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Modelling climate-weather change process including extreme weather hazards for maritime ferry

Keywords

climate-weather change process, semi-Markov model, extreme weather hazard states, maritime ferry

Abstract

The climate-weather change process for the maritime ferry operating at Port Gdynia and at Baltic Sea open waters between Gdynia bay and Karlskrona bay is considered and its states are defined. Further, the semi-Markov process is defined and used to create a general probabilistic model of the climate-weather change process for the maritime ferry operating at considered areas.

1. Introduction

As shown in [20], the climate-weather change processes for the real critical infrastructures operating areas could be treat as the semi-Markov process with discrete operation states defined by the mainly climate-weather hazards which have influence on the considered critical infrastructures operating areas. In this article, we will define parameters of the climate-weather change process for the maritime ferry operating at Port Gdynia and at Baltic Sea open waters between Gdynia bay and Karlskrona bay using the bases from [20]. All analyses included in this article could be found in [5].

2. Climate-Weather Change Process for Maritime Ferry Operation Area

2.1. Description of Maritime Ferry

The maritime ferry is a passenger Ro-Ro ship operating at the Baltic Sea between Gdynia and Karlskrona ports on regular everyday line. The mentioned earlier operated area of the maritime ferry could be divided into four different areas: Gdynia Port, Baltic Sea restricted waters, Baltic Sea open waters, Karlskrona Port. The detailed maritime ferry route is illustrated in *Figure 1*. More information about the maritime ferry, its assets and interconnections between them could be found in [8]. In following subsections, we will analyze the climate-weather change process of the maritime ferry operating at Port Gdynia (Point 1 in *Figure 1*) and at Baltic Sea open waters between Gdynia bay and Karlskrona bay (Points 3-6 in *Figure 1*). In points 1-7 marked in the above figure were obtained the climate-weather data.

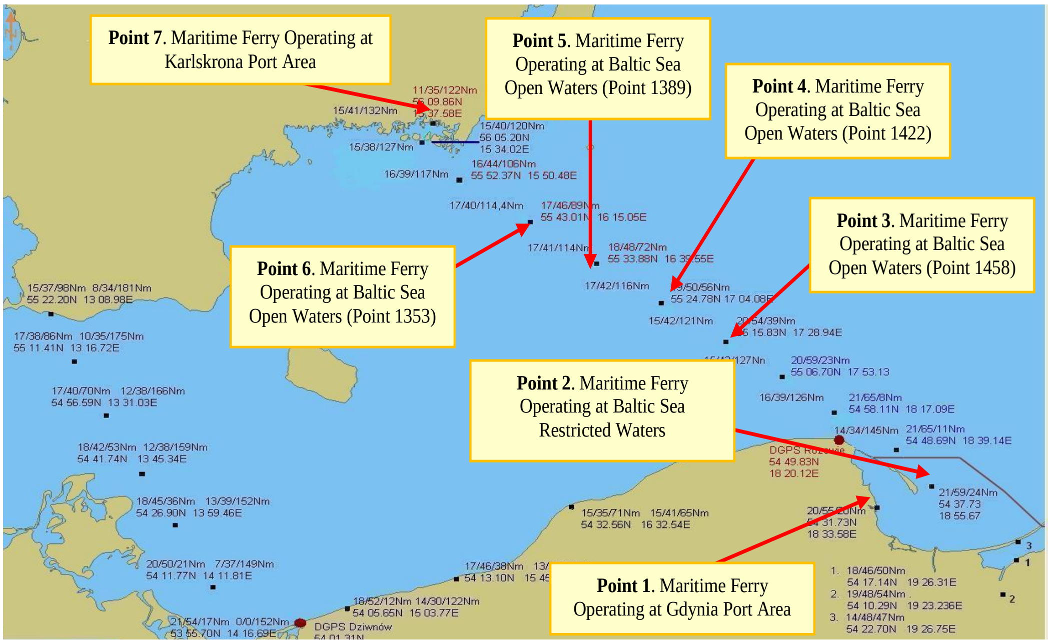

Figure 1. Maritime ferry route between Karlskrona and Gdynia ports

2.2. Defining parameters of climate-weather change process for Maritime Ferry operating at Gdynia Port

We distinguish $a = 2$ parameters which mainly describe the climate-weather states of the maritime ferry operating at Gdynia Port. These parameters are: w_1 – the sea level measured in centimeters and w_2 – the wind speed measured in meters per second. Next, we assume that the possible values of the parameters in this area can belong respectively to the intervals $w_1 \in <415, 620)$ and $w_2 \in <0, 33)$ and according to the data about ranges of hazard parameters in [9].
Moreover, the parameter w_1 values interval <415, 620) is divided into $n_1 = 4$ disjoint subintervals:

<415, 450), <450, 500), <500, 550), <550, 620)

and the parameter w_2 values interval <0, 33) into $n_2 = 2$ disjoint subintervals:

<0, 17.2), <17.2, 33).

Hence, the vector (w_1, w_2) which describes the climate-weather states can take values from the set of the following $a = 2$ dimensional space points of the Descartes products:

<415, 450) x <0, 17.2), <450, 500) x <0, 17.2),
<500, 550) x <0, 17.2), <550, 620) x <0, 17.2),
<415, 450) x <17.2, 33),<450, 500) x <17.2, 33),
<500, 550) x <17.2, 33),
<550, 620) x <17.2, 33).

We call these products the climate-weather states of the climate-weather change process. If all of them are sensible then they are numerated from 1 up to the value $w = n_1 \cdot n_2 = 4 \cdot 2 = 8$ and marked by $c_1, c_2, \ldots, c_8$. When some of them are not possible to happen (are not sensible), then according to an expert opinion, we can omit them and their numeration can be changed.
Hence, based on the expert opinion, there are distinguished the following w = 8 climate-weather states:
– the climate-weather state c_1 – the sea level from 415 cm up to 450 cm and the wind speed from 0 m/s up to 17.2 m/s;
– the climate-weather state c_2 – the sea level from 450 cm up to 500 cm and the wind speed from 0 m/s up to 17.2 m/s;
– the climate-weather state c_3 – the sea level from 500 cm up to 550 cm and the wind speed from 0 m/s up to 17.2 m/s;
– the climate-weather state c_4 – the sea level from 550 cm up to 620 cm and the wind speed from 0 m/s up to 17.2 m/s;
– the climate-weather state c_5 – the sea level from 415 cm up to 450 cm and the wind speed from 17.2 up to 33 m/s;
– the climate-weather state c_6 – the sea level from 450 cm up to 500 cm and the wind speed from 17.2 up to 33 m/s;
– the climate-weather state c_7 – the sea level from 500 cm up to 550 cm and the wind speed from 17.2 up to 33 m/s;
– the climate-weather state c_8 – the sea level from 550 cm up to 620 cm and the wind speed from 17.2 up to 33 m/s.

Further, taking into account the agreement assumed in [9] and [20], the 1st category extreme weather hazard state of the climate-weather parameter w_1 is the interval <550, 620) and the 1st category extreme weather hazard state of the climate-weather parameter w_2 is the interval <17.2, 33).

Consequently, the 2nd category extreme weather hazard state of the climate-weather change process is c_8, the 1st category extreme weather hazard states of the climate-weather change process are c_4, c_5, c_6, c_7 and the 0os category extreme weather hazard states of the climate-weather change process are c_1, c_2, c_3.

The unknown parameters of the climate-weather change process semi-Markov model are:

– the initial probabilities $q_b(0)$, $b = 1,2,\ldots,8$, of the climate-weather change process staying at the particular state c_b at the moment $t = 0$,

– the probabilities q_{bl}, b, $l = 1,2,\ldots,8$, $b \neq l$, of the climate-weather change process transitions from the climate-weather state c_b into the climate-weather state c_l,

– the distributions of the climate-weather change process conditional sojourn times C_{bl}, b, $l = 1,2,\ldots,8$, $b \neq l$, at the particular climate-weather change states and their mean values $M_{bl} = E[C_{bl}]$, b, $l = 1,2,\ldots,8$, $b \neq l$.

The identification of all these parameters of the climate-weather change process could be found in [17].

2.3. Defining parameters of climate-weather change process of Maritime Ferry operating at Baltic Sea open waters

We distinguish $a = 2$ parameters which mainly describe the climate-weather states of the maritime ferry operating at Baltic Sea open waters. These parameters are: w_1 – the wave height measured in meters and w_2 – the wind speed measured in meters per second. Next, we assume that the possible values of the parameters in this area can belong respectively to the intervals $w_1 \in <0, 14)$ and $w_2 \in <0, 33)$ according to the data about ranges of hazard parameters in [9].

Moreover, the parameter w_1 values interval <0, 14) is divided into $n_1 = 3$ disjoint subintervals:

<0, 2), <2, 5.5), <5.5, 14)

and the parameter w_2 values interval <0, 33) into $n_2 = 2$ disjoint subintervals:

<0, 17.2), <17.2, 33).

Hence, the vector (w_1, w_2) which describes the climate-weather states can take values from the set of the following $a = 2$ dimensional space points of the Descartes products:

<0, 2) x <0, 17.2), <2, 5.5) x <0, 17.2),
<5.5, 14) x <0, 17.2), <0, 2) x <17.2, 33),
<2, 5.5) x <17.2, 33), <5.5, 14) x <17.2, 33).

We call these products the climate-weather states of the climate-weather change process. If all of them are sensible then they are numerated from 1 up to the value $w = n_1 \cdot n_2 = 3 \cdot 2 = 6$ and marked by c_1, c_2, …, c_6. When some of them are not possible to happen (are not sensible), then according to an expert opinion, we can omit them and their numeration can be changed.

Hence, based on the expert opinion, there are distinguished the following $w = 6$ climate-weather states:

– the climate-weather state c_1 – the wave height from 0 m up to 2 m and the wind speed from 0 m/s up to 17.2 m/s;

– the climate-weather state c_2 – the wave height from 2 m up to 5.5 m and the wind speed from 0 m/s up to 17.2 m/s;

– the climate-weather state c_3 – the wave height from 5.5 m up to 14 m and the wind speed from 0 m/s up to 17.2 m/s;

– the climate-weather state c_4 – the wave height from 0 m up to 2 m and the wind speed from 17.2 m/s to 33 m/s;

– the climate-weather state c_5 – the wave height from 2 m up to 5.5 m and the wind speed from 17.2 m/s to 33 m/s;

– the climate-weather state c_6 – the wave height from 5.5 m up to 14 m and the wind speed from 17.2 m/s to 33 m/s.

Further, taking into account the agreement assumed in [9] and [20], the 1st category extreme weather hazard state of the climate-weather parameter w_1 is the interval <5.5, 14) and the 1st category extreme weather hazard state of the climate-weather parameter w_2 is the interval <17.2, 33).

Consequently, the 2nd category extreme weather hazard state of the climate-weather change process is c_6, the 1st category extreme weather hazard states of the climate-weather change process are c_3, c_4, c_5 and the 0os category extreme weather hazard states of the climate-weather change process are c_1, c_2.

The unknown parameters of the climate-weather change process semi-Markov model are:

– the initial probabilities $q_b(0)$, $b = 1,2,\ldots,6$, of the climate-weather change process staying at the particular state c_b at the moment $t = 0$,

– the probabilities q_{bl}, b, $l = 1,2,\ldots,6$, $b \neq l$, of the climate-weather change process transitions from the climate-weather state c_b into the climate-weather state c_l,

– the distributions of the climate-weather change process conditional sojourn times C_{bl}, $b, l = 1,2,\ldots,6$, $b \neq l$, at the particular climate-weather change states and their mean values $M_{bl} = E[C_{bl}]$, $b, l = 1,2,\ldots,6$, $b \neq l$.

The identification of all these parameters of the climate-weather change process could be found in [16].

3. Conclusions

The probabilistic models of the climate-weather change processes of the maritime ferry operating at Gdynia port area and at Baltic Sea open waters are the basis for the considerations in articles [16]-[17]. In these articles are shown statistical methods of identification and are identified the unknown parameters of the climate-weather change processes for the maritime ferry operating at Gdynia port area and at Baltic Sea open waters.

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