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Kołowrocki Krzysztof

Kuligowska Ewa

Soszyńska-Budny Joanna

Gdynia Maritime University, Gdynia, Poland

Identification and prediction of maritime ferry operation process related to climate-weather change

Keywords

operation process, identification, prediction, climate-weather change, maritime ferry

Abstract

The paper is concerned with an application of the critical infrastructure operation process related to climate-weather change model to identification and prediction of this process for maritime ferry. There are distinguished four different processes for the corresponding ferry operating area. Further, using identified parameters of the ferry operation process and the ferry operating area climate-weather change processes, there are determined the unknown parameters of those processes. Namely, there are determined the probabilities of the processes staying at the initial states, the probabilities of the transitions between the states and the mean values of the processes' conditional sojourn times at particular states. Finally, there are predicted the main characteristics of the ferry operation process related to climate-weather change processes at the distinguished operating area.

1. Introduction

The maritime ferry operation process is described in [1], [3]-[5]. The climate-weather change process for the ferry operating area is modelled in [2], [6]. In this paper, the identification of the ferry operation process related to climate-weather change is performed. To do this, we can use the evaluated parameters of the ferry operation process from [1] and parameters of the climate-weather change process at its operating area from [7]. This way, having these processes identified, the prediction of the ferry operation process related to climate-weather change characteristics is performed.

2. Maritime ferry operation process related to climate-weather change identification

Assuming that the maritime ferry operation process and the climate-weather change processes at its operating area are independent, to identify the unknown parameters of the maritime ferry operation process related to climate-weather change processes only the suitable statistical data coming from real realizations of the maritime ferry operation process and of the maritime ferry climate-weather change processes should be collected. The statistical identification of the maritime ferry operation process related to climate-weather change was performed: the operation states were distinguished and the following unknown basic parameters of the maritime ferry operation process related to climate-weather change, i.e. the vector of probabilities of the maritime ferry operation process related to climate-weather change staying at the initial operation states, the matrix of probabilities of the maritime ferry operation process related to climate-weather change transitions between the operation states, the matrix of the mean values of the conditional sojourn times of the maritime ferry operation process related to climate-weather change were evaluated.

2.1. States of maritime ferry operation process related to climate-weather change

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry Gdynia</u>

port operating area - data coming from first measurement points

The maritime ferry operation process related to climate-weather change process $ZC^1(t)$, $t \in <0,+\infty)$, can take $vw^1 = 18 \cdot 6 = 108$ different operation states $zc_{11}, zc_{12}, \ldots, zc_{186}$;

Maritime ferry operation process related to climate-weather change process for maritime ferry restricted waters operating area - data coming from second measurement point

The maritime ferry operation process related to climate-weather change process $ZC^2(t)$, $t \in <0,+\infty)$, can take $vw^2 = 18 \cdot 6 = 108$ different operation states $zc_{11}, zc_{12}, \ldots, zc_{186}$;

Maritime ferry operation process related to climate-weather change process for maritime ferry Baltic Sea open waters operating area - data coming from 1353, 1389, 1422 and 1458 measurement points

The maritime ferry operation process related to climate-weather change process $ZC^3(t)$, $t \in <0,+\infty)$, can take $vw^3 = 18 \cdot 6 = 108$ different operation states $zc_{11}, zc_{12}, \ldots, zc_{186}$;

Maritime ferry operation process related to climate-weather change process for maritime ferry Karlskrona port operating area - data coming from last measurement point

The maritime ferry operation process related to climate-weather change process $ZC^4(t)$, $t \in <0,+\infty)$, can take $vw^4 = 18 \cdot 6 = 108$ different operation states $zc_{11}, zc_{12}, \ldots, zc_{186}$;

2.2. Parameters of maritime ferry operation process related to climate-weather change

Maritime ferry operation process related to climate-weather change process for maritime ferry Gdynia port operating area - data coming from first measurement points

After assuming that the maritime ferry operation process and the climate-weather change process at its operating area are independent, it is possible to evaluate the following unknown basic parameters of the maritime ferry operation process related to climate-weather change process $ZC^1(t)$ [2]:
- the vector

$$[pq_{ij}(0)]_{1x42} = [0.447, 0.029, 0.424, 0.018, 0.082, 0, ..., 0] \quad (1)$$

of initial probabilities of the maritime ferry operation process related to climate-weather change process $ZC^1(t)$ staying at the initial moment $t = 0$ at the operation states zc_{ij}, $i = 1,2,\ldots,18$, $j = 1,2,\ldots,6$;
- the matrix $[pq_{ij\,kl}]_{108x108}$, of the probabilities $pq_{ij\,kl}$, i, $k = 1,2,\ldots,18$, $j,l = 1,2,\ldots,6$, of transitions of the maritime ferry operation process related to climate-weather change process $ZC^1(t)$ from the operation state zc_{ij} into the operation state zc_{kl}, where

$pq_{12,12} = 0.05, pq_{12,13} = 0.89, pq_{12,14} = 0.01,$
$pq_{12,15} = 0.05, pq_{12,21} = 0.93, pq_{12,24} = 0.07,$
$pq_{12,31} = 0.84, pq_{12,34} = 0.04, pq_{12,35} = 0.12,$
$pq_{12,41} = 0.22, pq_{12,42} = 0.45, pq_{12,43} = 0.33,$
$pq_{12,51} = 0.33, pq_{12,53} = 0.67, pq_{23,12} = 0.05,$
$pq_{23,13} = 0.89, pq_{23,14} = 0.01, pq_{23,15} = 0.05,$
$pq_{23,21} = 0.93, pq_{23,24} = 0.07, pq_{23,31} = 0.84,$
$pq_{23,34} = 0.04, pq_{23,35} = 0.12, pq_{23,41} = 0.22,$
$pq_{23,42} = 0.45, pq_{23,43} = 0.33, pq_{23,51} = 0.33,$
$pq_{23,53} = 0.67, pq_{34,12} = 0.05, pq_{34,13} = 0.89,$
$pq_{34,14} = 0.01, pq_{34,15} = 0.05, pq_{34,21} = 0.93,$
$pq_{34,24} = 0.07, pq_{34,31} = 0.84, pq_{34,34} = 0.04,$
$pq_{34,35} = 0.12, pq_{34,41} = 0.22, pq_{34,42} = 0.45,$
$pq_{34,43} = 0.33, pq_{34,51} = 0.33, pq_{34,53} = 0.67,$
$pq_{45,12} = 0.05, pq_{45,13} = 0.89, pq_{45,14} = 0.01,$
$pq_{45,15} = 0.05, pq_{45,21} = 0.93, pq_{45,24} = 0.07,$
$pq_{45,31} = 0.84, pq_{45,34} = 0.04, pq_{45,35} = 0.12,$
$pq_{45,41} = 0.22, pq_{45,42} = 0.45, pq_{45,43} = 0.33,$
$pq_{45,51} = 0.33, pq_{45,53} = 0.67, pq_{56,12} = 0.05,$
$pq_{56,13} = 0.89, pq_{56,14} = 0.01, pq_{56,15} = 0.05,$
$pq_{56,21} = 0.93, pq_{56,24} = 0.07, pq_{56,31} = 0.84,$
$pq_{56,34} = 0.04, pq_{56,35} = 0.12, pq_{56,41} = 0.22,$
$pq_{56,42} = 0.45, pq_{56,43} = 0.33, pq_{56,51} = 0.33,$
$pq_{56,53} = 0.67, pq_{67,12} = 0.05, pq_{67,13} = 0.89,$
$pq_{67,14} = 0.01, pq_{67,15} = 0.05, pq_{67,21} = 0.93,$
$pq_{67,24} = 0.07, pq_{67,31} = 0.84, pq_{67,34} = 0.04,$
$pq_{67,35} = 0.12, pq_{67,41} = 0.22, pq_{67,42} = 0.45,$
$pq_{67,43} = 0.33, pq_{67,51} = 0.33, pq_{67,53} = 0.67,$
$pq_{78,12} = 0.05, pq_{78,13} = 0.89, pq_{78,14} = 0.01,$
$pq_{78,15} = 0.05, pq_{78,21} = 0.93, pq_{78,24} = 0.07,$
$pq_{78,31} = 0.84, pq_{78,34} = 0.04, pq_{78,35} = 0.12,$
$pq_{78,41} = 0.22, pq_{78,42} = 0.45, pq_{78,43} = 0.33,$
$pq_{78,51} = 0.33, pq_{78,53} = 0.67, pq_{89,12} = 0.05,$
$pq_{89,13} = 0.89, pq_{89,14} = 0.01, pq_{89,15} = 0.05,$
$pq_{89,21} = 0.93, pq_{89,24} = 0.07, pq_{89,31} = 0.84,$
$pq_{89,34} = 0.04, pq_{89,35} = 0.12, pq_{89,41} = 0.22,$
$pq_{89,42} = 0.45, pq_{89,43} = 0.33, pq_{89,51} = 0.33,$
$pq_{89,53} = 0.67, pq_{9\,10,12} = 0.05, pq_{9\,10,13} = 0.89,$
$pq_{9\,10,14} = 0.01, pq_{9\,10,15} = 0.05, pq_{9\,10,21} = 0.93,$
$pq_{9\,10,24} = 0.07, pq_{9\,10,31} = 0.84, pq_{9\,10,34} = 0.04,$
$pq_{9\,10,35} = 0.12, pq_{9\,10,41} = 0.22, pq_{9\,10,42} = 0.45,$
$pq_{9\,10,43} = 0.33, pq_{9\,10,51} = 0.33, pq_{9\,10,53} = 0.67,$

$pq_{10\,11,1\,2} = 0.05, pq_{10\,11,1\,3} = 0.89, pq_{10\,11,1\,4} = 0.01,$
$pq_{10\,11,1\,5} = 0.05, pq_{10\,11,2\,1} = 0.93, pq_{10\,11,2\,4} = 0.07,$
$pq_{10\,11,3\,1} = 0.84, pq_{10\,11,3\,4} = 0.04, pq_{10\,11,3\,5} = 0.12,$
$pq_{10\,11,4\,1} = 0.22, pq_{10\,11,4\,2} = 0.45, pq_{10\,11,4\,3} = 0.33,$
$pq_{10\,11,5\,1} = 0.33, pq_{10\,11,5\,3} = 0.67, pq_{11\,12,1\,2} = 0.05,$
$pq_{11\,12,1\,3} = 0.89, pq_{11\,12,1\,4} = 0.01, pq_{11\,12,1\,5} = 0.05,$
$pq_{11\,12,2\,1} = 0.93, pq_{11\,12,2\,4} = 0.07, pq_{11\,12,3\,1} = 0.84,$
$pq_{11\,12,3\,4} = 0.04, pq_{11\,12,3\,5} = 0.12, pq_{11\,12,4\,1} = 0.22,$
$pq_{11\,12,4\,2} = 0.45, pq_{11\,12,4\,3} = 0.33, pq_{11\,12,5\,1} = 0.33,$
$pq_{11\,12,5\,3} = 0.67, pq_{12\,13,1\,2} = 0.05, pq_{12\,13,1\,3} = 0.89,$
$pq_{12\,13,1\,4} = 0.01, pq_{12\,13,1\,5} = 0.05, pq_{12\,13,2\,1} = 0.93,$
$pq_{12\,13,2\,4} = 0.07, pq_{12\,13,3\,1} = 0.84, pq_{12\,13,3\,4} = 0.04,$
$pq_{12\,13,3\,5} = 0.12, pq_{12\,13,4\,1} = 0.22, pq_{12\,13,4\,2} = 0.45,$
$pq_{12\,13,4\,3} = 0.33, pq_{12\,13,5\,1} = 0.33, pq_{12\,13,5\,3} = 0.67,$
$pq_{13\,14,1\,2} = 0.05, pq_{13\,14,1\,3} = 0.89, pq_{13\,14,1\,4} = 0.01,$
$pq_{13\,14,1\,5} = 0.05, pq_{13\,14,2\,1} = 0.93, pq_{13\,14,2\,4} = 0.07,$
$pq_{13\,14,3\,1} = 0.84, pq_{13\,14,3\,4} = 0.04, pq_{13\,14,3\,5} = 0.12,$
$pq_{13\,14,4\,1} = 0.22, pq_{13\,14,4\,2} = 0.45, pq_{13\,14,4\,3} = 0.33,$
$pq_{13\,14,5\,1} = 0.33, pq_{13\,14,5\,3} = 0.67, pq_{14\,15,1\,2} = 0.05,$
$pq_{14\,15,1\,3} = 0.89, pq_{14\,15,1\,4} = 0.01, pq_{14\,15,1\,5} = 0.05,$
$pq_{14\,15,2\,1} = 0.93, pq_{14\,15,2\,4} = 0.07, pq_{14\,15,3\,1} = 0.84,$
$pq_{14\,15,3\,4} = 0.04, pq_{14\,15,3\,5} = 0.12, pq_{14\,15,4\,1} = 0.22,$
$pq_{14\,15,4\,2} = 0.45, pq_{14\,15,4\,3} = 0.33, pq_{14\,15,5\,1} = 0.33,$
$pq_{14\,15,5\,3} = 0.67, pq_{15\,16,1\,2} = 0.05, pq_{15\,16,1\,3} = 0.89,$
$pq_{15\,16,1\,4} = 0.01, pq_{15\,16,1\,5} = 0.05, pq_{15\,16,2\,1} = 0.93,$
$pq_{15\,16,2\,4} = 0.07, pq_{15\,16,3\,1} = 0.84, pq_{15\,16,3\,4} = 0.04,$
$pq_{15\,16,3\,5} = 0.12, pq_{15\,16,4\,1} = 0.22, pq_{15\,16,4\,2} = 0.45,$
$pq_{15\,16,4\,3} = 0.33, pq_{15\,16,5\,1} = 0.33, pq_{15\,16,5\,3} = 0.67,$
$pq_{16\,17,1\,2} = 0.05, pq_{16\,17,1\,3} = 0.89, pq_{16\,17,1\,4} = 0.01,$
$pq_{16\,17,1\,5} = 0.05, pq_{16\,17,2\,1} = 0.93, pq_{16\,17,2\,4} = 0.07,$
$pq_{16\,17,3\,1} = 0.84, pq_{16\,17,3\,4} = 0.04, pq_{16\,17,3\,5} = 0.12,$
$pq_{16\,17,4\,1} = 0.22, pq_{16\,17,4\,2} = 0.45, pq_{16\,17,4\,3} = 0.33,$
$pq_{16\,17,5\,1} = 0.33, pq_{16\,17,5\,3} = 0.67, pq_{17\,18,1\,2} = 0.05,$
$pq_{17\,18,1\,3} = 0.89, pq_{17\,18,1\,4} = 0.01, pq_{17\,18,1\,5} = 0.05,$
$pq_{17\,18,2\,1} = 0.93, pq_{17\,18,2\,4} = 0.07, pq_{17\,18,3\,1} = 0.84,$
$pq_{17\,18,3\,4} = 0.04, pq_{17\,18,3\,5} = 0.12, pq_{17\,18,4\,1} = 0.22,$
$pq_{17\,18,4\,2} = 0.45, pq_{17\,18,4\,3} = 0.33, pq_{17\,18,5\,1} = 0.33,$
$pq_{17\,18,5\,3} = 0.67, pq_{18\,1,1\,2} = 0.05, pq_{18\,1,1\,3} = 0.89,$
$pq_{18\,1,1\,4} = 0.01, pq_{18\,1,1\,5} = 0.05, pq_{18\,1,2\,1} = 0.93,$
$pq_{18\,1,2\,4} = 0.07, pq_{18\,1,3\,1} = 0.84, pq_{18\,1,3\,4} = 0.04,$
$pq_{18\,1,3\,5} = 0.12, pq_{18\,1,4\,1} = 0.22, pq_{18\,1,4\,2} = 0.45,$
$pq_{18\,1,4\,3} = 0.33, pq_{18\,1,5\,1} = 0.33,$
$pq_{18\,1,5\,3} = 0.67;$ (2)

and remaining $pq_{ij\,kl}$, i, k = 1,2,…,18, j, l =1,2,…,16, are equal to 0;
- the matrix $[N_{ij\,kl}(t)]_{108x108}$ of the mean values of the maritime ferry operation process related to climate-weather change process $ZC^1(t)$ conditional sojourn times $\theta C^1_{ij\,kl}$, i, k = 1,2,…,18, j, l =1,2,…,6, at the operation state zc_{ij}, when the next operation state is zc_{kl} could be found in [2].

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry restricted waters operating area - data coming from second measurement point</u>

After assuming that the maritime ferry operation process and the climate-weather change process at its operating area are independent, it is possible to evaluate the following unknown basic parameters of the maritime ferry operation process related to climate-weather change process $ZC^2(t)$ [2]:
- the vector

$$[pq_{ij}(0)]_{1x42} = [0.670, 0.271, 0.006, 0, 0.024, 0.029, 0, ..., 0] \quad (3)$$

of initial probabilities of the maritime ferry operation process related to climate-weather change process $ZC^2(t)$ staying at the initial moment t = 0 at the operation states zc_{ij}, i = 1,2,…,18, j = 1,2,…,6;
- the matrix $[pq_{ij\,kl}]_{108x108}$, of the probabilities $pq_{ij\,kl}$, i, k = 1,2,…,18, j, l =1,2,…,6, of transitions of the maritime ferry operation process related to climate-weather change process $ZC^2(t)$ from the operation state zc_{ij} into the operation state zc_{kl}, where

$pq_{1\,2,1\,2} = 0.99, pq_{1\,2,1\,5} = 0.01, pq_{1\,2,2\,1} = 0.84,$
$pq_{1\,2,2\,3} = 0.02, pq_{1\,2,2\,5} = 0.14, pq_{1\,2,3\,2} = 0.8,$
$pq_{1\,2,3\,6} = 0.2, pq_{1\,2,5\,2} = 0.36, pq_{1\,2,5\,6} = 0.64,$
$pq_{1\,2,6\,3} = 0.93, pq_{1\,2,6\,5} = 0.07, pq_{2\,3,1\,2} = 0.99,$
$pq_{2\,3,1\,5} = 0.01, pq_{2\,3,2\,1} = 0.84, pq_{2\,3,2\,3} = 0.02,$
$pq_{2\,3,2\,5} = 0.14, pq_{2\,3,3\,2} = 0.8, pq_{2\,3,3\,6} = 0.2,$
$pq_{2\,3,5\,2} = 0.36, pq_{2\,3,5\,6} = 0.64, pq_{2\,3,6\,3} = 0.93,$
$pq_{2\,3,6\,5} = 0.07, pq_{3\,4,1\,2} = 0.99, pq_{3\,4,1\,5} = 0.01,$
$pq_{3\,4,2\,1} = 0.84, pq_{3\,4,2\,3} = 0.02, pq_{3\,4,2\,5} = 0.14,$
$pq_{3\,4,3\,2} = 0.8, pq_{3\,4,3\,6} = 0.2, pq_{3\,4,5\,2} = 0.36,$
$pq_{3\,4,5\,6} = 0.64, pq_{3\,4,6\,3} = 0.93, pq_{3\,4,6\,5} = 0.07,$
$pq_{4\,5,1\,2} = 0.99, pq_{4\,5,1\,5} = 0.01, pq_{4\,5,2\,1} = 0.84,$
$pq_{4\,5,2\,3} = 0.02, pq_{4\,5,2\,5} = 0.14, pq_{4\,5,3\,2} = 0.8,$
$pq_{4\,5,3\,6} = 0.2, pq_{4\,5,5\,2} = 0.36, pq_{4\,5,5\,6} = 0.64,$
$pq_{4\,5,6\,3} = 0.93, pq_{4\,5,6\,5} = 0.07, pq_{5\,6,1\,2} = 0.99,$
$pq_{5\,6,1\,5} = 0.01, pq_{5\,6,2\,1} = 0.84, pq_{5\,6,2\,3} = 0.02,$
$pq_{5\,6,2\,5} = 0.14, pq_{5\,6,3\,2} = 0.8, pq_{5\,6,3\,6} = 0.2,$
$pq_{5\,6,5\,2} = 0.36, pq_{5\,6,5\,6} = 0.64, pq_{5\,6,6\,3} = 0.93,$
$pq_{5\,6,6\,5} = 0.07, pq_{6\,7,1\,2} = 0.99, pq_{6\,7,1\,5} = 0.01,$
$pq_{6\,7,2\,1} = 0.84, pq_{6\,7,2\,3} = 0.02, pq_{6\,7,2\,5} = 0.14,$
$pq_{6\,7,3\,2} = 0.8, pq_{6\,7,3\,6} = 0.2, pq_{6\,7,5\,2} = 0.36,$
$pq_{6\,7,5\,6} = 0.64, pq_{6\,7,6\,3} = 0.93, pq_{6\,7,6\,5} = 0.07,$
$pq_{7\,8,1\,2} = 0.99, pq_{7\,8,1\,5} = 0.01, pq_{7\,8,2\,1} = 0.84,$
$pq_{7\,8,2\,3} = 0.02, pq_{7\,8,2\,5} = 0.14, pq_{7\,8,3\,2} = 0.8,$
$pq_{7\,8,3\,6} = 0.2, pq_{7\,8,5\,2} = 0.36, pq_{7\,8,5\,6} = 0.64,$
$pq_{7\,8,6\,3} = 0.93, pq_{7\,8,6\,5} = 0.07, pq_{8\,9,1\,2} = 0.99,$
$pq_{8\,9,1\,5} = 0.01, pq_{8\,9,2\,1} = 0.84, pq_{8\,9,2\,3} = 0.02,$
$pq_{8\,9,2\,5} = 0.14, pq_{8\,9,3\,2} = 0.8, pq_{8\,9,3\,6} = 0.2,$
$pq_{8\,9,5\,2} = 0.36, pq_{8\,9,5\,6} = 0.64, pq_{8\,9,6\,3} = 0.93,$
$pq_{8\,9,6\,5} = 0.07, pq_{9\,10,1\,2} = 0.99, pq_{9\,10,1\,5} = 0.01,$
$pq_{9\,10,2\,1} = 0.84, pq_{9\,10,2\,3} = 0.02, pq_{9\,10,2\,5} = 0.14,$

$pq_{9\,10,\,32} = 0.8$, $pq_{9\,10,\,36} = 0.2$, $pq_{9\,10,\,52} = 0.36$,
$pq_{9\,10,\,56} = 0.64$, $pq_{9\,10,\,63} = 0.93$, $pq_{9\,10,\,65} = 0.07$,
$pq_{10\,11,\,12} = 0.99$, $pq_{10\,11,\,15} = 0.01$, $pq_{10\,11,\,21} = 0.84$,
$pq_{10\,11,\,23} = 0.02$, $pq_{10\,11,\,25} = 0.14$, $pq_{10\,11,\,32} = 0.8$,
$pq_{10\,11,\,36} = 0.2$, $pq_{10\,11,\,52} = 0.36$, $pq_{10\,11,\,56} = 0.64$,
$pq_{10\,11,\,63} = 0.93$, $pq_{10\,11,\,65} = 0.07$, $pq_{11\,12,\,12} = 0.99$,
$pq_{11\,12,\,15} = 0.01$, $pq_{11\,12,\,21} = 0.84$, $pq_{11\,12,\,23} = 0.02$,
$pq_{11\,12,\,25} = 0.14$, $pq_{11\,12,\,32} = 0.8$,$pq_{11\,12,\,36} = 0.2$,
$pq_{11\,12,\,52} = 0.36$, $pq_{11\,12,\,56} = 0.64$, $pq_{11\,12,\,63} = 0.93$,
$pq_{11\,12,\,65} = 0.07$, $pq_{12\,13,\,12} = 0.99$,$pq_{12\,13,\,15} = 0.01$,
$pq_{12\,13,\,21} = 0.84$, $pq_{12\,13,\,23} = 0.02$, $pq_{12\,13,\,25} = 0.14$,
$pq_{12\,13,\,32} = 0.8$, $pq_{12\,13,\,36} = 0.2$,$pq_{12\,13,\,52} = 0.36$,
$pq_{12\,13,\,56} = 0.64$, $pq_{12\,13,\,63} = 0.93$, $pq_{12\,13,\,65} = 0.07$,
$pq_{13\,14,\,12} = 0.99$, $pq_{13\,14,\,15} = 0.01$ $pq_{13\,14,\,21} = 0.84$,
$pq_{13\,14,\,23} = 0.02$, $pq_{13\,14,\,25} = 0.14$, $pq_{13\,14,\,32} = 0.8$,
$pq_{13\,14,\,36} = 0.2$, $pq_{13\,14,\,52} = 0.36$,$pq_{13\,14,\,56} = 0.64$,
$pq_{13\,14,\,63} = 0.93$, $pq_{13\,14,\,65} = 0.07$, $pq_{14\,15,\,12} = 0.99$,
$pq_{14\,15,\,15} = 0.01$, $pq_{14\,15,\,21} = 0.84$,$pq_{14\,15,\,23} = 0.02$,
$pq_{14\,15,\,25} = 0.14$, $pq_{14\,15,\,32} = 0.8$, $pq_{14\,15,\,36} = 0.2$,
$pq_{14\,15,\,52} = 0.36$, $pq_{14\,15,\,56} = 0.64$,$pq_{14\,15,\,63} = 0.93$,
$pq_{14\,15,\,65} = 0.07$, $pq_{15\,16,\,12} = 0.99$, $pq_{15\,16,\,15} = 0.01$,
$pq_{15\,16,\,21} = 0.84$, $pq_{15\,16,\,23} = 0.02$,$pq_{15\,16,\,25} = 0.14$,
$pq_{15\,16,\,32} = 0.8$, $pq_{15\,16,\,36} = 0.2$, $pq_{15\,16,\,52} = 0.36$,
$pq_{15\,16,\,56} = 0.64$, $pq_{15\,16,\,63} = 0.93$,$pq_{15\,16,\,65} = 0.07$,
$pq_{16\,17,\,12} = 0.99$, $pq_{16\,17,\,15} = 0.01$, $pq_{16\,17,\,21} = 0.84$,
$pq_{16\,17,\,23} = 0.02$, $pq_{16\,17,\,25} = 0.14$,$pq_{16\,17,\,32} = 0.8$,
$pq_{16\,17,\,36} = 0.2$, $pq_{16\,17,\,52} = 0.36$, $pq_{16\,17,\,56} = 0.64$,
$pq_{16\,17,\,63} = 0.93$, $pq_{16\,17,\,65} = 0.07$,$pq_{17\,18,\,12} = 0.99$,
$pq_{17\,18,\,15} = 0.01$, $pq_{17\,18,\,21} = 0.84$, $pq_{17\,18,\,23} = 0.02$,
$pq_{17\,18,\,25} = 0.14$, $pq_{17\,18,\,32} = 0.8$,$pq_{17\,18,\,36} = 0.2$,
$pq_{17\,18,\,52} = 0.36$, $pq_{17\,18,\,56} = 0.64$, $pq_{17\,18,\,63} = 0.93$,
$pq_{17\,18,\,65} = 0.07$, $pq_{18\,1,\,12} = 0.99$,$pq_{18\,1,\,15} = 0.01$,
$pq_{18\,1,\,21} = 0.84$, $pq_{18\,1,\,23} = 0.02$, $pq_{18\,1,\,25} = 0.14$,
$pq_{18\,1,\,32} = 0.8$, $pq_{18\,1,\,36} = 0.2$,$pq_{18\,1,\,52} = 0.36$, $pq_{18\,1,\,56} = 0.64$, $pq_{18\,1,\,63} = 0.93$, $pq_{18\,1,\,65} = 0.07$, (4)

and remaining $pq_{ij\,kl}$, i, k = 1,2,…,18, j, l =1,2,…,16, are equal to 0;
- the matrix $[N_{ij\,kl}(t)]_{108x108}$ of the mean values of the maritime ferry operation process related to climate-weather change process $ZC^2(t)$ conditional sojourn times $\theta C^2_{ij\,kl}$, i, k = 1,2,…,18, j, l =1,2,…,6, at the operation state zc_{ij}, when the next operation state is zc_{kl} can be found in [2].

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry Baltic Sea open waters operating area - data coming from 1353, 1389, 1422 and 1458 measurement points</u>

After assuming that the maritime ferry operation process and the climate-weather change process at its operating area are independent, it is possible to evaluate the following unknown basic parameters of the maritime ferry operation process related to climate-weather change process $ZC^3(t)$ [2]:
- the vector

$$[pq_{ij}(0)]_{1x112} = [0.595, 0.349, 0, 0, 0.040, 0.016, 0, ..., 0] \quad (5)$$

of initial probabilities of the maritime ferry operation process related to climate-weather change process $ZC^3(t)$ staying at the initial moment $t = 0$ at the operation states zc_{ij}, i = 1,2,…,18, j = 1,2,…,6;
- the matrix $[pq_{ij\,kl}]_{108x108}$, of the probabilities $pq_{ij\,kl}$, i, k = 1,2,…,18, j, l =1,2,…,6, of transitions of the maritime ferry operation process related to climate-weather change process $ZC^3(t)$ from the operation state zc_{ij} into the the operation state zc_{kl}, where

$pq_{1\,2,\,12} = 0.99$, $pq_{1\,2,\,15} = 0.01$, $pq_{1\,2,\,21} = 0.78$,
$pq_{1\,2,\,25} = 0.22$, $pq_{1\,2,\,32} = 1$, $pq_{1\,2,\,45} = 1$,
$pq_{1\,2,\,52} = 0.73$, $pq_{1\,2,\,53} = 0.02$, $pq_{1\,2,\,56} = 0.25$,
$pq_{1\,2,\,62} = 0.31$, $pq_{1\,2,\,65} = 0.69$, $pq_{2\,3,\,12} = 0.99$,
$pq_{2\,3,\,15} = 0.01$, $pq_{2\,3,\,21} = 0.78$, $pq_{2\,3,\,25} = 0.22$,
$pq_{2\,3,\,32} = 1$, $pq_{2\,3,\,45} = 1$, $pq_{2\,3,\,52} = 0.73$,
$pq_{2\,3,\,53} = 0.02$, $pq_{2\,3,\,56} = 0.25$, $pq_{2\,3,\,62} = 0.31$,
$pq_{2\,3,\,65} = 0.69$, $pq_{3\,4,\,12} = 0.99$, $pq_{3\,4,\,15} = 0.01$,
$pq_{3\,4,\,21} = 0.78$, $pq_{3\,4,\,25} = 0.22$, $pq_{3\,4,\,32} = 1$,
$pq_{3\,4,\,45} = 1$, $pq_{3\,4,\,52} = 0.73$, $pq_{3\,4,\,53} = 0.02$,
$pq_{3\,4,\,56} = 0.25$, $pq_{3\,4,\,62} = 0.31$, $pq_{3\,4,\,65} = 0.69$,
$pq_{4\,5,\,12} = 0.99$, $pq_{4\,5,\,15} = 0.01$, $pq_{4\,5,\,21} = 0.78$,
$pq_{4\,5,\,25} = 0.22$, $pq_{4\,5,\,32} = 1$, $pq_{4\,5,\,45} = 1$,
$pq_{4\,5,\,52} = 0.73$, $pq_{4\,5,\,53} = 0.02$, $pq_{4\,5,\,56} = 0.25$,
$pq_{4\,5,\,62} = 0.31$, $pq_{4\,5,\,65} = 0.69$, $pq_{5\,6,\,12} = 0.99$,
$pq_{5\,6,\,15} = 0.01$, $pq_{5\,6,\,21} = 0.78$, $pq_{5\,6,\,25} = 0.22$,
$pq_{5\,6,\,32} = 1$, $pq_{5\,6,\,45} = 1$, $pq_{5\,6,\,52} = 0.73$,
$pq_{5\,6,\,53} = 0.02$, $pq_{5\,6,\,56} = 0.25$, $pq_{5\,6,\,62} = 0.31$,
$pq_{5\,6,\,65} = 0.69$, $pq_{6\,7,\,12} = 0.99$, $pq_{6\,7,\,15} = 0.01$,
$pq_{6\,7,\,21} = 0.78$, $pq_{6\,7,\,25} = 0.22$, $pq_{6\,7,\,32} = 1$,
$pq_{6\,7,\,45} = 1$, $pq_{6\,7,\,52} = 0.73$, $pq_{6\,7,\,53} = 0.02$,
$pq_{6\,7,\,56} = 0.25$, $pq_{6\,7,\,62} = 0.31$, $pq_{6\,7,\,65} = 0.69$,
$pq_{7\,8,\,12} = 0.99$, $pq_{7\,8,\,15} = 0.01$, $pq_{7\,8,\,21} = 0.78$,
$pq_{7\,8,\,25} = 0.22$, $pq_{7\,8,\,32} = 1$, $pq_{7\,8,\,45} = 1$,
$pq_{7\,8,\,52} = 0.73$, $pq_{7\,8,\,53} = 0.02$, $pq_{7\,8,\,56} = 0.25$,
$pq_{7\,8,\,62} = 0.31$, $pq_{7\,8,\,65} = 0.69$, $pq_{8\,9,\,12} = 0.99$,
$pq_{8\,9,\,15} = 0.01$, $pq_{8\,9,\,21} = 0.78$, $pq_{8\,9,\,25} = 0.22$,
$pq_{8\,9,\,32} = 1$, $pq_{8\,9,\,45} = 1$, $pq_{8\,9,\,52} = 0.73$,
$pq_{8\,9,\,53} = 0.02$, $pq_{8\,9,\,56} = 0.25$, $pq_{8\,9,\,62} = 0.31$,
$pq_{8\,9,\,65} = 0.69$, $pq_{9\,10,\,12} = 0.99$, $pq_{9\,10,\,15} = 0.01$,
$pq_{9\,10,\,21} = 0.78$, $pq_{9\,10,\,25} = 0.22$, $pq_{9\,10,\,32} = 1$,
$pq_{9\,10,\,45} = 1$, $pq_{9\,10,\,52} = 0.73$, $pq_{9\,10,\,53} = 0.02$,
$pq_{9\,10,\,56} = 0.25$, $pq_{9\,10,\,62} = 0.31$, $pq_{9\,10,\,65} = 0.69$,
$pq_{10\,11,\,12} = 0.99$, $pq_{10\,11,\,15} = 0.01$, $pq_{10\,11,\,21} = 0.78$,
$pq_{10\,11,\,25} = 0.22$, $pq_{10\,11,\,32} = 1$, $pq_{10\,11,\,45} = 1$,
$pq_{10\,11,\,52} = 0.73$, $pq_{10\,11,\,53} = 0.02$, $pq_{10\,11,\,56} = 0.25$,
$pq_{10\,11,\,62} = 0.31$, $pq_{10\,11,\,65} = 0.69$, $pq_{11\,12,\,12} = 0.99$,
$pq_{11\,12,\,15} = 0.01$, $pq_{11\,12,\,21} = 0.78$, $pq_{11\,12,\,25} = 0.22$,
$pq_{11\,12,\,32} = 1$, $pq_{11\,12,\,45} = 1$, $pq_{11\,12,\,52} = 0.73$,

$pq_{11\,12,\,5\,3} = 0.02, pq_{11\,12,\,5\,6} = 0.25, pq_{11\,12,\,6\,2} = 0.31,$
$pq_{11\,12,\,6\,5} = 0.69, pq_{12\,13,\,1\,2} = 0.99, pq_{12\,13,\,1\,5} = 0.01,$
$pq_{12\,13,\,2\,1} = 0.78, pq_{12\,13,\,2\,5} = 0.22, pq_{12\,13,\,3\,2} = 1,$
$pq_{12\,13,\,4\,5} = 1, pq_{12\,13,\,5\,2} = 0.73, pq_{12\,13,\,5\,3} = 0.02,$
$pq_{12\,13,\,5\,6} = 0.25, pq_{12\,13,\,6\,2} = 0.31, pq_{12\,13,\,6\,5} = 0.69,$
$pq_{13\,14,\,1\,2} = 0.99, pq_{13\,14,\,1\,5} = 0.01, pq_{13\,14,\,2\,1} = 0.78,$
$pq_{13\,14,\,2\,5} = 0.22, pq_{13\,14,\,3\,2} = 1, pq_{13\,14,\,4\,5} = 1,$
$pq_{13\,14,\,5\,2} = 0.73, pq_{13\,14,\,5\,3} = 0.02, pq_{13\,14,\,5\,6} = 0.25,$
$pq_{13\,14,\,6\,2} = 0.31, pq_{13\,14,\,6\,5} = 0.69, pq_{14\,15,\,1\,2} = 0.99,$
$pq_{14\,15,\,1\,5} = 0.01, pq_{14\,15,\,2\,1} = 0.78, pq_{14\,15,\,2\,5} = 0.22,$
$pq_{14\,15,\,3\,2} = 1, pq_{14\,15,\,4\,5} = 1, pq_{14\,15,\,5\,2} = 0.73,$
$pq_{14\,15,\,5\,3} = 0.02, pq_{14\,15,\,5\,6} = 0.25, pq_{14\,15,\,6\,2} = 0.31,$
$pq_{14\,15,\,6\,5} = 0.69, pq_{15\,16,\,1\,2} = 0.99, pq_{15\,16,\,1\,5} = 0.01,$
$pq_{15\,16,\,2\,1} = 0.78, pq_{15\,16,\,2\,5} = 0.22, pq_{15\,16,\,3\,2} = 1,$
$pq_{15\,16,\,4\,5} = 1, pq_{15\,16,\,5\,2} = 0.73, pq_{15\,16,\,5\,3} = 0.02,$
$pq_{15\,16,\,5\,6} = 0.25, pq_{15\,16,\,6\,2} = 0.31, pq_{15\,16,\,6\,5} = 0.69,$
$pq_{16\,17,\,1\,2} = 0.99, pq_{16\,17,\,1\,5} = 0.01, pq_{16\,17,\,2\,1} = 0.78,$
$pq_{16\,17,\,2\,5} = 0.22, pq_{16\,17,\,3\,2} = 1, pq_{16\,17,\,4\,5} = 1,$
$pq_{16\,17,\,5\,2} = 0.73, pq_{16\,17,\,5\,3} = 0.02, pq_{16\,17,\,5\,6} = 0.25,$
$pq_{16\,17,\,6\,2} = 0.31, pq_{16\,17,\,6\,5} = 0.69, pq_{17\,18,\,1\,2} = 0.99,$
$pq_{17\,18,\,1\,5} = 0.01, pq_{17\,18,\,2\,1} = 0.78, pq_{17\,18,\,2\,5} = 0.22,$
$pq_{17\,18,\,3\,2} = 1, pq_{17\,18,\,4\,5} = 1, pq_{17\,18,\,5\,2} = 0.73,$
$pq_{17\,18,\,5\,3} = 0.02, pq_{17\,18,\,5\,6} = 0.25, pq_{17\,18,\,6\,2} = 0.31,$
$pq_{17\,18,\,6\,5} = 0.69, pq_{18\,1,\,1\,2} = 0.99, pq_{18\,1,\,1\,5} = 0.01,$
$pq_{18\,1,\,2\,1} = 0.78, pq_{18\,1,\,2\,5} = 0.22, pq_{18\,1,\,3\,2} = 1,$
$pq_{18\,1,\,4\,5} = 1, pq_{18\,1,\,5\,2} = 0.73, pq_{18\,1,\,5\,3} = 0.02,$
$pq_{18\,1,\,5\,6} = 0.25, pq_{18\,1,\,6\,2} = 0.31, pq_{18\,1,\,6\,5} = 0.69;$ (6)

and remaining $pq_{ij\,kl}$, $i, k = 1,2,\ldots,18$, $j, l = 1,2,\ldots,6$, are equal to 0;

- the matrix $[N_{ij\,kl}(t)]_{108x108}$ of the mean values of the maritime ferry operation process related to climate-weather change process $ZC^3(t)$ conditional sojourn times $\theta C^3_{ij\,kl}$, $i, k = 1,2,\ldots,18$, $j, l = 1,2,\ldots,6$, at the operation state zc_{ij}, when the next operation state is zc_{kl} could be found in [2].

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry Karlskrona port operating area - data coming from last measurement point</u>

After assuming that the maritime ferry operation process and the climate-weather change process at its operating area are independent, it is possible to evaluate the following unknown basic parameters of the maritime ferry operation process related to climate-weather change process $ZC^4(t)$ [2]:

- the vector

$$[pq_{ij}(0)]_{1x112} = [0.324, 0.018, 0.447, 0.029, 0.182, 0, ..., 0] \quad (7)$$

of initial probabilities of the maritime ferry operation process related to climate-weather change process $ZC^4(t)$ staying at the initial moment $t = 0$ at the operation states zc_{ij}, $i = 1,2,\ldots,18$, $j = 1,2,\ldots,6$;

- the matrix $[pq_{ij\,kl}]_{108x108}$, of the probabilities $pq_{ij\,kl}$, $i, k = 1,2,\ldots,18$, $j, l = 1,2,\ldots,6$, of transitions of the maritime ferry operation process related to climate-weather change process $ZC^4(t)$ from the operation state zc_{ij} into the the operation state zc_{kl}, where

$pq_{1\,2,\,1\,2} = 0.14, pq_{1\,2,\,1\,3} = 0.54, pq_{1\,2,\,1\,4} = 0.01,$
$pq_{1\,2,\,1\,5} = 0.31, pq_{1\,2,\,2\,1} = 0.09, pq_{1\,2,\,2\,3} = 0.27,$
$pq_{1\,2,\,2\,4} = 0.64, pq_{1\,2,\,3\,1} = 0.7, pq_{1\,2,\,3\,2} = 0.01,$
$pq_{1\,2,\,3\,4} = 0.1, pq_{1\,2,\,3\,5} = 0.19, pq_{1\,2,\,4\,2} = 0.05,$
$pq_{1\,2,\,4\,3} = 0.95, pq_{1\,2,\,5\,1} = 0.43, pq_{1\,2,\,5\,3} = 0.57,$
$pq_{2\,3,\,1\,2} = 0.14, pq_{2\,3,\,1\,3} = 0.54, pq_{2\,3,\,1\,4} = 0.01,$
$pq_{2\,3,\,1\,5} = 0.31, pq_{2\,3,\,2\,1} = 0.09, pq_{2\,3,\,2\,3} = 0.27,$
$pq_{2\,3,\,2\,4} = 0.64, pq_{2\,3,\,3\,1} = 0.7, pq_{2\,3,\,3\,2} = 0.01,$
$pq_{2\,3,\,3\,4} = 0.1, pq_{2\,3,\,3\,5} = 0.19, pq_{2\,3,\,4\,2} = 0.05,$
$pq_{2\,3,\,4\,3} = 0.95, pq_{2\,3,\,5\,1} = 0.43, pq_{2\,3,\,5\,3} = 0.57,$
$pq_{3\,4,\,1\,2} = 0.14, pq_{3\,4,\,1\,3} = 0.54, pq_{3\,4,\,1\,4} = 0.01,$
$pq_{3\,4,\,1\,5} = 0.31, pq_{3\,4,\,2\,1} = 0.09, pq_{3\,4,\,2\,3} = 0.27,$
$pq_{3\,4,\,2\,4} = 0.64, pq_{3\,4,\,3\,1} = 0.7, pq_{3\,4,\,3\,2} = 0.01,$
$pq_{3\,4,\,3\,4} = 0.1, pq_{3\,4,\,3\,5} = 0.19, pq_{3\,4,\,4\,2} = 0.05,$
$pq_{3\,4,\,4\,3} = 0.95, pq_{3\,4,\,5\,1} = 0.43, pq_{3\,4,\,5\,3} = 0.57,$
$pq_{4\,5,\,1\,2} = 0.14, pq_{4\,5,\,1\,3} = 0.54, pq_{4\,5,\,1\,4} = 0.01,$
$pq_{4\,5,\,1\,5} = 0.31, pq_{4\,5,\,2\,1} = 0.09, pq_{4\,5,\,2\,3} = 0.27,$
$pq_{4\,5,\,2\,4} = 0.64, pq_{4\,5,\,3\,1} = 0.7, pq_{4\,5,\,3\,2} = 0.01,$
$pq_{4\,5,\,3\,4} = 0.1, pq_{4\,5,\,3\,5} = 0.19, pq_{4\,5,\,4\,2} = 0.05,$
$pq_{4\,5,\,4\,3} = 0.95, pq_{4\,5,\,5\,1} = 0.43, pq_{4\,5,\,5\,3} = 0.57,$
$pq_{5\,6,\,1\,2} = 0.14, pq_{5\,6,\,1\,3} = 0.54, pq_{5\,6,\,1\,4} = 0.01,$
$pq_{5\,6,\,1\,5} = 0.31, pq_{5\,6,\,2\,1} = 0.09, pq_{5\,6,\,2\,3} = 0.27,$
$pq_{5\,6,\,2\,4} = 0.64, pq_{5\,6,\,3\,1} = 0.7, pq_{5\,6,\,3\,2} = 0.01,$
$pq_{5\,6,\,3\,4} = 0.1, pq_{5\,6,\,3\,5} = 0.19, pq_{5\,6,\,4\,2} = 0.05,$
$pq_{5\,6,\,4\,3} = 0.95, pq_{5\,6,\,5\,1} = 0.43, pq_{5\,6,\,5\,3} = 0.57,$
$pq_{6\,7,\,1\,2} = 0.14, pq_{6\,7,\,1\,3} = 0.54, pq_{6\,7,\,1\,4} = 0.01,$
$pq_{6\,7,\,1\,5} = 0.31, pq_{6\,7,\,2\,1} = 0.09, pq_{6\,7,\,2\,3} = 0.27,$
$pq_{6\,7,\,2\,4} = 0.64, pq_{6\,7,\,3\,1} = 0.7, pq_{6\,7,\,3\,2} = 0.01,$
$pq_{6\,7,\,3\,4} = 0.1, pq_{6\,7,\,3\,5} = 0.19, pq_{6\,7,\,4\,2} = 0.05,$
$pq_{6\,7,\,4\,3} = 0.95, pq_{6\,7,\,5\,1} = 0.43, pq_{6\,7,\,5\,3} = 0.57,$
$pq_{7\,8,\,1\,2} = 0.14, pq_{7\,8,\,1\,3} = 0.54, pq_{7\,8,\,1\,4} = 0.01,$
$pq_{7\,8,\,1\,5} = 0.31, pq_{7\,8,\,2\,1} = 0.09, pq_{7\,8,\,2\,3} = 0.27,$
$pq_{7\,8,\,2\,4} = 0.64, pq_{7\,8,\,3\,1} = 0.7, pq_{7\,8,\,3\,2} = 0.01,$
$pq_{7\,8,\,3\,4} = 0.1, pq_{7\,8,\,3\,5} = 0.19, pq_{7\,8,\,4\,2} = 0.05,$
$pq_{7\,8,\,4\,3} = 0.95, pq_{7\,8,\,5\,1} = 0.43, pq_{7\,8,\,5\,3} = 0.57,$
$pq_{8\,9,\,1\,2} = 0.14, pq_{8\,9,\,1\,3} = 0.54, pq_{8\,9,\,1\,4} = 0.01,$
$pq_{8\,9,\,1\,5} = 0.31, pq_{8\,9,\,2\,1} = 0.09, pq_{8\,9,\,2\,3} = 0.27,$
$pq_{8\,9,\,2\,4} = 0.64, pq_{8\,9,\,3\,1} = 0.7, pq_{8\,9,\,3\,2} = 0.01,$
$pq_{8\,9,\,3\,4} = 0.1, pq_{8\,9,\,3\,5} = 0.19, pq_{8\,9,\,4\,2} = 0.05,$
$pq_{8\,9,\,4\,3} = 0.95, pq_{8\,9,\,5\,1} = 0.43, pq_{8\,9,\,5\,3} = 0.57,$
$pq_{9\,10,\,1\,2} = 0.14, pq_{9\,10,\,1\,3} = 0.54, pq_{9\,10,\,1\,4} = 0.01,$
$pq_{9\,10,\,1\,5} = 0.31, pq_{9\,10,\,2\,1} = 0.09, pq_{9\,10,\,2\,3} = 0.27,$
$pq_{9\,10,\,2\,4} = 0.64, pq_{9\,10,\,3\,1} = 0.7, pq_{9\,10,\,3\,2} = 0.01,$
$pq_{9\,10,\,3\,4} = 0.1, pq_{9\,10,\,3\,5} = 0.19, pq_{9\,10,\,4\,2} = 0.05,$
$pq_{9\,10,\,4\,3} = 0.95, pq_{9\,10,\,5\,1} = 0.43, pq_{9\,10,\,5\,3} = 0.57,$
$pq_{10\,11,\,1\,2} = 0.14, pq_{10\,11,\,1\,3} = 0.54, pq_{10\,11,\,1\,4} = 0.01,$
$pq_{10\,11,\,1\,5} = 0.31, pq_{10\,11,\,2\,1} = 0.09, pq_{10\,11,\,2\,3} = 0.27,$
$pq_{10\,11,\,2\,4} = 0.64, pq_{10\,11,\,3\,1} = 0.7, pq_{10\,11,\,3\,2} = 0.01,$

$pq_{10\,11,\,3\,4} = 0.1, pq_{10\,11,\,3\,5} = 0.19, pq_{10\,11,\,4\,2} = 0.05,$
$pq_{10\,11,\,4\,3} = 0.95, pq_{10\,11,\,5\,1} = 0.43, pq_{10\,11,\,5\,3} = 0.57,$
$pq_{11\,12,\,1\,2} = 0.14, pq_{11\,12,\,1\,3} = 0.54, pq_{11\,12,\,1\,4} = 0.01,$
$pq_{11\,12,\,1\,5} = 0.31, pq_{11\,12,\,2\,1} = 0.09, pq_{11\,12,\,2\,3} = 0.27,$
$pq_{11\,12,\,2\,4} = 0.64, pq_{11\,12,\,3\,1} = 0.7, pq_{11\,12,\,3\,2} = 0.01,$
$pq_{11\,12,\,3\,4} = 0.1, pq_{11\,12,\,3\,5} = 0.19, pq_{11\,12,\,4\,2} = 0.05,$
$pq_{11\,12,\,4\,3} = 0.95, pq_{11\,12,\,5\,1} = 0.43, pq_{11\,12,\,5\,3} = 0.57,$
$pq_{12\,13,\,1\,2} = 0.14, pq_{12\,13,\,1\,3} = 0.54, pq_{12\,13,\,1\,4} = 0.01,$
$pq_{12\,13,\,1\,5} = 0.31, pq_{12\,13,\,2\,1} = 0.09, pq_{12\,13,\,2\,3} = 0.27,$
$pq_{12\,13,\,2\,4} = 0.64, pq_{12\,13,\,3\,1} = 0.7, pq_{12\,13,\,3\,2} = 0.01,$
$pq_{12\,13,\,3\,4} = 0.1, pq_{12\,13,\,3\,5} = 0.19, pq_{12\,13,\,4\,2} = 0.05,$
$pq_{12\,13,\,4\,3} = 0.95, pq_{12\,13,\,5\,1} = 0.43, pq_{12\,13,\,5\,3} = 0.57,$
$pq_{13\,14,\,1\,2} = 0.14, pq_{13\,14,\,1\,3} = 0.54, pq_{13\,14,\,1\,4} = 0.01,$
$pq_{13\,14,\,1\,5} = 0.31, pq_{13\,14,\,2\,1} = 0.09, pq_{13\,14,\,2\,3} = 0.27,$
$pq_{13\,14,\,2\,4} = 0.64, pq_{13\,14,\,3\,1} = 0.7, pq_{13\,14,\,3\,2} = 0.01,$
$pq_{13\,14,\,3\,4} = 0.1, pq_{13\,14,\,3\,5} = 0.19, pq_{13\,14,\,4\,2} = 0.05,$
$pq_{13\,14,\,4\,3} = 0.95, pq_{13\,14,\,5\,1} = 0.43, pq_{13\,14,\,5\,3} = 0.57,$
$pq_{14\,15,\,1\,2} = 0.14, pq_{14\,15,\,1\,3} = 0.54, pq_{14\,15,\,1\,4} = 0.01,$
$pq_{14\,15,\,1\,5} = 0.31, pq_{14\,15,\,2\,1} = 0.09, pq_{14\,15,\,2\,3} = 0.27,$
$pq_{14\,15,\,2\,4} = 0.64, pq_{14\,15,\,3\,1} = 0.7, pq_{14\,15,\,3\,2} = 0.01,$
$pq_{14\,15,\,3\,4} = 0.1, pq_{14\,15,\,3\,5} = 0.19, pq_{14\,15,\,4\,2} = 0.05,$
$pq_{14\,15,\,4\,3} = 0.95, pq_{14\,15,\,5\,1} = 0.43, pq_{14\,15,\,5\,3} = 0.57,$
$pq_{15\,16,\,1\,2} = 0.14, pq_{15\,16,\,1\,3} = 0.54, pq_{15\,16,\,1\,4} = 0.01,$
$pq_{15\,16,\,1\,5} = 0.31, pq_{15\,16,\,2\,1} = 0.09, pq_{15\,16,\,2\,3} = 0.27,$
$pq_{15\,16,\,2\,4} = 0.64, pq_{15\,16,\,3\,1} = 0.7, pq_{15\,16,\,3\,2} = 0.01,$
$pq_{15\,16,\,3\,4} = 0.1, pq_{15\,16,\,3\,5} = 0.19, pq_{15\,16,\,4\,2} = 0.05,$
$pq_{15\,16,\,4\,3} = 0.95, pq_{15\,16,\,5\,1} = 0.43, pq_{15\,16,\,5\,3} = 0.57,$
$pq_{16\,17,\,1\,2} = 0.14, pq_{16\,17,\,1\,3} = 0.54, pq_{16\,17,\,1\,4} = 0.01,$
$pq_{16\,17,\,1\,5} = 0.31, pq_{16\,17,\,2\,1} = 0.09, pq_{16\,17,\,2\,3} = 0.27,$
$pq_{16\,17,\,2\,4} = 0.64, pq_{16\,17,\,3\,1} = 0.7, pq_{16\,17,\,3\,2} = 0.01,$
$pq_{16\,17,\,3\,4} = 0.1, pq_{16\,17,\,3\,5} = 0.19, pq_{16\,17,\,4\,2} = 0.05,$
$pq_{16\,17,\,4\,3} = 0.95, pq_{16\,17,\,5\,1} = 0.43, pq_{16\,17,\,5\,3} = 0.57,$
$pq_{17\,18,\,1\,2} = 0.14, pq_{17\,18,\,1\,3} = 0.54, pq_{17\,18,\,1\,4} = 0.01,$
$pq_{17\,18,\,1\,5} = 0.31, pq_{17\,18,\,2\,1} = 0.09, pq_{17\,18,\,2\,3} = 0.27,$
$pq_{17\,18,\,2\,4} = 0.64, pq_{17\,18,\,3\,1} = 0.7, pq_{17\,18,\,3\,2} = 0.01,$
$pq_{17\,18,\,3\,4} = 0.1, pq_{17\,18,\,3\,5} = 0.19, pq_{17\,18,\,4\,2} = 0.05,$
$pq_{17\,18,\,4\,3} = 0.95, pq_{17\,18,\,5\,1} = 0.43, pq_{17\,18,\,5\,3} = 0.57,$
$pq_{18\,1,\,1\,2} = 0.14, pq_{18\,1,\,1\,3} = 0.54, pq_{18\,1,\,1\,4} = 0.01,$
$pq_{18\,1,\,1\,5} = 0.31, pq_{18\,1,\,2\,1} = 0.09, pq_{18\,1,\,2\,3} = 0.27,$
$pq_{18\,1,\,2\,4} = 0.64, pq_{18\,1,\,3\,1} = 0.7, pq_{18\,1,\,3\,2} = 0.01,$
$pq_{18\,1,\,3\,4} = 0.1, pq_{18\,1,\,3\,5} = 0.19, pq_{18\,1,\,4\,2} = 0.05,$
$pq_{18\,1,\,4\,3} = 0.95, pq_{18\,1,\,5\,1} = 0.43,$
$pq_{18\,1,\,5\,3} = 0.57;$ (8)

and remaining $pq_{ij\,kl}$, $i, k = 1,2,\ldots,18$, $j, l = 1,2,\ldots,6$, are equal to 0;

- the matrix $[N_{ij\,kl}(t)]_{108x108}$ of the mean values of the maritime ferry operation process related to climate-weather change process $ZC^4(t)$ conditional sojourn times $\theta C^4_{ij\,kl}$, $i, k = 1,2,\ldots,18$, $j, l = 1,2,\ldots,6$, at the operation state zc_{ij}, when the next operation state is zc_{kl} can be found in [2].

3. Maritime ferry operation process related to climate-weather change prediction characteristics

The maritime ferry operation process related to climate-weather change is defined in [2], [6]. Considering these results and assuming that we have identified the unknown parameters of the maritime ferry operation process related to climate-weather change, we can predict basic characteristics of this process.

3.1. Transient probabilities of maritime ferry operation process related to climate-weather change

Maritime ferry operation process related to climate-weather change process for maritime ferry Gdynia port operating area - data coming from first measurement points

The limit values of the maritime ferry operation process related to climate-weather change process $ZC^1(t)$ transient probabilities pq_{ij}, $i = 1,2,\ldots,18$, $j = 1,2,\ldots,6$, at the particular operation states zc_{ij}, are given in the vector [2]:

$$[pq_{ij}]_{1x108} \cong [0.015352, 0.000418, 0.017138, 0.00038, 0.004712, 0, 0.000808, 0.000022, 0.000902, 0.00002, 0.000248, 0, 0.010504, 0.000286, 0.011726, 0.00026, 0.003224, 0, 0.014544, 0.000396, 0.016236, 0.00036, 0.004464, 0, 0.146652, 0.003993, 0.163713, 0.00363, 0.045012, 0, 0.010504, 0.000286, 0.011726, 0.00026, 0.003224, 0, 0.00202, 0.000055, 0.002255, 0.00005, 0.00062, 0, 0.006464, 0.000176, 0.007216, 0.00016, 0.001984, 0, 0.014948, 0.000407, 0.016687, 0.00037, 0.004588, 0, 0.000808, 0.000022, 0.000902, 0.00002, 0.000248, 0, 0.001212, 0.000033, 0.001353, 0.00003, 0.000372, 0, 0.006464, 0.000176, 0.007216, 0.00016, 0.001984, 0, 0.141804, 0.003861, 0.158301, 0.00351, 0.043524, 0, 0.013736, 0.000374, 0.015334, 0.00034, 0.004216, 0, 0.009696, 0.000264, 0.010824, 0.00024, 0.002976, 0, 0.001212, 0.000033, 0.001353, 0.00003, 0.000372, 0, 0.00202, 0.000055, 0.002255, 0.00005, 0.00062, 0, 0.005252, 0.000143, 0.005863, 0.00013, 0.001612, 0]; \quad (9)$$

Maritime ferry operation process related to climate-weather change process for maritime ferry restricted waters operating area - data coming from second measurement point

The limit values of the maritime ferry operation process related to climate-weather change process $ZC^2(t)$ transient probabilities pq_{ij}, $i = 1,2,\ldots,18$, $j = 1,2,\ldots,6$, at the particular operation states zc_{ij}, are given in the vector [2]:

$[pq_{ij}]_{1x108} \cong$ [0.03059, 0.006346, 0.000304, 0, 0.000266, 0.000494, 0.00161, 0.000334, 0.000016, 0, 0.000014, 0.000026, 0.02093, 0.004342, 0.000208, 0, 0.000182, 0.000338, 0.02898, 0.006012, 0.000288, 0, 0.000252, 0.000468, 0.292215, 0.060621, 0.002904, 0, 0.002541, 0.004719, 0.02093, 0.004342, 0.000208, 0, 0.000182, 0.000338, 0.004025, 0.000835, 0.00004, 0, 0.000035, 0.000065, 0.01288, 0.002672, 0.000128, 0, 0.000112, 0.000208, 0.029785, 0.006179, 0.000296, 0, 0.000259, 0.000481, 0.00161, 0.000334, 0.000016, 0, 0.000014, 0.000026, 0.002415, 0.000501, 0.000024, 0, 0.000021, 0.000039, 0.01288, 0.002672, 0.000128, 0, 0.000112, 0.000208, 0.282555, 0.058617, 0.002808, 0, 0.002457, 0.004563, 0.02737, 0.005678, 0.000272, 0, 0.000238, 0.000442, 0.01932, 0.004008, 0.000192, 0, 0.000168, 0.000312, 0.002415, 0.000501, 0.000024, 0, 0.000021, 0.000039, 0.004025, 0.000835, 0.00004, 0, 0.000035, 0.000065, 0.010465, 0.002171, 0.000104, 0, 0.000091, 0.000169]; (10)

Maritime ferry operation process related to climate-weather change process for maritime ferry Baltic Sea open waters operating area - data coming from 1353, 1389, 1422 and 1458 measurement points

The limit values of the maritime ferry operation process related to climate-weather change process $ZC^3(t)$ transient probabilities pq_{ij}, $i = 1,2,\ldots,18$, $j = 1,2,\ldots,6$, at the particular operation states zc_{ij}, are given in the vector [2]:

$[pq_{ij}]_{1x108} \cong$ [0.030096, 0.00703, 0, 0, 0.000608, 0.000266, 0.001584, 0.00037, 0, 0, 0.000032, 0.000014, 0.020592, 0.00481, 0, 0, 0.000416, 0.000182, 0.028512, 0.00666, 0, 0, 0.000576, 0.000252, 0.287496, 0.067155, 0, 0, 0.005808, 0.002541, 0.020592, 0.00481, 0, 0, 0.000416, 0.000182, 0.00396, 0.000925, 0, 0, 0.00008, 0.000035, 0.012672, 0.00296, 0, 0, 0.000256, 0.000112, 0.029304, 0.006845, 0, 0, 0.000592, 0.000259, 0.001584, 0.00037, 0, 0, 0.000032, 0.000014, 0.002376, 0.000555, 0, 0, 0.000048, 0.000021, 0.012672, 0.00296, 0, 0, 0.000256, 0.000112, 0.277992, 0.064935, 0, 0, 0.005616, 0.002457, 0.026928, 0.00629, 0, 0, 0.000544, 0.000238, 0.019008, 0.00444, 0, 0, 0.000384, 0.000168, 0.002376, 0.000555, 0, 0, 0.000048, 0.000021, 0.00396, 0.000925, 0, 0, 0.00008, 0.000035, 0.010296, 0.002405, 0, 0, 0.000208, 0.000091]. (12)

Maritime ferry operation process related to climate-weather change process for maritime ferry Karlskrona port operating area - data coming from last measurement point

The limit values of the maritime ferry operation process related to climate-weather change process $ZC^4(t)$ transient probabilities pq_{ij}, $i = 1,2,\ldots,18$, $j = 1,2,\ldots,6$, at the particular operation states zc_{ij}, are given in the vector [2]:

$[pq_{ij}]_{1x108} \cong$ [0.014972, 0.000608, 0.011818, 0.00114, 0.009462, 0, 0.000788, 0.000032, 0.000622, 0.00006, 0.000498, 0, 0.010244, 0.000416, 0.008086, 0.00078, 0.006474, 0, 0.014184, 0.000576, 0.011196, 0.00108, 0.008964, 0, 0.143022, 0.005808, 0.112893, 0.01089, 0.090387, 0, 0.010244, 0.000416, 0.008086, 0.00078, 0.006474, 0, 0.00197, 0.00008, 0.001555, 0.00015, 0.001245, 0, 0.006304, 0.000256, 0.004976, 0.00048, 0.003984, 0, 0.014578, 0.000592, 0.011507, 0.00111, 0.009213, 0, 0.000788, 0.000032, 0.000622, 0.00006, 0.000498, 0, 0.001182, 0.000048, 0.000933, 0.00009, 0.000747, 0, 0.006304, 0.000256, 0.004976, 0.00048, 0.003984, 0, 0.138294, 0.005616, 0.109161, 0.01053, 0.087399, 0, 0.013396, 0.000544, 0.010574, 0.00102, 0.008466, 0, 0.009456, 0.000384, 0.007464, 0.00072, 0.005976, 0, 0.001182, 0.000048, 0.000933, 0.00009, 0.000747, 0, 0.00197, 0.00008, 0.001555, 0.00015, 0.001245, 0, 0.005122, 0.000208, 0.004043, 0.00039, 0.003237, 0]; (11)

3.2. Total sojourn times of maritime ferry operation process related to climate-weather change

Maritime ferry operation process related to climate-weather change process for maritime ferry Gdynia port operating area - data coming from first measurement points

The expected values of the total sojourn times θC_{ij}^1,

i = 1,2,…,18, j =1,2,…,6, of the maritime ferry operation process related to climate-weather change process $ZC^1(t)$ at the particular operation states zc_{ij}, during the fixed operation time C^1 = 1 month (February) = 29 days, are given in the vector (its coordinates are measured in days) [2]:

$[\hat{M}\hat{N}^1_{ij}]_{1x108} = [E[\theta C^1_{ij}]]_{1x108} \cong$ [0.445208, 0.012122, 0.497002, 0.01102, 0.136648, 0, 0.023432, 0.000638, 0.026158, 0.00058, 0.007192, 0, 0.304616, 0.008294, 0.340054, 0.00754, 0.093496, 0, 0.421776, 0.011484, 0.470844, 0.01044, 0.129456, 0, 4.252908, 0.115797, 4.747677, 0.10527, 1.305348, 0, 0.304616, 0.008294, 0.340054, 0.00754, 0.093496, 0, 0.05858, 0.001595, 0.065395, 0.00145, 0.01798, 0, 0.187456, 0.005104, 0.209264, 0.00464, 0.057536, 0, 0.433492, 0.011803, 0.483923, 0.01073, 0.133052, 0, 0.023432, 0.000638, 0.026158, 0.00058, 0.007192, 0, 0.035148, 0.000957, 0.039237, 0.00087, 0.010788, 0, 0.187456, 0.005104, 0.209264, 0.00464, 0.057536, 0, 4.112316, 0.111969, 4.590729, 0.10179, 1.262196, 0, 0.398344, 0.010846, 0.444686, 0.00986, 0.122264, 0, 0.281184, 0.007656, 0.313896, 0.00696, 0.086304, 0, 0.035148, 0.000957, 0.039237, 0.00087, 0.010788, 0, 0.05858, 0.001595, 0.065395, 0.00145, 0.01798, 0, 0.152308, 0.004147, 0.170027, 0.00377, 0.046748, 0]; (12)

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry restricted waters operating area - data coming from second measurement point</u>

The expected values of the total sojourn times θC^2_{ij}, i = 1,2,…,18, j =1,2,…,6, of the maritime ferry operation process related to climate-weather change process $ZC^2(t)$ at the particular operation states zc_{ij}, during the fixed operation time C^2 = 1 month (February) = 29 days, are given in the vector (its coordinates are measured in days) [2]:

$[\hat{M}\hat{N}^2_{ij}]_{1x108} = [E[\theta C^2_{ij}]]_{1x108} \cong$ [0.88711, 0.184034, 0.008816, 0, 0.007714, 0.014326, 0.04669, 0.009686, 0.000464, 0, 0.000406, 0.000754, 0.60697, 0.125918, 0.006032, 0, 0.005278, 0.009802, 0.84042, 0.174348, 0.008352, 0, 0.007308, 0.013572, 8.474235, 1.758009, 0.084216, 0, 0.073689, 0.136851, 0.60697, 0.125918, 0.006032, 0, 0.005278, 0.009802, 0.116725, 0.024215, 0.00116, 0, 0.001015, 0.001885, 0.37352, 0.077488, 0.003712, 0, 0.003248, 0.006032, 0.863765, 0.179191, 0.008584, 0, 0.007511, 0.013949, 0.04669, 0.009686, 0.000464, 0, 0.000406, 0.000754, 0.070035, 0.014529, 0.000696, 0, 0.000609, 0.001131, 0.37352, 0.077488, 0.003712, 0, 0.003248, 0.006032, 8.194095, 1.699893, 0.081432, 0, 0.071253, 0.132327, 0.79373, 0.164662, 0.007888, 0, 0.006902, 0.012818, 0.56028, 0.116232, 0.005568, 0, 0.004872, 0.009048, 0.070035, 0.014529, 0.000696, 0, 0.000609, 0.001131, 0.116725, 0.024215, 0.00116, 0, 0.001015, 0.001885, 0.303485, 0.062959, 0.003016, 0, 0.002639, 0.004901]; (13)

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry Baltic Sea open waters operating area - data coming from 1353, 1389, 1422 and 1458 measurement points</u>

The expected values of the total sojourn times θC^3_{ij}, i = 1,2,…,18, j =1,2,…,16, of the maritime ferry operation process related to climate-weather change process $ZC^3(t)$ at the particular operation states zc_{ij}, during the fixed operation time C^3 = 1 month (February) = 29 days, are given in the vector (its coordinates are measured in days) [2]:

$[\hat{M}\hat{N}^3_{ij}]_{1x108} = [E[\theta C^3_{ij}]]_{1x108} \cong$ [0.872784, 0.20387, 0, 0, 0.017632, 0.007714, 0.045936, 0.01073, 0, 0, 0.000928, 0.000406, 0.597168, 0.13949, 0, 0, 0.012064, 0.005278, 0.826848, 0.19314, 0, 0, 0.016704, 0.007308, 8.337384, 1.947495, 0, 0, 0.168432, 0.073689, 0.597168, 0.13949, 0, 0, 0.012064, 0.005278, 0.11484, 0.026825, 0, 0, 0.00232, 0.001015, 0.367488, 0.08584, 0, 0, 0.007424, 0.003248, 0.849816, 0.198505, 0, 0, 0.017168, 0.007511, 0.045936, 0.01073, 0, 0, 0.000928, 0.000406, 0.068904, 0.016095, 0, 0, 0.001392, 0.000609, 0.367488, 0.08584, 0, 0, 0.007424, 0.003248, 8.061768, 1.883115, 0, 0, 0.162864, 0.071253, 0.780912, 0.18241, 0, 0, 0.015776, 0.006902, 0.551232, 0.12876, 0, 0, 0.011136, 0.004872, 0.068904, 0.016095, 0, 0, 0.001392, 0.000609, 0.11484, 0.026825, 0, 0, 0.00232, 0.001015, 0.298584, 0.069745, 0, 0, 0.006032, 0.002639]. (14)

<u>Maritime ferry operation process related to climate-weather change process for maritime ferry Karlskrona port operating area - data coming from last measurement point</u>

The expected values of the total sojourn times θC^4_{ij}, i = 1,2,…,18, j =1,2,…,16, of the maritime ferry operation process related to climate-weather change process $ZC^4(t)$ at the particular operation states zc_{ij}, during the fixed operation time C^4 = 1 month (February) = 29 days, are given in the vector (its coordinates are measured in days) [2]:

$$[\hat{M}\hat{N}^4_{ij}]_{1x108} = [E[\theta C^4_{ij}]]_{1x108} \cong [0.434188, 0.017632, 0.342722, 0.03306, 0.274398, 0, 0.022852, 0.000928, 0.018038, 0.00174, 0.014442, 0, 0.297076, 0.012064, 0.234494, 0.02262, 0.187746, 0, 0.411336, 0.016704, 0.324684, 0.03132, 0.259956, 0, 4.147638, 0.168432, 3.273897, 0.31581, 2.621223, 0, 0.297076, 0.012064, 0.234494, 0.02262, 0.187746, 0, 0.05713, 0.00232, 0.045095, 0.00435, 0.036105, 0, 0.182816, 0.007424, 0.144304, 0.01392, 0.115536, 0, 0.422762, 0.017168, 0.333703, 0.03219, 0.267177, 0, 0.022852, 0.000928, 0.018038, 0.00174, 0.014442, 0, 0.034278, 0.001392, 0.027057, 0.00261, 0.021663, 0, 0.182816, 0.007424, 0.144304, 0.01392, 0.115536, 0, 4.010526, 0.162864, 3.165669, 0.30537, 2.534571, 0, 0.388484, 0.015776, 0.306646, 0.02958, 0.245514, 0, 0.274224, 0.011136, 0.216456, 0.02088, 0.173304, 0, 0.034278, 0.001392, 0.027057, 0.00261, 0.021663, 0, 0.05713, 0.00232, 0.045095, 0.00435, 0.036105, 0, 0.148538, 0.006032, 0.117247, 0.01131, 0.093873, 0]. \quad (15)$$

4. Conclusions

The probabilistic model of the critical infrastructure operation process related to climate-weather change presented in [6] was applied to identification and prediction of this process for maritime ferry. The obtained results justify very high importance of considering the operation process related to climate-weather change. Especially, this considering is important in the investigation of the operation process related to climate weather change influence on the critical infrastructure safety as it could be different at various operating states and at the various operating areas [9].

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