Journal of Polish Safety and Reliability Association
Summer Safety and Reliability Seminars, Volume 8, Number 2, 2017

Kołowrocki Krzysztof
ORCID ID: 0000-0002-4836-4976

Soszyńska-Budny Joanna
ORCID ID: 0000-0003-1525-9392

Torbicki Mateusz
ORCID ID: 000-0003-4182-1932
Gdynia Maritime University, Gdynia, Poland

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 $ZC^1(t)$, $t \in <0,+\infty)$, can take $vw^1 = 7 \cdot 6 = 42$ different operation states $zc_{1\,1}, zc_{1\,2}, \ldots, zc_{7\,6}$;

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 $ZC^2(t)$, $t \in <0,+\infty)$, can take $vw^2 = 7 \cdot 6 = 42$ different operation states $zc_{1\,1}, zc_{1\,2}, \ldots, zc_{7\,6}$;

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 $ZC^3(t)$, $t \in <0,+\infty)$, can take $vw^3 = 7 \cdot 16 = 112$ different operation states $zc_{1\,1}, zc_{1\,2}, \ldots, zc_{7\,16}$.

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

$[pq_{ij}(0)]_{1x42}$
= [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)

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}, $i = 1,2,\ldots,7$, $j = 1,2,\ldots,6$;

- the matrix $[pq_{ij\,kl}]_{42x42}$, of the probabilities $pq_{ij\,kl}$, i, $k = 1,2,\ldots,7$, $j,l = 1,2,\ldots,6$, 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

$pq_{1\,2,\,1\,2} = 0.02178$, $pq_{1\,2,\,1\,5} = 0.00022$,
$pq_{1\,2,\,2\,1} = 0.01826$, $pq_{1\,2,\,2\,5} = 0.00374$,
$pq_{1\,2,\,3\,2} = 0.01804$, $pq_{1\,2,\,3\,6} = 0.00396$,
$pq_{1\,2,\,4\,5} = 0.022$, $pq_{1\,2,\,5\,1} = 0.00044$,
$pq_{1\,2,\,5\,2} = 0.01452$, $pq_{1\,2,\,5\,3} = 0.00176$,
$pq_{1\,2,\,5\,6} = 0.00528$, $pq_{1\,2,\,6\,2} = 0.0022$,
$pq_{1\,2,\,6\,3} = 0.0154$, $pq_{1\,2,\,6\,5} = 0.0044$;
$pq_{1\,3,\,1\,2} = 0.02178$, $pq_{1\,3,\,1\,5} = 0.00022$,
$pq_{1\,3,\,2\,1} = 0.01826$, $pq_{1\,3,\,2\,5} = 0.00374$,
$pq_{1\,3,\,3\,2} = 0.01804$, $pq_{1\,3,\,3\,6} = 0.00396$,
$pq_{1\,3,\,4\,5} = 0.022$, $pq_{1\,3,\,5\,1} = 0.00044$,
$pq_{1\,3,\,5\,2} = 0.01452$, $pq_{1\,3,\,5\,3} = 0.00176$,
$pq_{1\,3,\,5\,6} = 0.00528$, $pq_{1\,3,\,6\,2} = 0.0022$,
$pq_{1\,3,\,6\,3} = 0.0154$, $pq_{1\,3,\,6\,5} = 0.0044$;
$pq_{1\,5,\,1\,2} = 0.52866$, $pq_{1\,5,\,1\,5} = 0.00534$,
$pq_{1\,5,\,2\,1} = 0.44322$, $pq_{1\,5,\,2\,5} = 0.09078$,
$pq_{1\,5,\,3\,2} = 0.43788$, $pq_{1\,5,\,3\,6} = 0.09612$,
$pq_{1\,5,\,4\,5} = 0.534$, $pq_{1\,5,\,5\,1} = 0.01068$,
$pq_{1\,5,\,5\,2} = 0.35244$, $pq_{1\,5,\,5\,3} = 0.04272$,
$pq_{1\,5,\,5\,6} = 0.12816$, $pq_{1\,5,\,6\,2} = 0.0534$,
$pq_{1\,5,\,6\,3} = 0.3738$, $pq_{1\,5,\,6\,5} = 0.1068$;
$pq_{1\,6,\,1\,2} = 0.10989$, $pq_{1\,6,\,1\,5} = 0.00111$,
$pq_{1\,6,\,2\,1} = 0.09213$, $pq_{1\,6,\,2\,5} = 0.01887$,
$pq_{1\,6,\,3\,2} = 0.09102$, $pq_{1\,6,\,3\,6} = 0.01998$,
$pq_{1\,6,\,4\,5} = 0.111$, $pq_{1\,6,\,5\,1} = 0.00222$,
$pq_{1\,6,\,5\,2} = 0.07326$, $pq_{1\,6,\,5\,3} = 0.00888$,
$pq_{1\,6,\,5\,6} = 0.02664$, $pq_{1\,6,\,6\,2} = 0.0111$,
$pq_{1\,6,\,6\,3} = 0.0777$, $pq_{1\,6,\,6\,5} = 0.0222$;
$pq_{1\,7,\,1\,2} = 0.30789$, $pq_{1\,7,\,1\,5} = 0.00311$,
$pq_{1\,7,\,2\,1} = 0.25813$, $pq_{1\,7,\,2\,5} = 0.05287$,
$pq_{1\,7,\,3\,2} = 0.25502$, $pq_{1\,7,\,3\,6} = 0.05598$,
$pq_{1\,7,\,4\,5} = 0.311$, $pq_{1\,7,\,5\,1} = 0.00622$,
$pq_{1\,7,\,5\,2} = 0.20526$, $pq_{1\,7,\,5\,3} = 0.02488$,
$pq_{1\,7,\,5\,6} = 0.07464$, $pq_{1\,7,\,6\,2} = 0.0311$,
$pq_{1\,7,\,6\,3} = 0.2177$, $pq_{1\,7,\,6\,5} = 0.0622$;
$pq_{2\,1,\,1\,2} = 0.198$, $pq_{2\,1,\,1\,5} = 0.002$,
$pq_{2\,1,\,2\,1} = 0.166$, $pq_{2\,1,\,2\,5} = 0.034$,
$pq_{2\,1,\,3\,2} = 0.164$, $pq_{2\,1,\,3\,6} = 0.036$, $pq_{2\,1,\,4\,5} = 0.2$,
$pq_{2\,1,\,5\,1} = 0.004$, $pq_{2\,1,\,5\,2} = 0.132$,
$pq_{2\,1,\,5\,3} = 0.016$, $pq_{2\,1,\,5\,6} = 0.048$,
$pq_{2\,1,\,6\,2} = 0.02$, $pq_{2\,1,\,6\,3} = 0.14$, $pq_{2\,1,\,6\,5} = 0.04$;

$pq_{2\,7,\,1\,2} = 0.792$, $pq_{2\,7,\,1\,5} = 0.008$,
$pq_{2\,7,\,2\,1} = 0.664$, $pq_{2\,7,\,2\,5} = 0.136$,
$pq_{2\,7,\,3\,2} = 0.656$, $pq_{2\,7,\,3\,6} = 0.144$, $pq_{2\,7,\,4\,5} = 0.8$,
$pq_{2\,7,\,5\,1} = 0.016$, $pq_{2\,7,\,5\,2} = 0.528$,
$pq_{2\,7,\,5\,3} = 0.064$, $pq_{2\,7,\,5\,6} = 0.192$,
$pq_{2\,7,\,6\,2} = 0.08$, $pq_{2\,7,\,6\,3} = 0.56$, $pq_{2\,7,\,6\,5} = 0.16$;
$pq_{3\,1,\,1\,2} = 0.99$, $pq_{3\,1,\,1\,5} = 0.01$, $pq_{3\,1,\,2\,1} = 0.83$,
$pq_{3\,1,\,2\,5} = 0.17$, $pq_{3\,1,\,3\,2} = 0.82$, $pq_{3\,1,\,3\,6} = 0.18$,
$pq_{3\,1,\,4\,5} = 1$, $pq_{3\,1,\,5\,1} = 0.02$, $pq_{3\,1,\,5\,2} = 0.66$,
$pq_{3\,1,\,5\,3} = 0.08$, $pq_{3\,1,\,5\,6} = 0.24$, $pq_{3\,1,\,6\,2} = 0.1$,
$pq_{3\,1,\,6\,3} = 0.7$, $pq_{3\,1,\,6\,5} = 0.2$; $pq_{4\,7,\,1\,2} = 0.99$,
$pq_{4\,7,\,1\,5} = 0.01$, $pq_{4\,7,\,2\,1} = 0.83$, $pq_{4\,7,\,2\,5} = 0.17$,
$pq_{4\,7,\,3\,2} = 0.82$, $pq_{4\,7,\,3\,6} = 0.18$, $pq_{4\,7,\,4\,5} = 1$,
$pq_{4\,7,\,5\,1} = 0.02$, $pq_{4\,7,\,5\,2} = 0.66$, $pq_{4\,7,\,5\,3} = 0.08$,
$pq_{4\,7,\,5\,6} = 0.24$, $pq_{4\,7,\,6\,2} = 0.1$, $pq_{4\,7,\,6\,3} = 0.7$,
$pq_{4\,7,\,6\,5} = 0.2$; $pq_{5\,1,\,1\,2} = 0.48312$,
$pq_{5\,1,\,1\,5} = 0.00488$, $pq_{5\,1,\,2\,1} = 0.40504$,
$pq_{5\,1,\,2\,5} = 0.08296$, $pq_{5\,1,\,3\,2} = 0.40016$,
$pq_{5\,1,\,3\,6} = 0.08784$, $pq_{5\,1,\,4\,5} = 0.488$,
$pq_{5\,1,\,5\,1} = 0.00976$, $pq_{5\,1,\,5\,2} = 0.32208$,
$pq_{5\,1,\,5\,3} = 0.03904$, $pq_{5\,1,\,5\,6} = 0.11712$,
$pq_{5\,1,\,6\,2} = 0.0488$, $pq_{5\,1,\,6\,3} = 0.3416$,
$pq_{5\,1,\,6\,5} = 0.0976$; $pq_{5\,2,\,1\,2} = 0.02277$,
$pq_{5\,2,\,1\,5} = 0.00023$, $pq_{5\,2,\,2\,1} = 0.01909$,
$pq_{5\,2,\,2\,5} = 0.00391$, $pq_{5\,2,\,3\,2} = 0.01886$,
$pq_{5\,2,\,3\,6} = 0.00414$, $pq_{5\,2,\,4\,5} = 0.023$,
$pq_{5\,2,\,5\,1} = 0.00046$, $pq_{5\,2,\,5\,2} = 0.01518$,
$pq_{5\,2,\,5\,3} = 0.00184$, $pq_{5\,2,\,5\,6} = 0.00552$,
$pq_{5\,2,\,6\,2} = 0.0023$, $pq_{5\,2,\,6\,3} = 0.0161$,
$pq_{5\,2,\,6\,5} = 0.0046$; $pq_{5\,4,\,1\,2} = 0.02277$,
$pq_{5\,4,\,1\,5} = 0.00023$, $pq_{5\,4,\,2\,1} = 0.01909$,
$pq_{5\,4,\,2\,5} = 0.00391$, $pq_{5\,4,\,3\,2} = 0.01886$,
$pq_{5\,4,\,3\,6} = 0.00414$, $pq_{5\,4,\,4\,5} = 0.023$,
$pq_{5\,4,\,5\,1} = 0.00046$, $pq_{5\,4,\,5\,2} = 0.01518$,
$pq_{5\,4,\,5\,3} = 0.00184$, $pq_{5\,4,\,5\,6} = 0.00552$,
$pq_{5\,4,\,6\,2} = 0.0023$, $pq_{5\,4,\,6\,3} = 0.0161$,
$pq_{5\,4,\,6\,5} = 0.0046$; $pq_{5\,6,\,1\,2} = 0.23067$,
$pq_{5\,6,\,1\,5} = 0.00233$, $pq_{5\,6,\,2\,1} = 0.19339$,
$pq_{5\,6,\,2\,5} = 0.03961$, $pq_{5\,6,\,3\,2} = 0.19106$,
$pq_{5\,6,\,3\,6} = 0.04194$, $pq_{5\,6,\,4\,5} = 0.233$,
$pq_{5\,6,\,5\,1} = 0.00466$, $pq_{5\,6,\,5\,2} = 0.15378$,
$pq_{5\,6,\,5\,3} = 0.01864$, $pq_{5\,6,\,5\,6} = 0.05592$,
$pq_{5\,6,\,6\,2} = 0.0233$, $pq_{5\,6,\,6\,3} = 0.1631$,
$pq_{5\,6,\,6\,5} = 0.0466$; $pq_{5\,7,\,1\,2} = 0.23067$,
$pq_{5\,7,\,1\,5} = 0.00233$, $pq_{5\,7,\,2\,1} = 0.19339$,
$pq_{5\,7,\,2\,5} = 0.03961$, $pq_{5\,7,\,3\,2} = 0.19106$,
$pq_{5\,7,\,3\,6} = 0.04194$, $pq_{5\,7,\,4\,5} = 0.233$,
$pq_{5\,7,\,5\,1} = 0.00466$, $pq_{5\,7,\,5\,2} = 0.15378$,
$pq_{5\,7,\,5\,3} = 0.01864$, $pq_{5\,7,\,5\,6} = 0.05592$,
$pq_{5\,7,\,6\,2} = 0.0233$, $pq_{5\,7,\,6\,3} = 0.1631$,
$pq_{5\,7,\,6\,5} = 0.0466$; $pq_{6\,1,\,1\,2} = 0.09405$,
$pq_{6\,1,\,1\,5} = 0.00095$, $pq_{6\,1,\,2\,1} = 0.07885$,
$pq_{6\,1,\,2\,5} = 0.01615$, $pq_{6\,1,\,3\,2} = 0.0779$,
$pq_{6\,1,\,3\,6} = 0.0171$, $pq_{6\,1,\,4\,5} = 0.095$,
$pq_{6\,1,\,5\,1} = 0.0019$, $pq_{6\,1,\,5\,2} = 0.0627$,
$pq_{6\,1,\,5\,3} = 0.0076$, $pq_{6\,1,\,5\,6} = 0.0228$,
$pq_{6\,1,\,6\,2} = 0.0095$, $pq_{6\,1,\,6\,3} = 0.0665$,
$pq_{6\,1,\,6\,5} = 0.019$; $pq_{6\,5,\,1\,2} = 0.66033$,
$pq_{6\,5,\,1\,5} = 0.00667$, $pq_{6\,5,\,2\,1} = 0.55361$,
$pq_{6\,5,\,2\,5} = 0.11339$, $pq_{6\,5,\,3\,2} = 0.54694$,
$pq_{6\,5,\,3\,6} = 0.12006$, $pq_{6\,5,\,4\,5} = 0.667$,
$pq_{6\,5,\,5\,1} = 0.01334$, $pq_{6\,5,\,5\,2} = 0.44022$,
$pq_{6\,5,\,5\,3} = 0.05336$, $pq_{6\,5,\,5\,6} = 0.16008$,
$pq_{6\,5,\,6\,2} = 0.0667$, $pq_{6\,5,\,6\,3} = 0.4669$,
$pq_{6\,5,\,6\,5} = 0.1334$; $pq_{6\,7,\,1\,2} = 0.23562$,
$pq_{6\,7,\,1\,5} = 0.00238$, $pq_{6\,7,\,2\,1} = 0.19754$,
$pq_{6\,7,\,2\,5} = 0.04046$, $pq_{6\,7,\,3\,2} = 0.19516$,
$pq_{6\,7,\,3\,6} = 0.04284$, $pq_{6\,7,\,4\,5} = 0.238$,
$pq_{6\,7,\,5\,1} = 0.00476$, $pq_{6\,7,\,5\,2} = 0.15708$,
$pq_{6\,7,\,5\,3} = 0.01904$, $pq_{6\,7,\,5\,6} = 0.05712$,
$pq_{6\,7,\,6\,2} = 0.0238$, $pq_{6\,7,\,6\,3} = 0.1666$,
$pq_{6\,7,\,6\,5} = 0.0476$; $pq_{7\,1,\,1\,2} = 0.52569$,
$pq_{7\,1,\,1\,5} = 0.00531$, $pq_{7\,1,\,2\,1} = 0.44073$,
$pq_{7\,1,\,2\,5} = 0.09027$, $pq_{7\,1,\,3\,2} = 0.43542$,
$pq_{7\,1,\,3\,6} = 0.09558$, $pq_{7\,1,\,4\,5} = 0.531$,
$pq_{7\,1,\,5\,1} = 0.01062$, $pq_{7\,1,\,5\,2} = 0.35046$,
$pq_{7\,1,\,5\,3} = 0.04248$, $pq_{7\,1,\,5\,6} = 0.12744$,
$pq_{7\,1,\,6\,2} = 0.0531$, $pq_{7\,1,\,6\,3} = 0.3717$,
$pq_{7\,1,\,6\,5} = 0.1062$; $pq_{7\,2,\,1\,2} = 0.06138$,
$pq_{7\,2,\,1\,5} = 0.00062$, $pq_{7\,2,\,2\,1} = 0.05146$,
$pq_{7\,2,\,2\,5} = 0.01054$, $pq_{7\,2,\,3\,2} = 0.05084$,
$pq_{7\,2,\,3\,6} = 0.01116$, $pq_{7\,2,\,4\,5} = 0.062$,
$pq_{7\,2,\,5\,1} = 0.00124$, $pq_{7\,2,\,5\,2} = 0.04092$,
$pq_{7\,2,\,5\,3} = 0.00496$, $pq_{7\,2,\,5\,6} = 0.01488$,
$pq_{7\,2,\,6\,2} = 0.0062$, $pq_{7\,2,\,6\,3} = 0.0434$,
$pq_{7\,2,\,6\,5} = 0.0124$; $pq_{7\,5,\,1\,2} = 0.21681$,
$pq_{7\,5,\,1\,5} = 0.00219$, $pq_{7\,5,\,2\,1} = 0.18177$,
$pq_{7\,5,\,2\,5} = 0.03723$, $pq_{7\,5,\,3\,2} = 0.17958$,
$pq_{7\,5,\,3\,6} = 0.03942$, $pq_{7\,5,\,4\,5} = 0.219$,
$pq_{7\,5,\,5\,1} = 0.00438$, $pq_{7\,5,\,5\,2} = 0.14454$,
$pq_{7\,5,\,5\,3} = 0.01752$, $pq_{7\,5,\,5\,6} = 0.05256$,
$pq_{7\,5,\,6\,2} = 0.0219$, $pq_{7\,5,\,6\,3} = 0.1533$,
$pq_{7\,5,\,6\,5} = 0.0438$; $pq_{7\,6,\,1\,2} = 0.18612$,
$pq_{7\,6,\,1\,5} = 0.00188$, $pq_{7\,6,\,2\,1} = 0.15604$,
$pq_{7\,6,\,2\,5} = 0.03196$, $pq_{7\,6,\,3\,2} = 0.15416$,
$pq_{7\,6,\,3\,6} = 0.03384$, $pq_{7\,6,\,4\,5} = 0.188$,
$pq_{7\,6,\,5\,1} = 0.00376$, $pq_{7\,6,\,5\,2} = 0.12408$,
$pq_{7\,6,\,5\,3} = 0.01504$, $pq_{7\,6,\,5\,6} = 0.04512$,
$pq_{7\,6,\,6\,2} = 0.0188$, $pq_{7\,6,\,6\,3} = 0.1316$,
$pq_{7\,6,\,6\,5} = 0.0376$; (2)

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

- the matrix $[N_{ij\,kl}]_{42x42}$ of the mean values of the piping operation process related to climate-weather change process $ZC^1(t)$ conditional sojourn times $\theta C^1_{ij\,kl}$, i, k = 1,2,…,7, j, l =1,2,…,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,…,7, j, l =1,2,…,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

$$[pq_{ij}(0)]_{1x42}$$
$$= [0.32198, 0.00204, 0, 0.0119, 0.00408, 0; 0.04735, 0.0003, 0, 0.00175, 0.0006, 0; 0, 0, 0, 0, 0, 0; 0, 0, 0, 0, 0, 0; 0.21781, 0.00138, 0, 0.00805, 0.00276, 0; 0.17993, 0.00114, 0, 0.00665, 0.00228, 0; 0.17993, 0.00114, 0, 0.00665, 0.00228, 0] \quad (3)$$

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 zc_{ij}, $i = 1,2,\ldots,7, j = 1,2,\ldots,6$;
- the matrix $[pq_{ij\,kl}]_{42x42}$, of the probabilities $pq_{ij\,kl}$, i, $k = 1,2,\ldots,7$, j, $l = 1,2,\ldots,6$, of transitions of the piping operation process related to climate-weather change process $ZC^2(t)$ from the operation state zc_{ij} into the operation state zc_{kl}, where

$pq_{12,12} = 0.00748$, $pq_{12,14} = 0.01254$,
$pq_{12,15} = 0.00198$, $pq_{12,21} = 0.022$,
$pq_{12,41} = 0.01298$, $pq_{12,42} = 0.0011$,
$pq_{12,45} = 0.00792$, $pq_{12,54} = 0.022$;
$pq_{13,12} = 0.00748$, $pq_{13,14} = 0.01254$,
$pq_{13,15} = 0.00198$, $pq_{13,21} = 0.022$,
$pq_{13,41} = 0.01298$, $pq_{13,42} = 0.0011$,
$pq_{13,45} = 0.00792$, $pq_{13,54} = 0.022$;
$pq_{15,12} = 0.18156$, $pq_{15,14} = 0.30438$,
$pq_{15,15} = 0.04806$, $pq_{15,21} = 0.534$,
$pq_{15,41} = 0.31506$, $pq_{15,42} = 0.0267$,
$pq_{15,45} = 0.19224$, $pq_{15,54} = 0.534$;
$pq_{16,12} = 0.03774$, $pq_{16,14} = 0.06327$,
$pq_{16,15} = 0.00999$, $pq_{16,21} = 0.111$,
$pq_{16,41} = 0.06549$, $pq_{16,42} = 0.00555$,
$pq_{16,45} = 0.03996$, $pq_{16,54} = 0.111$;
$pq_{17,12} = 0.10574$, $pq_{17,14} = 0.17727$,
$pq_{17,15} = 0.02799$, $pq_{17,21} = 0.311$,
$pq_{17,41} = 0.18349$, $pq_{17,42} = 0.01555$,
$pq_{17,45} = 0.11196$, $pq_{17,54} = 0.311$;
$pq_{21,12} = 0.068$, $pq_{21,14} = 0.114$,
$pq_{21,15} = 0.018$, $pq_{21,21} = 0.2$, $pq_{21,41} = 0.118$,
$pq_{21,42} = 0.01$, $pq_{21,45} = 0.072$, $pq_{21,54} = 0.2$;
$pq_{27,12} = 0.272$, $pq_{27,14} = 0.456$,
$pq_{27,15} = 0.072$, $pq_{27,21} = 0.8$, $pq_{27,41} = 0.472$,
$pq_{27,42} = 0.04$, $pq_{27,45} = 0.288$, $pq_{27,54} = 0.8$;
$pq_{31,12} = 0.34$, $pq_{31,14} = 0.57$, $pq_{31,15} = 0.09$,
$pq_{31,21} = 1$, $pq_{31,41} = 0.59$, $pq_{31,42} = 0.05$,
$pq_{31,45} = 0.36$, $pq_{31,54} = 1$; $pq_{47,12} = 0.34$,
$pq_{47,14} = 0.57$, $pq_{47,15} = 0.09$, $pq_{47,21} = 1$,
$pq_{47,41} = 0.59$, $pq_{47,42} = 0.05$, $pq_{47,45} = 0.36$,
$pq_{47,54} = 1$; $pq_{51,12} = 0.16592$,
$pq_{51,14} = 0.27816$, $pq_{51,15} = 0.04392$,
$pq_{51,21} = 0.488$, $pq_{51,41} = 0.28792$,
$pq_{51,42} = 0.0244$, $pq_{51,45} = 0.17568$,
$pq_{51,54} = 0.488$; $pq_{52,12} = 0.00782$,
$pq_{52,14} = 0.01311$, $pq_{52,15} = 0.00207$,
$pq_{52,21} = 0.023$, $pq_{52,41} = 0.01357$,
$pq_{52,42} = 0.00115$, $pq_{52,45} = 0.00828$,
$pq_{52,54} = 0.023$; $pq_{54,12} = 0.00782$,
$pq_{54,14} = 0.01311$, $pq_{54,15} = 0.00207$,
$pq_{54,21} = 0.023$, $pq_{54,41} = 0.01357$,
$pq_{54,42} = 0.00115$, $pq_{54,45} = 0.00828$,
$pq_{54,54} = 0.023$; $pq_{56,12} = 0.07922$,
$pq_{56,14} = 0.13281$, $pq_{56,15} = 0.02097$,
$pq_{56,21} = 0.233$, $pq_{56,41} = 0.13747$,
$pq_{56,42} = 0.01165$, $pq_{56,45} = 0.08388$,
$pq_{56,54} = 0.233$; $pq_{57,12} = 0.07922$,
$pq_{57,14} = 0.13281$, $pq_{57,15} = 0.02097$,
$pq_{57,21} = 0.233$, $pq_{57,41} = 0.13747$,
$pq_{57,42} = 0.01165$, $pq_{57,45} = 0.08388$,
$pq_{57,54} = 0.233$; $pq_{61,12} = 0.0323$,
$pq_{61,14} = 0.05415$, $pq_{61,15} = 0.00855$,
$pq_{61,21} = 0.095$, $pq_{61,41} = 0.05605$,
$pq_{61,42} = 0.00475$, $pq_{61,45} = 0.0342$,
$pq_{61,54} = 0.095$; $pq_{65,12} = 0.22678$,
$pq_{65,14} = 0.38019$, $pq_{65,15} = 0.06003$,
$pq_{65,21} = 0.667$, $pq_{65,41} = 0.39353$,
$pq_{65,42} = 0.03335$, $pq_{65,45} = 0.24012$,
$pq_{65,54} = 0.667$; $pq_{67,12} = 0.08092$,
$pq_{67,14} = 0.13566$, $pq_{67,15} = 0.02142$,
$pq_{67,21} = 0.238$, $pq_{67,41} = 0.14042$,
$pq_{67,42} = 0.0119$, $pq_{67,45} = 0.08568$,
$pq_{67,54} = 0.238$; $pq_{71,12} = 0.18054$,
$pq_{71,14} = 0.30267$, $pq_{71,15} = 0.04779$,
$pq_{71,21} = 0.531$, $pq_{71,41} = 0.31329$,
$pq_{71,42} = 0.02655$, $pq_{71,45} = 0.19116$,
$pq_{71,54} = 0.531$; $pq_{72,12} = 0.02108$,
$pq_{72,14} = 0.03534$, $pq_{72,15} = 0.00558$,
$pq_{72,21} = 0.062$, $pq_{72,41} = 0.03658$,
$pq_{72,42} = 0.0031$, $pq_{72,45} = 0.02232$,
$pq_{72,54} = 0.062$; $pq_{75,12} = 0.07446$,
$pq_{75,14} = 0.12483$, $pq_{75,15} = 0.01971$,
$pq_{75,21} = 0.219$, $pq_{75,41} = 0.12921$,
$pq_{75,42} = 0.01095$, $pq_{75,45} = 0.07884$,
$pq_{75,54} = 0.219$; $pq_{76,12} = 0.06392$,
$pq_{76,14} = 0.10716$, $pq_{76,15} = 0.01692$,
$pq_{76,21} = 0.188$, $pq_{76,41} = 0.11092$,

$pq_{7 6, 4 2} = 0.0094$, $pq_{7 6, 4 5} = 0.06768$,
$pq_{7 6, 5 4} = 0.188$; (4)

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

- the matrix $[N_{ij\ kl}]_{42x42}$ of the mean values of the piping operation process related to climate-weather change process $ZC^2(t)$ conditional sojourn times $\theta C^2_{ij\ kl}$, i, k = 1,2,…,7, j, l =1,2,…,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,…,7, j, l =1,2,…,6, could be found in [3].

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

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

$[pq_{ij}(0)]_{1x112}$
= [0.00408, 0.04012, 0, 0, 0, 0.26622, 0.0119,
0, 0, 0, 0.01734, 0, 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, 0, 0.00276,
0.02714, 0, 0, 0, 0.18009, 0.00805, 0, 0, 0,
0.01173, 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, 0.00228, 0.02242, 0, 0, 0, 0.14877, 0.00665,
0, 0, 0, 0.00969, 0, 0, 0, 0, 0] (5)

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 zc_{ij}, i = 1,2,…,7, j = 1,2,…,16;

- the matrix $[pq_{ij\ kl}]_{112x112}$, of the probabilities $pq_{ij\ kl}$, i, k = 1,2,…,7, j, l =1,2,…,16, of transitions of the piping 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

$pq_{1 2, 1 2} = 0.022$, $pq_{1 2, 2 1} = 0.0022$,
$pq_{1 2, 2 6} = 0.0198$, $pq_{1 2, 6 2} = 0.00396$,
$pq_{1 2, 6 7} = 0.00484$, $pq_{1 2, 6 10} = 0.01034$,
$pq_{1 2, 6 11} = 0.00286$, $pq_{1 2, 7 6} = 0.01584$,
$pq_{1 2, 7 11} = 0.00616$, $pq_{1 2, 10 6} = 0.0121$,
$pq_{1 2, 10 7} = 0.00044$, $pq_{1 2, 10 11} = 0.00946$,
$pq_{1 2, 11 6} = 0.0044$, $pq_{1 2, 11 7} = 0.01518$,
$pq_{1 2, 11 10} = 0.00242$; $pq_{1 3, 1 2} = 0.022$,
$pq_{1 3, 2 1} = 0.0022$, $pq_{1 3, 2 6} = 0.0198$,
$pq_{1 3, 6 2} = 0.00396$, $pq_{1 3, 6 7} = 0.00484$,
$pq_{1 3, 6 10} = 0.01034$, $pq_{1 3, 6 11} = 0.00286$,
$pq_{1 3, 7 6} = 0.01584$, $pq_{1 3, 7 11} = 0.00616$,
$pq_{1 3, 10 6} = 0.0121$, $pq_{1 3, 10 7} = 0.00044$,
$pq_{1 3, 10 11} = 0.00946$, $pq_{1 3, 11 6} = 0.0044$,
$pq_{1 3, 11 7} = 0.01518$, $pq_{1 3, 11 10} = 0.00242$;
$pq_{1 5, 1 2} = 0.534$, $pq_{1 5, 2 1} = 0.0534$,
$pq_{1 5, 2 6} = 0.4806$, $pq_{1 5, 6 2} = 0.09612$,
$pq_{1 5, 6 7} = 0.11748$, $pq_{1 5, 6 10} = 0.25098$,
$pq_{1 5, 6 11} = 0.06942$, $pq_{1 5, 7 6} = 0.38448$,
$pq_{1 5, 7 11} = 0.14952$, $pq_{1 5, 10 6} = 0.2937$,
$pq_{1 5, 10 7} = 0.01068$, $pq_{1 5, 10 11} = 0.22962$,
$pq_{1 5, 11 6} = 0.1068$, $pq_{1 5, 11 7} = 0.36846$,
$pq_{1 5, 11 10} = 0.05874$; $pq_{1 6, 1 2} = 0.111$,
$pq_{1 6, 2 1} = 0.0111$, $pq_{1 6, 2 6} = 0.0999$,
$pq_{1 6, 6 2} = 0.01998$, $pq_{1 6, 6 7} = 0.02442$,
$pq_{1 6, 6 10} = 0.05217$, $pq_{1 6, 6 11} = 0.01443$,
$pq_{1 6, 7 6} = 0.07992$, $pq_{1 6, 7 11} = 0.03108$,
$pq_{1 6, 10 6} = 0.06105$, $pq_{1 6, 10 7} = 0.00222$,
$pq_{1 6, 10 11} = 0.04773$, $pq_{1 6, 11 6} = 0.0222$,
$pq_{1 6, 11 7} = 0.07659$, $pq_{1 6, 11 10} = 0.01221$;
$pq_{1 7, 1 2} = 0.311$, $pq_{1 7, 2 1} = 0.0311$,
$pq_{1 7, 2 6} = 0.2799$, $pq_{1 7, 6 2} = 0.05598$,
$pq_{1 7, 6 7} = 0.06842$, $pq_{1 7, 6 10} = 0.14617$,
$pq_{1 7, 6 11} = 0.04043$, $pq_{1 7, 7 6} = 0.22392$,
$pq_{1 7, 7 11} = 0.08708$, $pq_{1 7, 10 6} = 0.17105$,
$pq_{1 7, 10 7} = 0.00622$, $pq_{1 7, 10 11} = 0.13373$,
$pq_{1 7, 11 6} = 0.0622$, $pq_{1 7, 11 7} = 0.21459$,
$pq_{1 7, 11 10} = 0.03421$; $pq_{2 1, 1 2} = 0.2$,
$pq_{2 1, 2 1} = 0.02$, $pq_{2 1, 2 6} = 0.18$, $pq_{2 1, 6 2} = 0.036$,
$pq_{2 1, 6 7} = 0.044$, $pq_{2 1, 6 10} = 0.094$,
$pq_{2 1, 6 11} = 0.026$, $pq_{2 1, 7 6} = 0.144$,
$pq_{2 1, 7 11} = 0.056$, $pq_{2 1, 10 6} = 0.11$,
$pq_{2 1, 10 7} = 0.004$, $pq_{2 1, 10 11} = 0.086$,
$pq_{2 1, 11 6} = 0.04$, $pq_{2 1, 11 7} = 0.138$,
$pq_{2 1, 11 10} = 0.022$; $pq_{2 7, 1 2} = 0.8$, $pq_{2 7, 2 1} = 0.08$,
$pq_{2 7, 2 6} = 0.72$, $pq_{2 7, 6 2} = 0.144$,
$pq_{2 7, 6 7} = 0.176$, $pq_{2 7, 6 10} = 0.376$,
$pq_{2 7, 6 11} = 0.104$, $pq_{2 7, 7 6} = 0.576$,
$pq_{2 7, 7 11} = 0.224$, $pq_{2 7, 10 6} = 0.44$,
$pq_{2 7, 10 7} = 0.016$, $pq_{2 7, 10 11} = 0.344$,
$pq_{2 7, 11 6} = 0.16$, $pq_{2 7, 11 7} = 0.552$,
$pq_{2 7, 11 10} = 0.088$; $pq_{3 1, 1 2} = 1$, $pq_{3 1, 2 1} = 0.1$,
$pq_{3 1, 2 6} = 0.9$, $pq_{3 1, 6 2} = 0.18$, $pq_{3 1, 6 7} = 0.22$,
$pq_{3 1, 6 10} = 0.47$, $pq_{3 1, 6 11} = 0.13$, $pq_{3 1, 7 6} = 0.72$,
$pq_{3 1, 7 11} = 0.28$, $pq_{3 1, 10 6} = 0.55$,
$pq_{3 1, 10 7} = 0.02$, $pq_{3 1, 10 11} = 0.43$, $pq_{3 1, 11 6} = 0.2$,
$pq_{3 1, 11 7} = 0.69$, $pq_{3 1, 11 10} = 0.11$; $pq_{4 7, 1 2} = 1$,
$pq_{4 7, 2 1} = 0.1$, $pq_{4 7, 2 6} = 0.9$, $pq_{4 7, 6 2} = 0.18$,
$pq_{4 7, 6 7} = 0.22$, $pq_{4 7, 6 10} = 0.47$, $pq_{4 7, 6 11} = 0.13$,
$pq_{4 7, 7 6} = 0.72$, $pq_{4 7, 7 11} = 0.28$, $pq_{4 7, 10 6} = 0.55$,
$pq_{4 7, 10 7} = 0.02$, $pq_{4 7, 10 11} = 0.43$, $pq_{4 7, 11 6} = 0.2$,
$pq_{4 7, 11 7} = 0.69$, $pq_{4 7, 11 10} = 0.11$;
$pq_{5 1, 1 2} = 0.488$, $pq_{5 1, 2 1} = 0.0488$,

$pq_{5\,1,\,2\,6} = 0.4392$, $pq_{5\,1,\,6\,2} = 0.08784$,
$pq_{5\,1,\,6\,7} = 0.10736$, $pq_{5\,1,\,6\,10} = 0.22936$,
$pq_{5\,1,\,6\,11} = 0.06344$, $pq_{5\,1,\,7\,6} = 0.35136$,
$pq_{5\,1,\,7\,11} = 0.13664$, $pq_{5\,1,\,10\,6} = 0.2684$,
$pq_{5\,1,\,10\,7} = 0.00976$, $pq_{5\,1,\,10\,11} = 0.20984$,
$pq_{5\,1,\,11\,6} = 0.0976$, $pq_{5\,1,\,11\,7} = 0.33672$,
$pq_{5\,1,\,11\,10} = 0.05368$; $pq_{5\,2,\,1\,2} = 0.023$,
$pq_{5\,2,\,2\,1} = 0.0023$, $pq_{5\,2,\,2\,6} = 0.0207$,
$pq_{5\,2,\,6\,2} = 0.00414$, $pq_{5\,2,\,6\,7} = 0.00506$,
$pq_{5\,2,\,6\,10} = 0.01081$, $pq_{5\,2,\,6\,11} = 0.00299$,
$pq_{5\,2,\,7\,6} = 0.01656$, $pq_{5\,2,\,7\,11} = 0.00644$,
$pq_{5\,2,\,10\,6} = 0.01265$, $pq_{5\,2,\,10\,7} = 0.00046$,
$pq_{5\,2,\,10\,11} = 0.00989$, $pq_{5\,2,\,11\,6} = 0.0046$,
$pq_{5\,2,\,11\,7} = 0.01587$, $pq_{5\,2,\,11\,10} = 0.00253$;
$pq_{5\,4,\,1\,2} = 0.023$, $pq_{5\,4,\,2\,1} = 0.0023$,
$pq_{5\,4,\,2\,6} = 0.0207$, $pq_{5\,4,\,6\,2} = 0.00414$,
$pq_{5\,4,\,6\,7} = 0.00506$, $pq_{5\,4,\,6\,10} = 0.01081$,
$pq_{5\,4,\,6\,11} = 0.00299$, $pq_{5\,4,\,7\,6} = 0.01656$,
$pq_{5\,4,\,7\,11} = 0.00644$, $pq_{5\,4,\,10\,6} = 0.01265$,
$pq_{5\,4,\,10\,7} = 0.00046$, $pq_{5\,4,\,10\,11} = 0.00989$,
$pq_{5\,4,\,11\,6} = 0.0046$, $pq_{5\,4,\,11\,7} = 0.01587$,
$pq_{5\,4,\,11\,10} = 0.00253$; $pq_{5\,6,\,1\,2} = 0.233$,
$pq_{5\,6,\,2\,1} = 0.0233$, $pq_{5\,6,\,2\,6} = 0.2097$,
$pq_{5\,6,\,6\,2} = 0.04194$, $pq_{5\,6,\,6\,7} = 0.05126$,
$pq_{5\,6,\,6\,10} = 0.10951$, $pq_{5\,6,\,6\,11} = 0.03029$,
$pq_{5\,6,\,7\,6} = 0.16776$, $pq_{5\,6,\,7\,11} = 0.06524$,
$pq_{5\,6,\,10\,6} = 0.12815$, $pq_{5\,6,\,10\,7} = 0.00466$,
$pq_{5\,6,\,10\,11} = 0.10019$, $pq_{5\,6,\,11\,6} = 0.0466$,
$pq_{5\,6,\,11\,7} = 0.16077$, $pq_{5\,6,\,11\,10} = 0.02563$;
$pq_{5\,7,\,1\,2} = 0.233$, $pq_{5\,7,\,2\,1} = 0.0233$,
$pq_{5\,7,\,2\,6} = 0.2097$, $pq_{5\,7,\,6\,2} = 0.04194$,
$pq_{5\,7,\,6\,7} = 0.05126$, $pq_{5\,7,\,6\,10} = 0.10951$,
$pq_{5\,7,\,6\,11} = 0.03029$, $pq_{5\,7,\,7\,6} = 0.16776$,
$pq_{5\,7,\,7\,11} = 0.06524$, $pq_{5\,7,\,10\,6} = 0.12815$,
$pq_{5\,7,\,10\,7} = 0.00466$, $pq_{5\,7,\,10\,11} = 0.10019$,
$pq_{5\,7,\,11\,6} = 0.0466$, $pq_{5\,7,\,11\,7} = 0.16077$,
$pq_{5\,7,\,11\,10} = 0.02563$; $pq_{6\,1,\,1\,2} = 0.095$,
$pq_{6\,1,\,2\,1} = 0.0095$, $pq_{6\,1,\,2\,6} = 0.0855$,
$pq_{6\,1,\,6\,2} = 0.0171$, $pq_{6\,1,\,6\,7} = 0.0209$,
$pq_{6\,1,\,6\,10} = 0.04465$, $pq_{6\,1,\,6\,11} = 0.01235$,
$pq_{6\,1,\,7\,6} = 0.0684$, $pq_{6\,1,\,7\,11} = 0.0266$,
$pq_{6\,1,\,10\,6} = 0.05225$, $pq_{6\,1,\,10\,7} = 0.0019$,
$pq_{6\,1,\,10\,11} = 0.04085$, $pq_{6\,1,\,11\,6} = 0.019$,
$pq_{6\,1,\,11\,7} = 0.06555$, $pq_{6\,1,\,11\,10} = 0.01045$;
$pq_{6\,5,\,1\,2} = 0.667$, $pq_{6\,5,\,2\,1} = 0.0667$,
$pq_{6\,5,\,2\,6} = 0.6003$, $pq_{6\,5,\,6\,2} = 0.12006$,
$pq_{6\,5,\,6\,7} = 0.14674$, $pq_{6\,5,\,6\,10} = 0.31349$,
$pq_{6\,5,\,6\,11} = 0.08671$, $pq_{6\,5,\,7\,6} = 0.48024$,
$pq_{6\,5,\,7\,11} = 0.18676$, $pq_{6\,5,\,10\,6} = 0.36685$,
$pq_{6\,5,\,10\,7} = 0.01334$, $pq_{6\,5,\,10\,11} = 0.28681$,
$pq_{6\,5,\,11\,6} = 0.1334$, $pq_{6\,5,\,11\,7} = 0.46023$,
$pq_{6\,5,\,11\,10} = 0.07337$; $pq_{6\,7,\,1\,2} = 0.238$,
$pq_{6\,7,\,2\,1} = 0.0238$, $pq_{6\,7,\,2\,6} = 0.2142$,
$pq_{6\,7,\,6\,2} = 0.04284$, $pq_{6\,7,\,6\,7} = 0.05236$,
$pq_{6\,7,\,6\,10} = 0.11186$, $pq_{6\,7,\,6\,11} = 0.03094$,
$pq_{6\,7,\,7\,6} = 0.17136$, $pq_{6\,7,\,7\,11} = 0.06664$,
$pq_{6\,7,\,10\,6} = 0.1309$, $pq_{6\,7,\,10\,7} = 0.00476$,
$pq_{6\,7,\,10\,11} = 0.10234$, $pq_{6\,7,\,11\,6} = 0.0476$,
$pq_{6\,7,\,11\,7} = 0.16422$, $pq_{6\,7,\,11\,10} = 0.02618$;
$pq_{7\,1,\,1\,2} = 0.531$, $pq_{7\,1,\,2\,1} = 0.0531$,
$pq_{7\,1,\,2\,6} = 0.4779$, $pq_{7\,1,\,6\,2} = 0.09558$,
$pq_{7\,1,\,6\,7} = 0.11682$, $pq_{7\,1,\,6\,10} = 0.24957$,
$pq_{7\,1,\,6\,11} = 0.06903$, $pq_{7\,1,\,7\,6} = 0.38232$,
$pq_{7\,1,\,7\,11} = 0.14868$, $pq_{7\,1,\,10\,6} = 0.29205$,
$pq_{7\,1,\,10\,7} = 0.01062$, $pq_{7\,1,\,10\,11} = 0.22833$,
$pq_{7\,1,\,11\,6} = 0.1062$, $pq_{7\,1,\,11\,7} = 0.36639$,
$pq_{7\,1,\,11\,10} = 0.05841$; $pq_{7\,2,\,1\,2} = 0.062$,
$pq_{7\,2,\,2\,1} = 0.0062$, $pq_{7\,2,\,2\,6} = 0.0558$,
$pq_{7\,2,\,6\,2} = 0.01116$, $pq_{7\,2,\,6\,7} = 0.01364$,
$pq_{7\,2,\,6\,10} = 0.02914$, $pq_{7\,2,\,6\,11} = 0.00806$,
$pq_{7\,2,\,7\,6} = 0.04464$, $pq_{7\,2,\,7\,11} = 0.01736$,
$pq_{7\,2,\,10\,6} = 0.0341$, $pq_{7\,2,\,10\,7} = 0.00124$,
$pq_{7\,2,\,10\,11} = 0.02666$, $pq_{7\,2,\,11\,6} = 0.0124$,
$pq_{7\,2,\,11\,7} = 0.04278$, $pq_{7\,2,\,11\,10} = 0.00682$;
$pq_{7\,5,\,1\,2} = 0.219$, $pq_{7\,5,\,2\,1} = 0.0219$,
$pq_{7\,5,\,2\,6} = 0.1971$, $pq_{7\,5,\,6\,2} = 0.03942$,
$pq_{7\,5,\,6\,7} = 0.04818$, $pq_{7\,5,\,6\,10} = 0.10293$,
$pq_{7\,5,\,6\,11} = 0.02847$, $pq_{7\,5,\,7\,6} = 0.15768$,
$pq_{7\,5,\,7\,11} = 0.06132$, $pq_{7\,5,\,10\,6} = 0.12045$,
$pq_{7\,5,\,10\,7} = 0.00438$, $pq_{7\,5,\,10\,11} = 0.09417$,
$pq_{7\,5,\,11\,6} = 0.0438$, $pq_{7\,5,\,11\,7} = 0.15111$,
$pq_{7\,5,\,11\,10} = 0.02409$; $pq_{7\,6,\,1\,2} = 0.188$,
$pq_{7\,6,\,2\,1} = 0.0188$, $pq_{7\,6,\,2\,6} = 0.1692$,
$pq_{7\,6,\,6\,2} = 0.03384$, $pq_{7\,6,\,6\,7} = 0.04136$,
$pq_{7\,6,\,6\,10} = 0.08836$, $pq_{7\,6,\,6\,11} = 0.02444$,
$pq_{7\,6,\,7\,6} = 0.13536$, $pq_{7\,6,\,7\,11} = 0.05264$,
$pq_{7\,6,\,10\,6} = 0.1034$, $pq_{7\,6,\,10\,7} = 0.00376$,
$pq_{7\,6,\,10\,11} = 0.08084$, $pq_{7\,6,\,11\,6} = 0.0376$,
$pq_{7\,6,\,11\,7} = 0.12972$, $pq_{7\,6,\,11\,10} = 0.02068$; (6)

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

- the matrix $[N_{ij\,kl}]_{112x112}$ of the mean values of the piping operation process related to climate-weather change process $ZC^3(t)$ conditional sojourn times $\theta C^3_{ij\,kl}$, i, k = 1,2,…,7, j, l =1,2,…,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,…,7, j, l =1,2,…,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,…,7, j =1,2,…,6, at the particular operation states zc_{ij}, are given in the vector [3]:

$$[pq_{ij}]_{1x42} \cong [0.355895, 0.034365, 0.000395, 0, 0.00316, 0.001185, 0.05406, 0.00522, 0.00006, 0, 0.00048, 0.00018, 0.002703, 0.000261, 0.000003, 0, 0.000024, 0.000009, 0.001802, 0.000174, 0.000002, 0, 0.000016, 0.000006, 0.1802, 0.0174, 0.0002, 0, 0.0016, 0.0006, 0.052258, 0.005046, 0.000058, 0, 0.000464, 0.000174, 0.254082, 0.024534, 0.000282, 0, 0.002256, 0.000846]; \quad (7)$$

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,…,7, j =1,2,…,6, at the particular operation states zc_{ij}, are given in the vector [3]:

$$[pq_{ij}]_{1x42} \cong [0.378805, 0.002765, 0, 0.008295, 0.005135, 0, 0.05754, 0.00042, 0, 0.00126, 0.00078, 0, 0.002877, 0.000021, 0, 0.000063, 0.000039, 0, 0.001918, 0.000014, 0, 0.000042, 0.000026, 0, 0.191800, 0.001400, 0, 0.004200, 0.002600, 0, 0.055622, 0.000406, 0, 0.001218, 0.000754, 0, 0.270438, 0.001974, 0, 0.005922, 0.003666, 0]; \quad (8)$$

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,…,7, j =1,2,…,16, at the particular operation states zc_{ij}, are given in the vector [3]:

$$[pq_{ij}]_{1x112} \cong [0.000395, 0.01501, 0, 0, 0, 0.34286, 0.012245, 0, 0, 0.004345, 0.020145, 0, 0, 0, 0, 0, 0.000060, 0.00228, 0, 0, 0, 0.05208, 0.00186, 0, 0, 0.00066, 0.00306, 0, 0, 0, 0, 0, 0.000003, 0.000114, 0, 0, 0, 0.002604, 0.000093, 0, 0, 0.000033, 0.000153, 0, 0, 0, 0, 0, 0.000002, 0.000076, 0, 0, 0, 0.001736, 0.000062, 0, 0, 0.000022, 0.000102, 0, 0, 0, 0, 0, 0.0002, 0.0076, 0, 0, 0, 0.1736, 0.0062, 0, 0, 0.0022, 0.0102, 0, 0, 0, 0, 0, 0.000058, 0.002204, 0, 0, 0, 0.050344, 0.001798, 0, 0, 0.000638, 0.002958, 0, 0, 0, 0, 0, 0.000282, 0.010716, 0, 0, 0, 0.244776, 0.008742, 0, 0, 0.003102, 0.014382, 0, 0, 0, 0, 0]. \quad (9)$$

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 θC^1_{ij}, i = 1,2,…,7, j =1,2,…,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]:

$$[\hat{M}\hat{N}^1_{ij}]_{1x42} = [E[\theta C^1_{ij}]]_{1x42} \cong [10.32095, 0.996585, 0.011455, 0, 0.09164, 0.034365, 1.56774, 0.15138, 0.00174, 0, 0.01392, 0.00522, 0.078387, 0.007569, 0.000087, 0, 0.000696, 0.000261, 0.052258, 0.005046, 0.000058, 0, 0.000464, 0.000174, 5.2258, 0.5046, 0.0058, 0, 0.0464, 0.0174, 1.515482, 0.146334, 0.001682, 0, 0.013456, 0.005046, 7.368378, 0.711486, 0.008178, 0, 0.065424, 0.024534]; \quad (10)$$

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 θC^2_{ij}, i = 1,2,…,7, j =1,2,…,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]:

$$[\hat{M}\hat{N}_{ij}^{2}]_{1x42} = [E[\theta C_{ij}^{2}]]_{1x42} \cong [10.98535, 0.080185, 0, 0.240555, 0.148915, 0, 1.66866, 0.01218, 0, 0.03654, 0.02262, 0, 0.083433, 0.000609, 0, 0.001827, 0.001131, 0, 0.055622, 0.000406, 0, 0.001218, 0.000754, 0, 5.5622, 0.0406, 0, 0.1218, 0.0754, 0, 1.613038, 0.011774, 0, 0.035322, 0.021866, 0, 7.842702, 0.057246, 0, 0.171738, 0.106314, 0]; \quad (11)$$

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

The expected values of the total sojourn times θC_{ij}^{3}, i = 1,2,…,7, j =1,2,…,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]:

$$[\hat{M}\hat{N}_{ij}^{3}]_{1x112} = [E[\theta C_{ij}^{3}]]_{1x112} \cong [0.011455, 0.43529, 0, 0, 0, 9.94294, 0.355105, 0, 0, 0.126005, 0.584205, 0, 0, 0, 0, 0, 0.00174, 0.06612, 0, 0, 0, 1.51032, 0.05394, 0, 0, 0.01914, 0.08874, 0, 0, 0, 0, 0, 0.000087, 0.003306, 0, 0, 0, 0.075516, 0.002697, 0, 0, 0.000957, 0.004437, 0, 0, 0, 0, 0, 0.000058, 0.002204, 0, 0, 0, 0.050344, 0.001798, 0, 0, 0.000638, 0.002958, 0, 0, 0, 0, 0, 0.0058, 0.2204, 0, 0, 0, 5.0344, 0.1798, 0, 0, 0.0638, 0.2958, 0, 0, 0, 0, 0, 0.001682, 0.063916, 0, 0, 0, 1.459976, 0.052142, 0, 0, 0.018502, 0.085782, 0, 0, 0, 0, 0, 0.008178, 0.310764, 0, 0, 0, 7.098504, 0.253518, 0, 0, 0.089958, 0.417078, 0, 0, 0, 0, 0]. \quad (12)$$

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].

Acknowledgments

The paper presents the results developed in the scope of the EU-CIRCLE project titled "A pan – European framework for strengthening Critical Infrastructure resilience to climate change" that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653824. http://www.eu-circle.eu/.

References

[1] EU-CIRCLE Report D3.3-GMU3-CIOP Model1. (2016). *Critical Infrastructure Operation Process (CIOP) Model1*.

[2] EU-CIRCLE Report D3.3-GMU3-C-WCP. (2016). *Critical Infrastructure Operating Area Climate-Weather Change Process (C-WCP) Including Extreme Weather Hazards (EWH) C-WCP Model*.

[3] EU-CIRCLE Report D6.4-GMU1. (2017). *Critical Infrastructure Operation Process General Model (CIOPGM) Application to Port Piping Transportation System Operation Process Related to Operating Environment Threats (OET) and Extreme Weather Hazards (EWH)*.

[4] Kołowrocki, K. (2014). *Reliability of large and complex systems*, Elsevier, ISBN: 978080999494.

[5] Kołowrocki, K. & Soszyńska-Budny, J. (2017). Critical infrastructure operation process, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 2, 1-6.

[6] Kołowrocki, K. & Soszyńska-Budny, J. (2011). *Reliability and Safety of Complex Technical Systems and Processes: Modeling-Identification-Prediction-Optimization*. Springer, ISBN: 9780857296931.

[7] Kołowrocki, K., Soszyńska-Budny, J. & Torbicki, M. (2017). Critical infrastructure operation process related to climate-weather change process including extreme weather hazards, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 2, 7-14.

[8] Kołowrocki, K., Soszyńska-Budny, J. & Torbicki, M. (2017). Identification methods and procedures of climate-weather change process including extreme weather hazards, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 2, 59-84.

[9] Kołowrocki, K., Soszyńska-Budny, J. & Torbicki, M. (2017). Integrated impact model on critical infrastructure safety related to climate-weather change process including extreme weather hazards, *Summer Safety & Reliability Seminars.*

Journal of Polish Safety and Reliability Association 8, 4, 33-48.

[10] Torbicki, M. (2017). Identification and prediction of climate-weather change process for port oil piping transportation system operating area, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 2, 107-112.