. The risk analysis is made for present conditions and for future projections. In this case, the prognosis is performed for the years 2050, 2100, and 2150, assuming sea level rise corresponding to the mean prediction of the RCP 8.5 scenario (see Figure 1 for an example of model output).

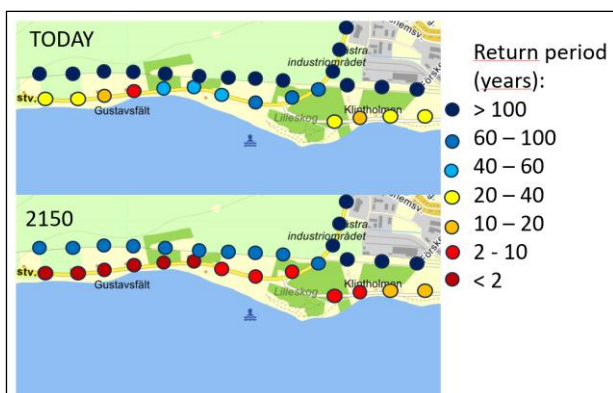


Figure 1 - Example of results from the risk assessment tool. Risk maps are generated for each impact (erosion, flooding, and overtopping) and each year, e.g. 2150.

In each computation point, a coastal transect is derived from the digital elevation model. From the transect, beach slope and sediment volume used for the erosion and runup calculations are derived. The tool includes the

following processes:

Long-term coastal evolution - erosion/accretion is determined based on the Bruun rule (Bruun, 1962) and historically observed coastline changes.

Overtopping - the probability of runup reaching the road surface is determined based on a Generalized Extreme Value analysis (GEV) of a time series of total water levels computed from simultaneous wave and water level data. The selection of runup equation is adjusted for beach type (sandy beaches - Stockdon et al (2008), gravel beaches - Poate et al (2016), and structures - Eurotop (2018)).

Flooding - inundation due to still water levels exceeding the road elevation is determined from GEV analysis of water level records.

Storm erosion - the probability of storm erosion reaching the road is determined by calculating the erosion probability of the entire volume of sediment available between the road and the coastline. For this, the simplified approach by Hallermeier and Rhodes (1988) is applied:

$$\text{Erosion [m}^2\text{]} = C \cdot (\text{Return period [yr]})^{0.4}$$

The probability of erosion is adjusted to the local conditions through calibration of the C parameter ($C=8$ in the original study) depending on sediment properties and wave exposure.

CASE STUDY

The tool is applied to the south coast of Sweden (Figure 2). A 100 km-long low-lying coastal stretch with several near-coastal roads. Within the study area, the area seaward of the roads consists of sandy beaches, gravel beaches, and revetments. Simulated wave data from 1959 - 2023 together with water level observations from 1887 - 2023 are used for the analysis. In October 2023, the coast was hit by the storm Babet that caused a storm surge reaching about 130 cm above normal sea level in combination with large waves. Significant wave heights of up to 4.5 m were observed in the Southern Baltic Sea, offshore from the study site. The storm surge caused road undermining and wave overtopping on the road at several locations, but no inundation.

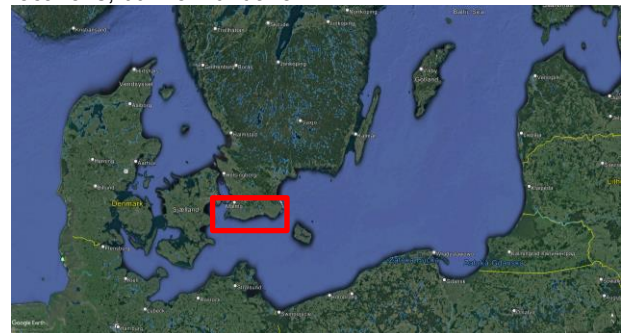


Figure 2 - Study site, the south coast of Sweden. Map from Google Earth.

DISCUSSION AND OUTLOOK

ROAD-RAT is intended for screening coastal risks at a regional level. The tool employs data that is commonly available in coastal areas, such as digital elevation models, still water observations, simulated wave data, and rates of historical coastline changes. Furthermore, the tool requires input of coastal type and the presence of structures. The simplified methods allow for calculations of the probability of flooding, erosion, and overtopping influencing coastal roads with relatively high probability, return periods in the order of 1 - 100 years. The risk assessment is based on a bottom-up approach where the probability of failure is described instead of prescribing a specific return period. With this approach, road authorities and other affected agencies can make a risk assessment for each exposed facility and, case by case, determine whether the probabilities are acceptable or whether further investigations and measures should be taken.

In the next step of this work, we will estimate the probability of the impact from Babet to validate the model by comparing the model output to the observed impact during the storm (Figures 3 and 4).



Figure 3 - Undermining of road caused by wave runup on a road bank protected by a revetment.



Figure 4 - Complete destruction of a road caused storm erosion. This part of the coast that has been subject to long-term coastline retreat.

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