

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 operating environment threats and extreme weather hazards

Keywords

climate-weather change process, identification, prediction, operating environment threats, piping transportation system

Abstract

The paper is concerned with an application of the critical infrastructure operation process including operating environment threats and extreme weather hazards model to identification and prediction of this process for the port oil piping transportation system. There are distinguished three processes for the considered piping operating area. Further, using identified parameters of the operation process including operating environment threats and the climate-weather change processes for the piping operating area, there are determined the unknown parameters of these processes. Namely, the probabilities of the piping processes staying at the initial states, the probabilities of the piping processes transitions between the states and the mean values of the piping processes conditional sojourn times at particular states. Finally, there are predicted the main characteristics of the piping operation process including operating environment threats and extreme weather hazards at the distinguished operating area.

1. Introduction

The piping operation process including operating environment threats is described in [1]. The climate-weather change process for the piping operating area is modelled in [2], [7]-[8]. In this paper, the identification of the piping operation process including operating environment threats and extreme weather hazards is performed. To do this, we can use the evaluated parameters of the piping operation process including operating environment threats from [1] and parameters of the climate-weather change process at its operating area from [8]. This way, having this processes identified, the prediction of the piping operation process including operating environment threats and extreme weathers hazards characteristics is performed.

2. Port oil piping transportation system operation process including operating environment threats related to climate-weather change identification

Assuming that the piping operation process including operating environment threats and the climate-weather change processes at its operating area are independent, to identify the unknown parameters of the piping operation process including operating environment threats related to climate-weather change processes only the suitable statistical data coming from real realizations of the piping operation process including operating environment threats and of the piping climate-weather change processes should be collected. The statistical identification of the piping operation process including operating environment threats related to climate-weather change was performed: the operation states were distinguished and the vector of probabilities of the piping operation process including operating environment threats related to climate-weather

Piping operation process including operating environment threats 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 including operating environment threats 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 including operating environment threats related to climate-weather change process $ZC^2(t)$ [3]:

- the vector

$$\begin{aligned} [p'q_{ij}(0)]_{1 \times 168} = & [0.32109361, 0.00203438, 0, \\ & 0.01186724, 0.00406877, 0, 0.00081442, \\ & 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, \\ & 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, \\ & 0.00000091, 0, 0.04646361, 0.00029438, 0, \\ & 0.00171724, 0.00058877, 0, 0.00081442, \\ & 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, \\ & 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, \\ & 0.00000091, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.21692361, \\ & 0.00137438, 0, 0.00801724, 0.00274877, 0, \\ & 0.00081442, 0.00000516, 0, 0.0000301, \\ & 0.00001032, 0, 0, 0, 0, 0, 0, 0.00007197, \\ & 0.00000046, 0, 0.00000266, 0.00000091, 0, \\ & 0.17904361, 0.00113438, 0, 0.00661724, \\ & 0.00226877, 0, 0.00081442, 0.00000516, 0, \\ & 0.0000301, 0.00001032, 0, 0, 0, 0, 0, 0, 0, \\ & 0.00007197, 0.00000046, 0, 0.00000266, \\ & 0.00000091, 0, 0.17904361, 0.00113438, 0, \\ & 0.00661724, 0.00226877, 0, 0.00081442, \\ & 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, \\ & 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, \\ & 0.00000091, 0] \end{aligned} \quad (4)$$

of initial probabilities of the piping operation process including operating environment threats related to climate-weather change process $ZC^2(t)$ staying at the initial moment $t = 0$ at the operation states $z'c_{ij}$, $i = 1, 2, \dots, 28, j = 1, 2, \dots, 6$;

- the matrix $[p'q_{ijkl}]_{168 \times 168}$, of the probabilities $p'q_{ijkl}$, $i, k = 1, 2, \dots, 28, j, l = 1, 2, \dots, 6$, of transitions of the piping operation process related to climate-weather change process $ZC^2(t)$ from the operation state $z'c_{ij}$ into the operation state $z'c_{kl}$ could be found in [3];

- the matrix $[N'_{ijkl}(t)]_{168 \times 168}$ of the mean values of the piping operation process related to climate-weather change process $ZC^2(t)$ conditional sojourn times $\theta' C'_{ijkl}$, $i, k = 1, 2, \dots, 28, j, l = 1, 2, \dots, 6$, at the

operation state $z'c_{ij}$, when the next operation state is $z'c_{kl}$ could be found in [3].

Piping operation process including operating environment threats 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 including operating environment threats 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 including operating environment threats related to climate-weather change process $ZC^3(t)$ [3]:

- the vector

$$\begin{aligned} [p'q_{ij}(0)]_{1 \times 448} = & [0.00406877, 0.04000955, 0, 0, 0, \\ & 0.26582618, 0.01186724, 0, 0, 0, 0.01729226, 0, 0, \\ & 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, \\ & 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0.00000091, 0.00000897, 0, 0, 0, 0.00005958, \\ & 0.00000266, 0, 0, 0, 0.00000388, 0, 0, 0, 0, 0, \\ & 0.00058877, 0.00578955, 0, 0, 0, 0.03846618, \\ & 0.00171724, 0, 0, 0, 0.00250226, 0, 0, 0, 0, 0, \\ & 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, \\ & 0.0000301, 0, 0, 0, 0.00004386, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, \\ & 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, 0, \\ & 0, 0.00000388, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0.00274877, 0.02702955, 0, 0, 0, 0.17958618, \\ & 0.00801724, 0, 0, 0, 0.01168226, 0, 0, 0, 0, 0, \\ & 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, \\ & 0.0000301, 0, 0, 0, 0.00004386, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, \\ & 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, \\ & 0, 0, 0.00000388, 0, 0, 0, 0, 0.00226877, \\ & 0.02230955, 0, 0, 0, 0.14822618, 0.00661724, 0, \\ & 0, 0, 0.00964226, 0, 0, 0, 0, 0, 0.00001032, \\ & 0.00010148, 0, 0, 0, 0.00067424, 0.0000301, 0, 0, \\ & 0, 0.00004386, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, 0, 0, 0.00000091, 0.00000897, 0, 0, 0, \\ & 0.00005958, 0.00000266, 0, 0, 0, 0.00000388, 0, \\ & 0, 0, 0, 0, 0.00226877, 0.02230955, 0, 0, 0, \\ & 0.14822618, 0.00661724, 0, 0, 0, 0.00964226, 0, \\ & 0, 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, \\ & 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0, \end{aligned}$$

0.00041345, 0, 0.00124034, 0.00076783, 0,
 0.00082474, 0.00000602, 0, 0.00001806,
 0.00001118, 0, 0, 0, 0, 0, 0, 0.00007288,
 0.00000053, 0, 0.0000016, 0.00000099, 0,
 0.00197938, 0.00001445, 0, 0.00004334,
 0.00002683, 0, 0.00082474, 0.00000602, 0,
 0.00001806, 0.00001118, 0, 0, 0, 0, 0, 0,
 0.00007288, 0.00000053, 0, 0.0000016,
 0.00000099, 0, 0.00102038, 0.00000745, 0,
 0.00002234, 0.00001383, 0, 0.00082474,
 0.00000602, 0, 0.00001806, 0.00001118, 0, 0,
 0, 0, 0, 0, 0, 0.00007288, 0.00000053, 0,
 0.0000016, 0.00000099, 0, 0.19090238,
 0.00139345, 0, 0.00418034, 0.00258783, 0,
 0.00082474, 0.00000602, 0, 0.00001806,
 0.00001118, 0, 0, 0, 0, 0, 0.00007288,
 0.00000053, 0, 0.0000016, 0.00000099, 0,
 0.05472438, 0.00039945, 0, 0.00119834,
 0.00074183, 0, 0.00082474, 0.00000602, 0,
 0.00001806, 0.00001118, 0, 0, 0, 0, 0, 0,
 0.00007288, 0.00000053, 0, 0.0000016,
 0.00000099, 0, 0.26954038, 0.00196745, 0,
 0.00590234, 0.00365383, 0, 0.00082474,
 0.00000602, 0, 0.00001806, 0.00001118, 0, 0,
 0, 0, 0, 0, 0, 0.00007288, 0.00000053, 0,
 0.0000016, 0.00000099, 0]; (11)

Piping operation process including operating environment threats 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 including operating environment threats related to climate-weather change process $Z^3C^3(t)$ transient probabilities $p'q_{ij}$, $i = 1, 2, \dots, 28$, $j = 1, 2, \dots, 16$, at the particular operation states z^3c_{ij} , are given in the vector [3]:

$[p'q_{ij}]_{1 \times 448} \cong [0.00039406, 0.01497443, 0, 0,$
 $0, 0.34165349, 0.01221598, 0, 0, 0.0043347,$
 $0.02049133, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0.00005906, 0.00224443,$
 $0, 0, 0, 0.05120849, 0.00183098, 0, 0, 0.0006497,$
 $0.00307133, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0, 0.00000206, 0.00007843,$

$0, 0, 0, 0.00178949, 0.00006398, 0, 0, 0.0000227,$
 $0.00010733, 0, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0.00000106, 0.00004043,$
 $0, 0, 0, 0.00092249, 0.00003298, 0, 0, 0.0000117,$
 $0.00005533, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0.00019906, 0.00756443,$
 $0, 0, 0, 0.17258849, 0.00617098, 0, 0, 0.0021897,$
 $0.01035133, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0.00005706, 0.00216843,$
 $0, 0, 0, 0.04947449, 0.00176898, 0, 0, 0.0006277,$
 $0.00296733, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0.00028106, 0.01068043,$
 $0, 0, 0, 0.24368249, 0.00871298, 0, 0, 0.0030917,$
 $0.01461533, 0, 0, 0, 0, 0.00000086, 0.00003268,$
 $0, 0, 0, 0.00074562, 0.00002666, 0, 0, 0.00000946,$
 $0.00004472, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,$
 $0, 0, 0, 0, 0, 0.00000008, 0.00000289, 0, 0, 0,$
 $0.00006589, 0.00000236, 0, 0, 0.00000084,$
 $0.00000395, 0, 0, 0, 0, 0].$ (12)

3.2. Total sojourn times of piping operation process including operating environment threats related to climate-weather change

Piping operation process including operating environment threats 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 $\theta^1 C_{ij}^1$, $i = 1, 2, \dots, 28$, $j = 1, 2, \dots, 6$, of the piping operation process including operating environment threats related to climate-weather change process $Z^1C^1(t)$ at the particular operation states z^1c_{ij} , during the fixed operation time $Z^1C^1 = 1$ month (February) = 29 days, are given in the vector (its coordinates are measured in days) [3]:

$$[\hat{M}' \hat{N}_{ij}^1]_{1 \times 168} = [E[\theta' C_{ij}^1]]_{1 \times 168} \cong [10.296498, 0.99422353, 0.01142774, 0, 0.09142279, 0.03428351, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 1.5432831, 0.14901853, 0.00171274, 0, 0.01370279, 0.00513851, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 0.05393014, 0.00520753, 0.00005974, 0, 0.00047879, 0.00017951, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 0.02780114, 0.00268453, 0.00003074, 0, 0.00024679, 0.00009251, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 1.4910251, 0.14397253, 0.00165474, 0, 0.01323879, 0.00496451, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 7.3439211, 0.70912453, 0.00815074, 0, 0.06520679, 0.02445251, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667]; (13)$$

Piping operation process including operating environment threats 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 $\theta' C_{ij}^2$, $i = 1, 2, \dots, 28, j = 1, 2, \dots, 6$, of the piping operation process including operating environment threats related to climate-weather change process $Z^C(t)$ at the particular operation states z^c_{ij} , during the fixed operation time $Z^C = 1$ month (February) = 29 days, are given in the vector (its coordinates are measured in days) [3]:

$$[\hat{M}' \hat{N}_{ij}^2]_{1 \times 168} = [E[\theta' C_{ij}^2]]_{1 \times 168} \cong [10.959314, 0.07999505, 0, 0.23998486, 0.14856207, 0,$$

$$0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 1.642629, 0.01199005, 0, 0.03596986, 0.02226707, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 0.05740202, 0.00041905, 0, 0.00125686, 0.00077807, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 0.02959102, 0.00021605, 0, 0.00064786, 0.00040107, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 5.536169, 0.04041005, 0, 0.12122986, 0.07504707, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 1.587007, 0.01158405, 0, 0.03475186, 0.02151307, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 7.816671, 0.05705605, 0, 0.17116786, 0.10596107, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0]; (14)$$

Piping operation process including operating environment threats 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 $\theta' C_{ij}^3$, $i = 1, 2, \dots, 28, j = 1, 2, \dots, 16$, of the piping operation process including operating environment threats related to climate-weather change process $Z^C(t)$ at the particular operation states z^c_{ij} , during the fixed operation time $Z^C = 1$ month (February) = 29 days, are given in the vector (its coordinates are measured in days) [3]:

$$[\hat{M}' \hat{N}_{ij}^3]_{1 \times 448} = [E[\theta' C_{ij}^3]]_{1 \times 448} \cong [0.01142774, 0.43425847, 0, 0, 0, 9.9079512, 0.35426342, 0, 0, 0.1257063, 0.59424857, 0, 0, 0, 0, 0, 0.00002494, 0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0, 0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232, 0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0, 0.00002436, 0.00011455, 0, 0, 0, 0, 0, 0.00171274, 0.06508847, 0, 0, 0, 1.4850462, 0.05309842, 0, 0, 0.0188413, 0.08906857, 0, 0, 0, 0, 0, 0.00002494,$$

0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0,
0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232,
0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0,
0.00002436, 0.00011455, 0, 0, 0, 0, 0.00005974,
0.00227447, 0, 0, 0, 0.05189521, 0.00185542, 0, 0,
0.0006583, 0.00311257, 0, 0, 0, 0, 0.00002494,
0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0,
0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232,
0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0,
0.00002436, 0.00011455, 0, 0, 0, 0, 0.00003074,
0.00117247, 0, 0, 0, 0.02675221, 0.00095642, 0, 0,
0.0003393, 0.00160457, 0, 0, 0, 0, 0.00002494,
0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0,
0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232,
0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0,
0.00002436, 0.00011455, 0, 0, 0, 0, 0.00577274,
0.21936847, 0, 0, 0, 5.0050662, 0.17895842, 0, 0,
0.0635013, 0.30018857, 0, 0, 0, 0, 0.00002494,
0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0,
0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232,
0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0,
0.00002436, 0.00011455, 0, 0, 0, 0, 0.00165474,
0.06288447, 0, 0, 0, 1.4347602, 0.05130042, 0, 0,
0.0182033, 0.08605257, 0, 0, 0, 0, 0.00002494,
0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0,
0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232,
0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0,
0.00002436, 0.00011455, 0, 0, 0, 0, 0.00815074,
0.30973247, 0, 0, 0, 7.0667922, 0.25267642, 0, 0,
0.0896593, 0.42384457, 0, 0, 0, 0, 0.00002494,
0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0,
0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232,
0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0,
0.00002436, 0.00011455, 0, 0, 0, 0, 0]. (15)

4. Conclusions

The probabilistic model of the critical infrastructure operation process including operating environment threats and extreme weather hazards presented in [5]-[6] was applied to identification and prediction of this process for the port oil 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 including operating environment threats 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 [4].

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 Model2. (2016). *Critical Infrastructure Operation Process (CIOP) Including Operating Environment Threats (OET) Model2*.
- [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. & Soszyńska-Budny, J. (2017). Integrated impact model on critical infrastructure safety related to its operation process including operating environment threat and climate-weather change process including extreme weather hazards, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 4, 49-66.
- [5] Kołowrocki, K., Soszyńska-Budny, J. & Torbicki, M. (2017). Critical infrastructure operation process related to operating environment threats and extreme weather hazards, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 2, 41-58.
- [6] Kołowrocki, K. & Soszyńska-Budny, J. (2017). Identification methods and procedures of critical infrastructure operation process including operating environment threats, *Summer Safety & Reliability Seminars. Journal of Polish Safety and Reliability Association* 8, 2, 59-84.
- [7] Kuligowska, E. & Torbicki, M. Identification and prediction of climate-weather change processes for port oil piping transportation system and maritime ferry operation areas after their realisations successful uniformity testing. *17th ASMDA Conference Proceedings*, Applied

Stochastic Models and Data Analysis 2017,
London, United Kingdom, 2017.

- [8] 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.