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## **Identification and prediction of port oil piping transportation system operation process related to climate-weather change**

### **Keywords**

operation process, climate-weather change, identification, prediction, piping transportation system

### **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 the port oil piping transportation system. There are distinguished three different processes for the corresponding piping operating area. Further, using identified parameters of the piping operation process and the piping 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 piping operation process related to climate-weather change processes at the distinguished operating area.

### **1. Introduction**

The port oil piping transportation system operation process is described in [1], [4]-[6]. The climate-weather change process for the piping operating area is modelled in [2], [10]. In this paper, the identification of the piping operation process related to climate-weather change is performed. To do this, we can use the evaluated parameters of the piping operation process from [5] and parameters of the climate-weather change process at its operating area from [10]. This way, having this processes identified, the prediction of the piping operation process related to climate-weather change characteristics is performed.

### **2. Port oil piping transportation system operation process related to climate-weather change identification**

Assuming that the piping operation process and the climate-weather change processes at its operating area are independent, to identify the unknown parameters of the piping operation process related to climate-weather change processes only the suitable

statistical data of the piping operation process and of the piping climate-weather change processes should be collected. The statistical identification of the piping operation process related to climate-weather change was performed: the states were distinguished and the following unknown basic parameters of the piping operation process, i.e. the vector of probabilities of the piping operation process staying at the initial states, the matrix of probabilities of the piping operation process transitions between the states, the matrix of the mean values of the conditional sojourn times of the piping operation process were evaluated.

#### **2.1. States of piping operation process related to climate-weather change**

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from initial, middle east, middle west measurement points

The piping operation process related to climate-weather change process  $ZC^l(t)$ ,  $t \in \langle 0, +\infty \rangle$ ,

can take  $\nu w^1 = 7 \cdot 6 = 42$  different operation states  $zc_{11}, zc_{12}, \dots, zc_{76}$ ;

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from end measurement point

The piping operation process related to climate-weather change process  $ZC^2(t)$ ,  $t \in \langle 0, +\infty \rangle$ , can take  $\nu w^2 = 7 \cdot 6 = 42$  different operation states  $zc_{11}, zc_{12}, \dots, zc_{76}$ ;

Piping operation process related to climate-weather change process for piping Baltic seaside land operating area - data coming from land measurement point

The piping operation process related to climate-weather change process  $ZC^3(t)$ ,  $t \in \langle 0, +\infty \rangle$ , can take  $\nu w^3 = 7 \cdot 16 = 112$  different operation states  $zc_{11}, zc_{12}, \dots, zc_{716}$ .

## 2.2. Parameters of piping operation process related to climate-weather change

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from initial, middle east, middle west measurement points

After assuming that the piping 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 piping operation process related to climate-weather change process  $ZC^1(t)$  [3]:

- the vector

$$\begin{aligned}
 & [pq_{ij}(0)]_{1 \times 42} \\
 & = [0.24412, 0.07650, 0.00136, 0, 0.01190, 0.00612; \\
 & 0.03590, 0.01125, 0.00020, 0, 0.00175, 0.00090; \\
 & 0, 0, 0, 0, 0, 0; 0, 0, 0, 0, 0, 0; \\
 & 0.16514, 0.05175, 0.00092, 0, 0.00805, 0.00414; \\
 & 0.13642, 0.04275, 0.00076, 0, 0.00665, 0.00342; \\
 & 0.13642, 0.04275, 0.00076, 0, 0.00665, 0.00342](1)
 \end{aligned}$$

of initial probabilities of the piping operation process related to climate-weather change process  $ZC^1(t)$  staying at the initial moment  $t = 0$  at the operation states  $zc_{ij}$ ,  $i = 1, 2, \dots, 7, j = 1, 2, \dots, 6$ ;

- the matrix  $[pq_{ij\,kl}]_{42 \times 42}$ , of the probabilities  $pq_{ij\,kl}$ ,  $i, k = 1, 2, \dots, 7, j, l = 1, 2, \dots, 6$ , of transitions of the

piping operation process related to climate-weather change process  $ZC^1(t)$  from the operation state  $zc_{ij}$  into the operation state  $zc_{kl}$ , where

$$\begin{aligned}
 & pq_{12,12} = 0.02178, \quad pq_{12,15} = 0.00022, \\
 & pq_{12,21} = 0.01826, \quad pq_{12,25} = 0.00374, \\
 & pq_{12,32} = 0.01804, \quad pq_{12,36} = 0.00396, \\
 & pq_{12,45} = 0.022, \quad pq_{12,51} = 0.00044, \\
 & pq_{12,52} = 0.01452, \quad pq_{12,53} = 0.00176, \\
 & pq_{12,56} = 0.00528, \quad pq_{12,62} = 0.0022, \\
 & pq_{12,63} = 0.0154, \quad pq_{12,65} = 0.0044; \\
 & pq_{13,12} = 0.02178, \quad pq_{13,15} = 0.00022, \\
 & pq_{13,21} = 0.01826, \quad pq_{13,25} = 0.00374, \\
 & pq_{13,32} = 0.01804, \quad pq_{13,36} = 0.00396, \\
 & pq_{13,45} = 0.022, \quad pq_{13,51} = 0.00044, \\
 & pq_{13,52} = 0.01452, \quad pq_{13,53} = 0.00176, \\
 & pq_{13,56} = 0.00528, \quad pq_{13,62} = 0.0022, \\
 & pq_{13,63} = 0.0154, \quad pq_{13,65} = 0.0044; \\
 & pq_{15,12} = 0.52866, \quad pq_{15,15} = 0.00534, \\
 & pq_{15,21} = 0.44322, \quad pq_{15,25} = 0.09078, \\
 & pq_{15,32} = 0.43788, \quad pq_{15,36} = 0.09612, \\
 & pq_{15,45} = 0.534, \quad pq_{15,51} = 0.01068, \\
 & pq_{15,52} = 0.35244, \quad pq_{15,53} = 0.04272, \\
 & pq_{15,56} = 0.12816, \quad pq_{15,62} = 0.0534, \\
 & pq_{15,63} = 0.3738, \quad pq_{15,65} = 0.1068; \\
 & pq_{16,12} = 0.10989, \quad pq_{16,15} = 0.00111, \\
 & pq_{16,21} = 0.09213, \quad pq_{16,25} = 0.01887, \\
 & pq_{16,32} = 0.09102, \quad pq_{16,36} = 0.01998, \\
 & pq_{16,45} = 0.111, \quad pq_{16,51} = 0.00222, \\
 & pq_{16,52} = 0.07326, \quad pq_{16,53} = 0.00888, \\
 & pq_{16,56} = 0.02664, \quad pq_{16,62} = 0.0111, \\
 & pq_{16,63} = 0.0777, \quad pq_{16,65} = 0.0222; \\
 & pq_{17,12} = 0.30789, \quad pq_{17,15} = 0.00311, \\
 & pq_{17,21} = 0.25813, \quad pq_{17,25} = 0.05287, \\
 & pq_{17,32} = 0.25502, \quad pq_{17,36} = 0.05598, \\
 & pq_{17,45} = 0.311, \quad pq_{17,51} = 0.00622, \\
 & pq_{17,52} = 0.20526, \quad pq_{17,53} = 0.02488, \\
 & pq_{17,56} = 0.07464, \quad pq_{17,62} = 0.0311, \\
 & pq_{17,63} = 0.2177, \quad pq_{17,65} = 0.0622; \\
 & pq_{21,12} = 0.198, \quad pq_{21,15} = 0.002, \\
 & pq_{21,21} = 0.166, \quad pq_{21,25} = 0.034, \\
 & pq_{21,32} = 0.164, \quad pq_{21,36} = 0.036, \quad pq_{21,45} = 0.2, \\
 & pq_{21,51} = 0.004, \quad pq_{21,52} = 0.132, \\
 & pq_{21,53} = 0.016, \quad pq_{21,56} = 0.048, \\
 & pq_{21,62} = 0.02, \quad pq_{21,63} = 0.14, \quad pq_{21,65} = 0.04; \\
 & pq_{27,12} = 0.792, \quad pq_{27,15} = 0.008, \\
 & pq_{27,21} = 0.664, \quad pq_{27,25} = 0.136, \\
 & pq_{27,32} = 0.656, \quad pq_{27,36} = 0.144, \quad pq_{27,45} = 0.8, \\
 & pq_{27,51} = 0.016, \quad pq_{27,52} = 0.528, \\
 & pq_{27,53} = 0.064, \quad pq_{27,56} = 0.192, \\
 & pq_{27,62} = 0.08, \quad pq_{27,63} = 0.56, \quad pq_{27,65} = 0.16; \\
 & pq_{31,12} = 0.99, \quad pq_{31,15} = 0.01, \quad pq_{31,21} = 0.83, \\
 & pq_{31,25} = 0.17, \quad pq_{31,32} = 0.82, \quad pq_{31,36} = 0.18, \\
 & pq_{31,45} = 1, \quad pq_{31,51} = 0.02, \quad pq_{31,52} = 0.66, \\
 & pq_{31,53} = 0.08, \quad pq_{31,56} = 0.24, \quad pq_{31,62} = 0.1,
 \end{aligned}$$

$pq_{31,63} = 0.7$ ,  $pq_{31,65} = 0.2$ ;  $pq_{47,12} = 0.99$ ,  
 $pq_{47,15} = 0.01$ ,  $pq_{47,21} = 0.83$ ,  $pq_{47,25} = 0.17$ ,  
 $pq_{47,32} = 0.82$ ,  $pq_{47,36} = 0.18$ ,  $pq_{47,45} = 1$ ,  
 $pq_{47,51} = 0.02$ ,  $pq_{47,52} = 0.66$ ,  $pq_{47,53} = 0.08$ ,  
 $pq_{47,56} = 0.24$ ,  $pq_{47,62} = 0.1$ ,  $pq_{47,63} = 0.7$ ,  
 $pq_{47,65} = 0.2$ ;  $pq_{51,12} = 0.48312$ ,  
 $pq_{51,15} = 0.00488$ ,  $pq_{51,21} = 0.40504$ ,  
 $pq_{51,25} = 0.08296$ ,  $pq_{51,32} = 0.40016$ ,  
 $pq_{51,36} = 0.08784$ ,  $pq_{51,45} = 0.488$ ,  
 $pq_{51,51} = 0.00976$ ,  $pq_{51,52} = 0.32208$ ,  
 $pq_{51,53} = 0.03904$ ,  $pq_{51,56} = 0.11712$ ,  
 $pq_{51,62} = 0.0488$ ,  $pq_{51,63} = 0.3416$ ,  
 $pq_{51,65} = 0.0976$ ;  $pq_{52,12} = 0.02277$ ,  
 $pq_{52,15} = 0.00023$ ,  $pq_{52,21} = 0.01909$ ,  
 $pq_{52,25} = 0.00391$ ,  $pq_{52,32} = 0.01886$ ,  
 $pq_{52,36} = 0.00414$ ,  $pq_{52,45} = 0.023$ ,  
 $pq_{52,51} = 0.00046$ ,  $pq_{52,52} = 0.01518$ ,  
 $pq_{52,53} = 0.00184$ ,  $pq_{52,56} = 0.00552$ ,  
 $pq_{52,62} = 0.0023$ ,  $pq_{52,63} = 0.0161$ ,  
 $pq_{52,65} = 0.0046$ ;  $pq_{54,12} = 0.02277$ ,  
 $pq_{54,15} = 0.00023$ ,  $pq_{54,21} = 0.01909$ ,  
 $pq_{54,25} = 0.00391$ ,  $pq_{54,32} = 0.01886$ ,  
 $pq_{54,36} = 0.00414$ ,  $pq_{54,45} = 0.023$ ,  
 $pq_{54,51} = 0.00046$ ,  $pq_{54,52} = 0.01518$ ,  
 $pq_{54,53} = 0.00184$ ,  $pq_{54,56} = 0.00552$ ,  
 $pq_{54,62} = 0.0023$ ,  $pq_{54,63} = 0.0161$ ,  
 $pq_{54,65} = 0.0046$ ;  $pq_{56,12} = 0.23067$ ,  
 $pq_{56,15} = 0.00233$ ,  $pq_{56,21} = 0.19339$ ,  
 $pq_{56,25} = 0.03961$ ,  $pq_{56,32} = 0.19106$ ,  
 $pq_{56,36} = 0.04194$ ,  $pq_{56,45} = 0.233$ ,  
 $pq_{56,51} = 0.00466$ ,  $pq_{56,52} = 0.15378$ ,  
 $pq_{56,53} = 0.01864$ ,  $pq_{56,56} = 0.05592$ ,  
 $pq_{56,62} = 0.0233$ ,  $pq_{56,63} = 0.1631$ ,  
 $pq_{56,65} = 0.0466$ ;  $pq_{57,12} = 0.23067$ ,  
 $pq_{57,15} = 0.00233$ ,  $pq_{57,21} = 0.19339$ ,  
 $pq_{57,25} = 0.03961$ ,  $pq_{57,32} = 0.19106$ ,  
 $pq_{57,36} = 0.04194$ ,  $pq_{57,45} = 0.233$ ,  
 $pq_{57,51} = 0.00466$ ,  $pq_{57,52} = 0.15378$ ,  
 $pq_{57,53} = 0.01864$ ,  $pq_{57,56} = 0.05592$ ,  
 $pq_{57,62} = 0.0233$ ,  $pq_{57,63} = 0.1631$ ,  
 $pq_{57,65} = 0.0466$ ;  $pq_{61,12} = 0.09405$ ,  
 $pq_{61,15} = 0.00095$ ,  $pq_{61,21} = 0.07885$ ,  
 $pq_{61,25} = 0.01615$ ,  $pq_{61,32} = 0.0779$ ,  
 $pq_{61,36} = 0.0171$ ,  $pq_{61,45} = 0.095$ ,  
 $pq_{61,51} = 0.0019$ ,  $pq_{61,52} = 0.0627$ ,  
 $pq_{61,53} = 0.0076$ ,  $pq_{61,56} = 0.0228$ ,  
 $pq_{61,62} = 0.0095$ ,  $pq_{61,63} = 0.0665$ ,  
 $pq_{61,65} = 0.019$ ;  $pq_{65,12} = 0.66033$ ,  
 $pq_{65,15} = 0.00667$ ,  $pq_{65,21} = 0.55361$ ,  
 $pq_{65,25} = 0.11339$ ,  $pq_{65,32} = 0.54694$ ,  
 $pq_{65,36} = 0.12006$ ,  $pq_{65,45} = 0.667$ ,  
 $pq_{65,51} = 0.01334$ ,  $pq_{65,52} = 0.44022$ ,  
 $pq_{65,53} = 0.05336$ ,  $pq_{65,56} = 0.16008$ ,  
 $pq_{65,62} = 0.0667$ ,  $pq_{65,63} = 0.4669$ ,  
 $pq_{65,65} = 0.1334$ ;  $pq_{67,12} = 0.23562$ ,  
 $pq_{67,15} = 0.00238$ ,  $pq_{67,21} = 0.19754$ ,

$pq_{67,25} = 0.04046$ ,  $pq_{67,32} = 0.19516$ ,  
 $pq_{67,36} = 0.04284$ ,  $pq_{67,45} = 0.238$ ,  
 $pq_{67,51} = 0.00476$ ,  $pq_{67,52} = 0.15708$ ,  
 $pq_{67,53} = 0.01904$ ,  $pq_{67,56} = 0.05712$ ,  
 $pq_{67,62} = 0.0238$ ,  $pq_{67,63} = 0.1666$ ,  
 $pq_{67,65} = 0.0476$ ;  $pq_{71,12} = 0.52569$ ,  
 $pq_{71,15} = 0.00531$ ,  $pq_{71,21} = 0.44073$ ,  
 $pq_{71,25} = 0.09027$ ,  $pq_{71,32} = 0.43542$ ,  
 $pq_{71,36} = 0.09558$ ,  $pq_{71,45} = 0.531$ ,  
 $pq_{71,51} = 0.01062$ ,  $pq_{71,52} = 0.35046$ ,  
 $pq_{71,53} = 0.04248$ ,  $pq_{71,56} = 0.12744$ ,  
 $pq_{71,62} = 0.0531$ ,  $pq_{71,63} = 0.3717$ ,  
 $pq_{71,65} = 0.1062$ ;  $pq_{72,12} = 0.06138$ ,  
 $pq_{72,15} = 0.00062$ ,  $pq_{72,21} = 0.05146$ ,  
 $pq_{72,25} = 0.01054$ ,  $pq_{72,32} = 0.05084$ ,  
 $pq_{72,36} = 0.01116$ ,  $pq_{72,45} = 0.062$ ,  
 $pq_{72,51} = 0.00124$ ,  $pq_{72,52} = 0.04092$ ,  
 $pq_{72,53} = 0.00496$ ,  $pq_{72,56} = 0.01488$ ,  
 $pq_{72,62} = 0.0062$ ,  $pq_{72,63} = 0.0434$ ,  
 $pq_{72,65} = 0.0124$ ;  $pq_{75,12} = 0.21681$ ,  
 $pq_{75,15} = 0.00219$ ,  $pq_{75,21} = 0.18177$ ,  
 $pq_{75,25} = 0.03723$ ,  $pq_{75,32} = 0.17958$ ,  
 $pq_{75,36} = 0.03942$ ,  $pq_{75,45} = 0.219$ ,  
 $pq_{75,51} = 0.00438$ ,  $pq_{75,52} = 0.14454$ ,  
 $pq_{75,53} = 0.01752$ ,  $pq_{75,56} = 0.05256$ ,  
 $pq_{75,62} = 0.0219$ ,  $pq_{75,63} = 0.1533$ ,  
 $pq_{75,65} = 0.0438$ ;  $pq_{76,12} = 0.18612$ ,  
 $pq_{76,15} = 0.00188$ ,  $pq_{76,21} = 0.15604$ ,  
 $pq_{76,25} = 0.03196$ ,  $pq_{76,32} = 0.15416$ ,  
 $pq_{76,36} = 0.03384$ ,  $pq_{76,45} = 0.188$ ,  
 $pq_{76,51} = 0.00376$ ,  $pq_{76,52} = 0.12408$ ,  
 $pq_{76,53} = 0.01504$ ,  $pq_{76,56} = 0.04512$ ,  
 $pq_{76,62} = 0.0188$ ,  $pq_{76,63} = 0.1316$ ,  
 $pq_{76,65} = 0.0376$ ;

(2)

and remaining  $pq_{ij\ kl}$ ,  $i, k = 1,2,\dots,7, j, l = 1,2,\dots,16$ , are equal to 0;

- the matrix  $[N_{ij\ kl}]_{42 \times 42}$  of the mean values of the piping operation process related to climate-weather change process  $ZC^1(t)$  conditional sojourn times  $\theta_{ij\ kl}^1$ ,  $i, k = 1,2,\dots,7, j, l = 1,2,\dots,6$ , at the operation state  $zc_{ij}$ , when the next operation state is  $zc_{kl}$ , where the particular  $N_{ij\ kl}$ ,  $i, k = 1,2,\dots,7, j, l = 1,2,\dots,6$ , could be found in [3].

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from end measurement point

After assuming that the piping 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 piping operation process related to climate-weather change process  $ZC^2(t)$  [3]:  
 - the vector

$$\begin{aligned}
 & [pq_{ij}(0)]_{1 \times 42} \\
 & = [0.32198, 0.00204, 0, 0.0119, 0.00408, 0; \\
 & 0.04735, 0.0003, 0, 0.00175, 0.0006, 0; \\
 & 0, 0, 0, 0, 0, 0; 0, 0, 0, 0, 0, 0; \\
 & 0.21781, 0.00138, 0, 0.00805, 0.00276, 0; \\
 & 0.17993, 0.00114, 0, 0.00665, 0.00228, 0; \\
 & 0.17993, 0.00114, 0, 0.00665, 0.00228, 0] \quad (3)
 \end{aligned}$$

of initial probabilities of the piping operation process related to climate-weather change process  $ZC^2(t)$  staying at the initial moment  $t = 0$  at the operation states  $z_{Cij}$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 6$ ;  
 - the matrix  $[pq_{ij kl}]_{42 \times 42}$ , of the probabilities  $pq_{ij kl}$ ,  $i, k = 1, 2, \dots, 7$ ,  $j, l = 1, 2, \dots, 6$ , of transitions of the piping operation process related to climate-weather change process  $ZC^2(t)$  from the operation state  $z_{Cij}$  into the operation state  $z_{Ckl}$ , where

$$\begin{aligned}
 & pq_{12,12} = 0.00748, \quad pq_{12,14} = 0.01254, \\
 & pq_{12,15} = 0.00198, \quad pq_{12,21} = 0.022, \\
 & pq_{12,41} = 0.01298, \quad pq_{12,42} = 0.0011, \\
 & pq_{12,45} = 0.00792, \quad pq_{12,54} = 0.022; \\
 & pq_{13,12} = 0.00748, \quad pq_{13,14} = 0.01254, \\
 & pq_{13,15} = 0.00198, \quad pq_{13,21} = 0.022, \\
 & pq_{13,41} = 0.01298, \quad pq_{13,42} = 0.0011, \\
 & pq_{13,45} = 0.00792, \quad pq_{13,54} = 0.022; \\
 & pq_{15,12} = 0.18156, \quad pq_{15,14} = 0.30438, \\
 & pq_{15,15} = 0.04806, \quad pq_{15,21} = 0.534, \\
 & pq_{15,41} = 0.31506, \quad pq_{15,42} = 0.0267, \\
 & pq_{15,45} = 0.19224, \quad pq_{15,54} = 0.534; \\
 & pq_{16,12} = 0.03774, \quad pq_{16,14} = 0.06327, \\
 & pq_{16,15} = 0.00999, \quad pq_{16,21} = 0.111, \\
 & pq_{16,41} = 0.06549, \quad pq_{16,42} = 0.00555, \\
 & pq_{16,45} = 0.03996, \quad pq_{16,54} = 0.111; \\
 & pq_{17,12} = 0.10574, \quad pq_{17,14} = 0.17727, \\
 & pq_{17,15} = 0.02799, \quad pq_{17,21} = 0.311, \\
 & pq_{17,41} = 0.18349, \quad pq_{17,42} = 0.01555, \\
 & pq_{17,45} = 0.11196, \quad pq_{17,54} = 0.311; \\
 & pq_{21,12} = 0.068, \quad pq_{21,14} = 0.114, \\
 & pq_{21,15} = 0.018, \quad pq_{21,21} = 0.2, \quad pq_{21,41} = 0.118, \\
 & pq_{21,42} = 0.01, \quad pq_{21,45} = 0.072, \quad pq_{21,54} = 0.2; \\
 & pq_{27,12} = 0.272, \quad pq_{27,14} = 0.456, \\
 & pq_{27,15} = 0.072, \quad pq_{27,21} = 0.8, \quad pq_{27,41} = 0.472, \\
 & pq_{27,42} = 0.04, \quad pq_{27,45} = 0.288, \quad pq_{27,54} = 0.8; \\
 & pq_{31,12} = 0.34, \quad pq_{31,14} = 0.57, \quad pq_{31,15} = 0.09, \\
 & pq_{31,21} = 1, \quad pq_{31,41} = 0.59, \quad pq_{31,42} = 0.05, \\
 & pq_{31,45} = 0.36, \quad pq_{31,54} = 1; \quad pq_{47,12} = 0.34, \\
 & pq_{47,14} = 0.57, \quad pq_{47,15} = 0.09, \quad pq_{47,21} = 1, \\
 & pq_{47,41} = 0.59, \quad pq_{47,42} = 0.05, \quad pq_{47,45} = 0.36, \\
 & pq_{47,54} = 1; \quad pq_{51,12} = 0.16592, \\
 & pq_{51,14} = 0.27816, \quad pq_{51,15} = 0.04392,
 \end{aligned}$$

$$\begin{aligned}
 & pq_{51,21} = 0.488, \quad pq_{51,41} = 0.28792, \\
 & pq_{51,42} = 0.0244, \quad pq_{51,45} = 0.17568, \\
 & pq_{51,54} = 0.488; \quad pq_{52,12} = 0.00782, \\
 & pq_{52,14} = 0.01311, \quad pq_{52,15} = 0.00207, \\
 & pq_{52,21} = 0.023, \quad pq_{52,41} = 0.01357, \\
 & pq_{52,42} = 0.00115, \quad pq_{52,45} = 0.00828, \\
 & pq_{52,54} = 0.023; \quad pq_{54,12} = 0.00782, \\
 & pq_{54,14} = 0.01311, \quad pq_{54,15} = 0.00207, \\
 & pq_{54,21} = 0.023, \quad pq_{54,41} = 0.01357, \\
 & pq_{54,42} = 0.00115, \quad pq_{54,45} = 0.00828, \\
 & pq_{54,54} = 0.023; \quad pq_{56,12} = 0.07922, \\
 & pq_{56,14} = 0.13281, \quad pq_{56,15} = 0.02097, \\
 & pq_{56,21} = 0.233, \quad pq_{56,41} = 0.13747, \\
 & pq_{56,42} = 0.01165, \quad pq_{56,45} = 0.08388, \\
 & pq_{56,54} = 0.233; \quad pq_{57,12} = 0.07922, \\
 & pq_{57,14} = 0.13281, \quad pq_{57,15} = 0.02097, \\
 & pq_{57,21} = 0.233, \quad pq_{57,41} = 0.13747, \\
 & pq_{57,42} = 0.01165, \quad pq_{57,45} = 0.08388, \\
 & pq_{57,54} = 0.233; \quad pq_{61,12} = 0.0323, \\
 & pq_{61,14} = 0.05415, \quad pq_{61,15} = 0.00855, \\
 & pq_{61,21} = 0.095, \quad pq_{61,41} = 0.05605, \\
 & pq_{61,42} = 0.00475, \quad pq_{61,45} = 0.0342, \\
 & pq_{61,54} = 0.095; \quad pq_{65,12} = 0.22678, \\
 & pq_{65,14} = 0.38019, \quad pq_{65,15} = 0.06003, \\
 & pq_{65,21} = 0.667, \quad pq_{65,41} = 0.39353, \\
 & pq_{65,42} = 0.03335, \quad pq_{65,45} = 0.24012, \\
 & pq_{65,54} = 0.667; \quad pq_{67,12} = 0.08092, \\
 & pq_{67,14} = 0.13566, \quad pq_{67,15} = 0.02142, \\
 & pq_{67,21} = 0.238, \quad pq_{67,41} = 0.14042, \\
 & pq_{67,42} = 0.0119, \quad pq_{67,45} = 0.08568, \\
 & pq_{67,54} = 0.238; \quad pq_{71,12} = 0.18054, \\
 & pq_{71,14} = 0.30267, \quad pq_{71,15} = 0.04779, \\
 & pq_{71,21} = 0.531, \quad pq_{71,41} = 0.31329, \\
 & pq_{71,42} = 0.02655, \quad pq_{71,45} = 0.19116, \\
 & pq_{71,54} = 0.531; \quad pq_{72,12} = 0.02108, \\
 & pq_{72,14} = 0.03534, \quad pq_{72,15} = 0.00558, \\
 & pq_{72,21} = 0.062, \quad pq_{72,41} = 0.03658, \\
 & pq_{72,42} = 0.0031, \quad pq_{72,45} = 0.02232, \\
 & pq_{72,54} = 0.062; \quad pq_{75,12} = 0.07446, \\
 & pq_{75,14} = 0.12483, \quad pq_{75,15} = 0.01971, \\
 & pq_{75,21} = 0.219, \quad pq_{75,41} = 0.12921, \\
 & pq_{75,42} = 0.01095, \quad pq_{75,45} = 0.07884, \\
 & pq_{75,54} = 0.219; \quad pq_{76,12} = 0.06392, \\
 & pq_{76,14} = 0.10716, \quad pq_{76,15} = 0.01692, \\
 & pq_{76,21} = 0.188, \quad pq_{76,41} = 0.11092, \\
 & pq_{76,42} = 0.0094, \quad pq_{76,45} = 0.06768, \\
 & pq_{76,54} = 0.188; \quad (4)
 \end{aligned}$$

and remaining  $pq_{ij kl}$ ,  $i, k = 1, 2, \dots, 7$ ,  $j, l = 1, 2, \dots, 16$ , are equal to 0;

- the matrix  $[N_{ij kl}]_{42 \times 42}$  of the mean values of the piping operation process related to climate-weather change process  $ZC^2(t)$  conditional sojourn times  $\theta_{ij kl}^2$ ,  $i, k = 1, 2, \dots, 7$ ,  $j, l = 1, 2, \dots, 6$ , at the operation

state  $z_{ij}$ , when the next operation state is  $z_{kl}$ , where the particular  $N_{ij\ kl}$ ,  $i, k = 1, 2, \dots, 7$ ,  $j, l = 1, 2, \dots, 6$ , could be found in [3].

Piping operation process related to climate-weather change process for piping Baltic seaside land operating area - data coming from land measurement point

After assuming that the piping 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 piping operation process related to climate-weather change process  $ZC^3(t)$  [3]:

- the vector

$$\begin{aligned}
 & [pq_{ij}(0)]_{1 \times 12} \\
 & = [0.00408, 0.04012, 0, 0, 0, 0.26622, 0.0119, \\
 & 0, 0, 0, 0.01734, 0, 0, 0, 0, 0.000600, 0.0059, \\
 & 0, 0, 0, 0.03915, 0.00175, 0, 0, 0, 0.00255, 0, 0, \\
 & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\
 & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00276, \\
 & 0.02714, 0, 0, 0, 0.18009, 0.00805, 0, 0, 0, \\
 & 0.01173, 0, 0, 0, 0, 0.00228, 0.02242, 0, 0, 0, \\
 & 0.14877, 0.00665, 0, 0, 0, 0.00969, 0, 0, 0, 0, \\
 & 0, 0.00228, 0.02242, 0, 0, 0, 0.14877, 0.00665, \\
 & 0, 0, 0, 0.00969, 0, 0, 0, 0, 0] \quad (5)
 \end{aligned}$$

of initial probabilities of the piping operation process related to climate-weather change process  $ZC^3(t)$  staying at the initial moment  $t = 0$  at the operation states  $z_{ij}$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 16$ ;

- the matrix  $[pq_{ij\ kl}]_{12 \times 12}$ , of the probabilities  $pq_{ij\ kl}$ ,  $i, k = 1, 2, \dots, 7$ ,  $j, l = 1, 2, \dots, 16$ , of transitions of the piping operation process related to climate-weather change process  $ZC^3(t)$  from the operation state  $z_{ij}$  into the the operation state  $z_{kl}$ , where

$$\begin{aligned}
 & pq_{1\ 2, 1\ 2} = 0.022, \quad pq_{1\ 2, 2\ 1} = 0.0022, \\
 & pq_{1\ 2, 2\ 6} = 0.0198, \quad pq_{1\ 2, 6\ 2} = 0.00396, \\
 & pq_{1\ 2, 6\ 7} = 0.00484, \quad pq_{1\ 2, 6\ 10} = 0.01034, \\
 & pq_{1\ 2, 6\ 11} = 0.00286, \quad pq_{1\ 2, 7\ 6} = 0.01584, \\
 & pq_{1\ 2, 7\ 11} = 0.00616, \quad pq_{1\ 2, 10\ 6} = 0.0121, \\
 & pq_{1\ 2, 10\ 7} = 0.00044, \quad pq_{1\ 2, 10\ 11} = 0.00946, \\
 & pq_{1\ 2, 11\ 6} = 0.0044, \quad pq_{1\ 2, 11\ 7} = 0.01518, \\
 & pq_{1\ 2, 11\ 10} = 0.00242; \quad pq_{1\ 3, 1\ 2} = 0.022, \\
 & pq_{1\ 3, 2\ 1} = 0.0022, \quad pq_{1\ 3, 2\ 6} = 0.0198, \\
 & pq_{1\ 3, 6\ 2} = 0.00396, \quad pq_{1\ 3, 6\ 7} = 0.00484, \\
 & pq_{1\ 3, 6\ 10} = 0.01034, \quad pq_{1\ 3, 6\ 11} = 0.00286, \\
 & pq_{1\ 3, 7\ 6} = 0.01584, \quad pq_{1\ 3, 7\ 11} = 0.00616, \\
 & pq_{1\ 3, 10\ 6} = 0.0121, \quad pq_{1\ 3, 10\ 7} = 0.00044, \\
 & pq_{1\ 3, 10\ 11} = 0.00946, \quad pq_{1\ 3, 11\ 6} = 0.0044, \\
 & pq_{1\ 3, 11\ 7} = 0.01518, \quad pq_{1\ 3, 11\ 10} = 0.00242; \\
 & pq_{1\ 5, 1\ 2} = 0.534, \quad pq_{1\ 5, 2\ 1} = 0.0534, \\
 & pq_{1\ 5, 2\ 6} = 0.4806, \quad pq_{1\ 5, 6\ 2} = 0.09612,
 \end{aligned}$$

$$\begin{aligned}
 & pq_{1\ 5, 6\ 7} = 0.11748, \quad pq_{1\ 5, 6\ 10} = 0.25098, \\
 & pq_{1\ 5, 6\ 11} = 0.06942, \quad pq_{1\ 5, 7\ 6} = 0.38448, \\
 & pq_{1\ 5, 7\ 11} = 0.14952, \quad pq_{1\ 5, 10\ 6} = 0.2937, \\
 & pq_{1\ 5, 10\ 7} = 0.01068, \quad pq_{1\ 5, 10\ 11} = 0.22962, \\
 & pq_{1\ 5, 11\ 6} = 0.1068, \quad pq_{1\ 5, 11\ 7} = 0.36846, \\
 & pq_{1\ 5, 11\ 10} = 0.05874; \quad pq_{1\ 6, 1\ 2} = 0.111, \\
 & pq_{1\ 6, 2\ 1} = 0.0111, \quad pq_{1\ 6, 2\ 6} = 0.0999, \\
 & pq_{1\ 6, 6\ 2} = 0.01998, \quad pq_{1\ 6, 6\ 7} = 0.02442, \\
 & pq_{1\ 6, 6\ 10} = 0.05217, \quad pq_{1\ 6, 6\ 11} = 0.01443, \\
 & pq_{1\ 6, 7\ 6} = 0.07992, \quad pq_{1\ 6, 7\ 11} = 0.03108, \\
 & pq_{1\ 6, 10\ 6} = 0.06105, \quad pq_{1\ 6, 10\ 7} = 0.00222, \\
 & pq_{1\ 6, 10\ 11} = 0.04773, \quad pq_{1\ 6, 11\ 6} = 0.0222, \\
 & pq_{1\ 6, 11\ 7} = 0.07659, \quad pq_{1\ 6, 11\ 10} = 0.01221; \\
 & pq_{1\ 7, 1\ 2} = 0.311, \quad pq_{1\ 7, 2\ 1} = 0.0311, \\
 & pq_{1\ 7, 2\ 6} = 0.2799, \quad pq_{1\ 7, 6\ 2} = 0.05598, \\
 & pq_{1\ 7, 6\ 7} = 0.06842, \quad pq_{1\ 7, 6\ 10} = 0.14617, \\
 & pq_{1\ 7, 6\ 11} = 0.04043, \quad pq_{1\ 7, 7\ 6} = 0.22392, \\
 & pq_{1\ 7, 7\ 11} = 0.08708, \quad pq_{1\ 7, 10\ 6} = 0.17105, \\
 & pq_{1\ 7, 10\ 7} = 0.00622, \quad pq_{1\ 7, 10\ 11} = 0.13373, \\
 & pq_{1\ 7, 11\ 6} = 0.0622, \quad pq_{1\ 7, 11\ 7} = 0.21459, \\
 & pq_{1\ 7, 11\ 10} = 0.03421; \quad pq_{2\ 1, 1\ 2} = 0.2, \\
 & pq_{2\ 1, 2\ 1} = 0.02, \quad pq_{2\ 1, 2\ 6} = 0.18, \quad pq_{2\ 1, 6\ 2} = 0.036, \\
 & pq_{2\ 1, 6\ 7} = 0.044, \quad pq_{2\ 1, 6\ 10} = 0.094, \\
 & pq_{2\ 1, 6\ 11} = 0.026, \quad pq_{2\ 1, 7\ 6} = 0.144, \\
 & pq_{2\ 1, 7\ 11} = 0.056, \quad pq_{2\ 1, 10\ 6} = 0.11, \\
 & pq_{2\ 1, 10\ 7} = 0.004, \quad pq_{2\ 1, 10\ 11} = 0.086, \\
 & pq_{2\ 1, 11\ 6} = 0.04, \quad pq_{2\ 1, 11\ 7} = 0.138, \\
 & pq_{2\ 1, 11\ 10} = 0.022; \quad pq_{2\ 7, 1\ 2} = 0.8, \quad pq_{2\ 7, 2\ 1} = 0.08, \\
 & pq_{2\ 7, 2\ 6} = 0.72, \quad pq_{2\ 7, 6\ 2} = 0.144, \\
 & pq_{2\ 7, 6\ 7} = 0.176, \quad pq_{2\ 7, 6\ 10} = 0.376, \\
 & pq_{2\ 7, 6\ 11} = 0.104, \quad pq_{2\ 7, 7\ 6} = 0.576, \\
 & pq_{2\ 7, 7\ 11} = 0.224, \quad pq_{2\ 7, 10\ 6} = 0.44, \\
 & pq_{2\ 7, 10\ 7} = 0.016, \quad pq_{2\ 7, 10\ 11} = 0.344, \\
 & pq_{2\ 7, 11\ 6} = 0.16, \quad pq_{2\ 7, 11\ 7} = 0.552, \\
 & pq_{2\ 7, 11\ 10} = 0.088; \quad pq_{3\ 1, 1\ 2} = 1, \quad pq_{3\ 1, 2\ 1} = 0.1, \\
 & pq_{3\ 1, 2\ 6} = 0.9, \quad pq_{3\ 1, 6\ 2} = 0.18, \quad pq_{3\ 1, 6\ 7} = 0.22, \\
 & pq_{3\ 1, 6\ 10} = 0.47, \quad pq_{3\ 1, 6\ 11} = 0.13, \quad pq_{3\ 1, 7\ 6} = 0.72, \\
 & pq_{3\ 1, 7\ 11} = 0.28, \quad pq_{3\ 1, 10\ 6} = 0.55, \\
 & pq_{3\ 1, 10\ 7} = 0.02, \quad pq_{3\ 1, 10\ 11} = 0.43, \quad pq_{3\ 1, 11\ 6} = 0.2, \\
 & pq_{3\ 1, 11\ 7} = 0.69, \quad pq_{3\ 1, 11\ 10} = 0.11; \quad pq_{4\ 7, 1\ 2} = 1, \\
 & pq_{4\ 7, 2\ 1} = 0.1, \quad pq_{4\ 7, 2\ 6} = 0.9, \quad pq_{4\ 7, 6\ 2} = 0.18, \\
 & pq_{4\ 7, 6\ 7} = 0.22, \quad pq_{4\ 7, 6\ 10} = 0.47, \quad pq_{4\ 7, 6\ 11} = 0.13, \\
 & pq_{4\ 7, 7\ 6} = 0.72, \quad pq_{4\ 7, 7\ 11} = 0.28, \quad pq_{4\ 7, 10\ 6} = 0.55, \\
 & pq_{4\ 7, 10\ 7} = 0.02, \quad pq_{4\ 7, 10\ 11} = 0.43, \quad pq_{4\ 7, 11\ 6} = 0.2, \\
 & pq_{4\ 7, 11\ 7} = 0.69, \quad pq_{4\ 7, 11\ 10} = 0.11; \\
 & pq_{5\ 1, 1\ 2} = 0.488, \quad pq_{5\ 1, 2\ 1} = 0.0488, \\
 & pq_{5\ 1, 2\ 6} = 0.4392, \quad pq_{5\ 1, 6\ 2} = 0.08784, \\
 & pq_{5\ 1, 6\ 7} = 0.10736, \quad pq_{5\ 1, 6\ 10} = 0.22936, \\
 & pq_{5\ 1, 6\ 11} = 0.06344, \quad pq_{5\ 1, 7\ 6} = 0.35136, \\
 & pq_{5\ 1, 7\ 11} = 0.13664, \quad pq_{5\ 1, 10\ 6} = 0.2684, \\
 & pq_{5\ 1, 10\ 7} = 0.00976, \quad pq_{5\ 1, 10\ 11} = 0.20984, \\
 & pq_{5\ 1, 11\ 6} = 0.0976, \quad pq_{5\ 1, 11\ 7} = 0.33672, \\
 & pq_{5\ 1, 11\ 10} = 0.05368; \quad pq_{5\ 2, 1\ 2} = 0.023, \\
 & pq_{5\ 2, 2\ 1} = 0.0023, \quad pq_{5\ 2, 2\ 6} = 0.0207, \\
 & pq_{5\ 2, 6\ 2} = 0.00414, \quad pq_{5\ 2, 6\ 7} = 0.00506, \\
 & pq_{5\ 2, 6\ 10} = 0.01081, \quad pq_{5\ 2, 6\ 11} = 0.00299,
 \end{aligned}$$

$$\begin{aligned}
 & pq_{5,2,76} = 0.01656, \quad pq_{5,2,711} = 0.00644, \\
 & pq_{5,2,106} = 0.01265, \quad pq_{5,2,107} = 0.00046, \\
 & pq_{5,2,1011} = 0.00989, \quad pq_{5,2,116} = 0.0046, \\
 & pq_{5,2,117} = 0.01587, \quad pq_{5,2,1110} = 0.00253; \\
 & pq_{5,4,12} = 0.023, \quad pq_{5,4,21} = 0.0023, \\
 & pq_{5,4,26} = 0.0207, \quad pq_{5,4,62} = 0.00414, \\
 & pq_{5,4,67} = 0.00506, \quad pq_{5,4,610} = 0.01081, \\
 & pq_{5,4,611} = 0.00299, \quad pq_{5,4,76} = 0.01656, \\
 & pq_{5,4,711} = 0.00644, \quad pq_{5,4,106} = 0.01265, \\
 & pq_{5,4,107} = 0.00046, \quad pq_{5,4,1011} = 0.00989, \\
 & pq_{5,4,116} = 0.0046, \quad pq_{5,4,117} = 0.01587, \\
 & pq_{5,4,1110} = 0.00253; \quad pq_{5,6,12} = 0.233, \\
 & pq_{5,6,21} = 0.0233, \quad pq_{5,6,26} = 0.2097, \\
 & pq_{5,6,62} = 0.04194, \quad pq_{5,6,67} = 0.05126, \\
 & pq_{5,6,610} = 0.10951, \quad pq_{5,6,611} = 0.03029, \\
 & pq_{5,6,76} = 0.16776, \quad pq_{5,6,711} = 0.06524, \\
 & pq_{5,6,106} = 0.12815, \quad pq_{5,6,107} = 0.00466, \\
 & pq_{5,6,1011} = 0.10019, \quad pq_{5,6,116} = 0.0466, \\
 & pq_{5,6,117} = 0.16077, \quad pq_{5,6,1110} = 0.02563; \\
 & pq_{5,7,12} = 0.233, \quad pq_{5,7,21} = 0.0233, \\
 & pq_{5,7,26} = 0.2097, \quad pq_{5,7,62} = 0.04194, \\
 & pq_{5,7,67} = 0.05126, \quad pq_{5,7,610} = 0.10951, \\
 & pq_{5,7,611} = 0.03029, \quad pq_{5,7,76} = 0.16776, \\
 & pq_{5,7,711} = 0.06524, \quad pq_{5,7,106} = 0.12815, \\
 & pq_{5,7,107} = 0.00466, \quad pq_{5,7,1011} = 0.10019, \\
 & pq_{5,7,116} = 0.0466, \quad pq_{5,7,117} = 0.16077, \\
 & pq_{5,7,1110} = 0.02563; \quad pq_{6,1,12} = 0.095, \\
 & pq_{6,1,21} = 0.0095, \quad pq_{6,1,26} = 0.0855, \\
 & pq_{6,1,62} = 0.0171, \quad pq_{6,1,67} = 0.0209, \\
 & pq_{6,1,610} = 0.04465, \quad pq_{6,1,611} = 0.01235, \\
 & pq_{6,1,76} = 0.0684, \quad pq_{6,1,711} = 0.0266, \\
 & pq_{6,1,106} = 0.05225, \quad pq_{6,1,107} = 0.0019, \\
 & pq_{6,1,1011} = 0.04085, \quad pq_{6,1,116} = 0.019, \\
 & pq_{6,1,117} = 0.06555, \quad pq_{6,1,1110} = 0.01045; \\
 & pq_{6,5,12} = 0.667, \quad pq_{6,5,21} = 0.0667, \\
 & pq_{6,5,26} = 0.6003, \quad pq_{6,5,62} = 0.12006, \\
 & pq_{6,5,67} = 0.14674, \quad pq_{6,5,610} = 0.31349, \\
 & pq_{6,5,611} = 0.08671, \quad pq_{6,5,76} = 0.48024, \\
 & pq_{6,5,711} = 0.18676, \quad pq_{6,5,106} = 0.36685, \\
 & pq_{6,5,107} = 0.01334, \quad pq_{6,5,1011} = 0.28681, \\
 & pq_{6,5,116} = 0.1334, \quad pq_{6,5,117} = 0.46023, \\
 & pq_{6,5,1110} = 0.07337; \quad pq_{6,7,12} = 0.238, \\
 & pq_{6,7,21} = 0.0238, \quad pq_{6,7,26} = 0.2142, \\
 & pq_{6,7,62} = 0.04284, \quad pq_{6,7,67} = 0.05236, \\
 & pq_{6,7,610} = 0.11186, \quad pq_{6,7,611} = 0.03094, \\
 & pq_{6,7,76} = 0.17136, \quad pq_{6,7,711} = 0.06664, \\
 & pq_{6,7,106} = 0.1309, \quad pq_{6,7,107} = 0.00476, \\
 & pq_{6,7,1011} = 0.10234, \quad pq_{6,7,116} = 0.0476, \\
 & pq_{6,7,117} = 0.16422, \quad pq_{6,7,1110} = 0.02618; \\
 & pq_{7,1,12} = 0.531, \quad pq_{7,1,21} = 0.0531, \\
 & pq_{7,1,26} = 0.4779, \quad pq_{7,1,62} = 0.09558, \\
 & pq_{7,1,67} = 0.11682, \quad pq_{7,1,610} = 0.24957, \\
 & pq_{7,1,611} = 0.06903, \quad pq_{7,1,76} = 0.38232, \\
 & pq_{7,1,711} = 0.14868, \quad pq_{7,1,106} = 0.29205, \\
 & pq_{7,1,107} = 0.01062, \quad pq_{7,1,1011} = 0.22833,
 \end{aligned}$$

$$\begin{aligned}
 & pq_{7,1,116} = 0.1062, \quad pq_{7,1,117} = 0.36639, \\
 & pq_{7,1,1110} = 0.05841; \quad pq_{7,2,12} = 0.062, \\
 & pq_{7,2,21} = 0.0062, \quad pq_{7,2,26} = 0.0558, \\
 & pq_{7,2,62} = 0.01116, \quad pq_{7,2,67} = 0.01364, \\
 & pq_{7,2,610} = 0.02914, \quad pq_{7,2,611} = 0.00806, \\
 & pq_{7,2,76} = 0.04464, \quad pq_{7,2,711} = 0.01736, \\
 & pq_{7,2,106} = 0.0341, \quad pq_{7,2,107} = 0.00124, \\
 & pq_{7,2,1011} = 0.02666, \quad pq_{7,2,116} = 0.0124, \\
 & pq_{7,2,117} = 0.04278, \quad pq_{7,2,1110} = 0.00682; \\
 & pq_{7,5,12} = 0.219, \quad pq_{7,5,21} = 0.0219, \\
 & pq_{7,5,26} = 0.1971, \quad pq_{7,5,62} = 0.03942, \\
 & pq_{7,5,67} = 0.04818, \quad pq_{7,5,610} = 0.10293, \\
 & pq_{7,5,611} = 0.02847, \quad pq_{7,5,76} = 0.15768, \\
 & pq_{7,5,711} = 0.06132, \quad pq_{7,5,106} = 0.12045, \\
 & pq_{7,5,107} = 0.00438, \quad pq_{7,5,1011} = 0.09417, \\
 & pq_{7,5,116} = 0.0438, \quad pq_{7,5,117} = 0.15111, \\
 & pq_{7,5,1110} = 0.02409; \quad pq_{7,6,12} = 0.188, \\
 & pq_{7,6,21} = 0.0188, \quad pq_{7,6,26} = 0.1692, \\
 & pq_{7,6,62} = 0.03384, \quad pq_{7,6,67} = 0.04136, \\
 & pq_{7,6,610} = 0.08836, \quad pq_{7,6,611} = 0.02444, \\
 & pq_{7,6,76} = 0.13536, \quad pq_{7,6,711} = 0.05264, \\
 & pq_{7,6,106} = 0.1034, \quad pq_{7,6,107} = 0.00376, \\
 & pq_{7,6,1011} = 0.08084, \quad pq_{7,6,116} = 0.0376, \\
 & pq_{7,6,117} = 0.12972, \quad pq_{7,6,1110} = 0.02068; \quad (6)
 \end{aligned}$$

and remaining  $pq_{ij\ kl}$ ,  $i, k = 1,2,\dots,7, j, l = 1,2,\dots,16$ , are equal to 0;

- the matrix  $[N_{ij\ kl}]_{112 \times 112}$  of the mean values of the piping operation process related to climate-weather change process  $ZC^3(t)$  conditional sojourn times  $\theta C_{ij\ kl}^3$ ,  $i, k = 1,2,\dots,7, j, l = 1,2,\dots,16$ , at the operation state  $zc_{ij}$ , when the next operation state is  $zc_{kl}$ , where the particular  $N_{ij\ kl}$ ,  $i, k = 1,2,\dots,7, j, l = 1,2,\dots,6$ , could be found in [3].

### 3. Piping operation process related to climate-weather change prediction characteristics

The piping operation process related to climate-weather change is defined in [3]. Considering these results and assuming that we have identified the unknown parameters of the piping operation process related to climate-weather change, we can predict basic characteristics of this process.

#### 3.1. Transient probabilities of piping operation process related to climate-weather change

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from initial, middle east, middle west measurement points

The limit values of the piping operation process related to climate-weather change process  $ZC^1(t)$  transient probabilities  $pq_{ij}$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 6$ , at the particular operation states  $zc_{ij}$ , are given in the vector [3]:

$$[pq_{ij}]_{1 \times 42} \cong [0.355895, 0.034365, 0.000395, 0, 0.00316, 0.001185, 0.05406, 0.00522, 0.00006, 0, 0.00048, 0.00018, 0.002703, 0.000261, 0.000003, 0, 0.000024, 0.000009, 0.001802, 0.000174, 0.000002, 0, 0.000016, 0.000006, 0.1802, 0.0174, 0.0002, 0, 0.0016, 0.0006, 0.052258, 0.005046, 0.000058, 0, 0.000464, 0.000174, 0.254082, 0.024534, 0.000282, 0, 0.002256, 0.000846]; \quad (7)$$

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from end measurement point

The limit values of the piping operation process related to climate-weather change process  $ZC^2(t)$  transient probabilities  $pq_{ij}$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 6$ , at the particular operation states  $zc_{ij}$ , are given in the vector [3]:

$$[pq_{ij}]_{1 \times 42} \cong [0.378805, 0.002765, 0, 0.008295, 0.005135, 0, 0.05754, 0.00042, 0, 0.00126, 0.00078, 0, 0.002877, 0.000021, 0, 0.000063, 0.000039, 0, 0.001918, 0.000014, 0, 0.000042, 0.000026, 0, 0.191800, 0.001400, 0, 0.004200, 0.002600, 0, 0.055622, 0.000406, 0, 0.001218, 0.000754, 0, 0.270438, 0.001974, 0, 0.005922, 0.003666, 0]; \quad (8)$$

Piping operation process related to climate-weather change process for piping Baltic seaside land operating area - data coming from land measurement point

The limit values of the piping operation process related to climate-weather change process  $ZC^3(t)$  transient probabilities  $pq_{ij}$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 16$ , at the particular operation states  $zc_{ij}$ , are given in the vector [3]:

$$[pq_{ij}]_{1 \times 112} \cong [0.000395, 0.01501, 0, 0, 0, 0.34286, 0.012245, 0, 0, 0.004345, 0.020145, 0, 0, 0, 0, 0, 0.000060, 0.00228, 0, 0, 0, 0.05208, 0.00186, 0, 0, 0.00066, 0.00306, 0, 0, 0, 0, 0.000003, 0.000114, 0, 0, 0, 0.002604, 0.000093, 0, 0, 0.000033, 0.000153, 0, 0, 0, 0, 0.000002,$$

$$0.000076, 0, 0, 0, 0.001736, 0.000062, 0, 0, 0.000022, 0.000102, 0, 0, 0, 0, 0.0002, 0.0076, 0, 0, 0, 0.1736, 0.0062, 0, 0, 0.0022, 0.0102, 0, 0, 0, 0, 0.000058, 0.002204, 0, 0, 0, 0.050344, 0.001798, 0, 0, 0.000638, 0.002958, 0, 0, 0, 0, 0.000282, 0.010716, 0, 0, 0, 0.244776, 0.008742, 0, 0, 0.003102, 0.014382, 0, 0, 0, 0, 0]. \quad (9)$$

**3.2. Total sojourn times of piping operation process related to climate-weather change**

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from initial, middle east, middle west measurement points

The expected values of the total sojourn times  $\theta C_{ij}^1$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 6$ , of the piping 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) [3]:

$$[\hat{M}\hat{N}_{ij}^1]_{1 \times 42} = [E[\theta C_{ij}^1]]_{1 \times 42} \cong [10.32095, 0.996585, 0.011455, 0, 0.09164, 0.034365, 1.56774, 0.15138, 0.00174, 0, 0.01392, 0.00522, 0.078387, 0.007569, 0.000087, 0, 0.000696, 0.000261, 0.052258, 0.005046, 0.000058, 0, 0.000464, 0.000174, 5.2258, 0.5046, 0.0058, 0, 0.0464, 0.0174, 1.515482, 0.146334, 0.001682, 0, 0.013456, 0.005046, 7.368378, 0.711486, 0.008178, 0, 0.065424, 0.024534]; \quad (10)$$

Piping operation process related to climate-weather change process for piping under water Baltic Sea operating area - data coming from end measurement point

The expected values of the total sojourn times  $\theta C_{ij}^2$ ,  $i = 1, 2, \dots, 7$ ,  $j = 1, 2, \dots, 6$ , of the piping 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) [3]:

$$[\hat{M}\hat{N}_{ij}^2]_{1 \times 42} = [E[\theta C_{ij}^2]]_{1 \times 42} \cong [10.98535, 0.080185, 0, 0.240555, 0.148915, 0, 1.66866, 0.01218, 0, 0.03654, 0.02262, 0, 0.083433, 0.000609, 0, 0.001827, 0.001131, 0, 0.055622, 0.000406, 0, 0.001218, 0.000754, 0, 5.5622, 0.0406, 0, 0.1218, 0.0754, 0, 1.613038, 0.011774, 0,$$

0.035322, 0.021866, 0, 7.842702, 0.057246, 0,  
 0.171738, 0.106314, 0]; (11)

Piping operation process related to climate-weather change process for piping Baltic seaside land operating area - data coming from land measurement point

The expected values of the total sojourn times  $\theta C_{ij}^3$ ,  $i = 1,2,\dots,7$ ,  $j = 1,2,\dots,16$ , of the piping 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) [3]:

$[\hat{M}\hat{N}_{ij}^3]_{1 \times 112} = [E[\theta C_{ij}^3]]_{1 \times 112} \cong [0.011455, 0.43529,$   
 $0, 0, 0, 9.94294, 0.355105, 0, 0, 0.126005,$   
 $0.584205, 0, 0, 0, 0, 0.00174, 0.06612, 0, 0,$   
 $0, 1.51032, 0.05394, 0, 0, 0.01914, 0.08874, 0,$   
 $0, 0, 0, 0.000087, 0.003306, 0, 0, 0, 0.075516,$   
 $0.002697, 0, 0, 0.000957, 0.004437, 0, 0, 0, 0,$   
 $0.000058, 0.002204, 0, 0, 0, 0.050344, 0.001798,$   
 $0, 0, 0.000638, 0.002958, 0, 0, 0, 0, 0.0058,$   
 $0.2204, 0, 0, 0, 5.0344, 0.1798, 0, 0, 0.0638,$   
 $0.2958, 0, 0, 0, 0, 0.001682, 0.063916, 0, 0, 0,$   
 $1.459976, 0.052142, 0, 0, 0.018502, 0.085782, 0,$   
 $0, 0, 0, 0, 0.008178, 0.310764, 0, 0, 0, 7.098504,$   
 $0.253518, 0, 0, 0.089958, 0.417078, 0, 0, 0, 0, 0].(12)$

**4. Conclusions**

The probabilistic model of the critical infrastructure operation process related to climate-weather change presented in [7] was applied to identification and prediction of this process for the port piping transportation system. 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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