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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 change staying at the initial operation states were evaluated.

2.1. States 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 piping operation process including operating environment threats related to climate-weather change process $Z'C^1(t),\ t \in <0,+\infty)$, can take $v'w^1 = 28 \cdot 6 = 168$ different operation states $z'c_{1\,1}, z'c_{1\,2}, \ldots, z'c_{28\,6}$;

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 piping operation process including operating environment threats related to climate-weather change process $Z'C^2(t),\ t \in <0,+\infty)$, can take $v'w^2 = 28 \cdot 6 = 168$ different operation states $z'c_{1\,1}, z'c_{1\,2}, \ldots, z'c_{28\,6}$;

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 piping operation process including operating environment threats related to climate-weather change process $Z'C^3(t),\ t \in <0,+\infty)$, can take $v'w^3 = 28 \cdot 16 = 448$ different operation states $z'c_{1\,1}, z'c_{1\,2}, \ldots, z'c_{28\,16}$.

2.2. Parameters of piping operation process 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

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 $Z'C^1(t)$ [3]:

- the vector

$$[p'q_{ij}(0)]_{1x168} = [0.24344795, 0.0762894, 0.00135626, 0, 0.01186724, 0.00610315, 0.00061748, 0.0001935, 0.00000344, 0, 0.0000301, 0.00001548, 0, 0, 0, 0, 0, 0, 0.00005457, 0.0000171, 0.0000003, 0, 0.00000266, 0.00000137, 0.03522795, 0.0110394, 0.00019626, 0, 0.00171724, 0.00088315, 0.00061748, 0.0001935, 0.00000344, 0, 0.0000301, 0.00001548, 0, 0, 0, 0, 0, 0, 0.00005457, 0.0000171, 0.0000003, 0, 0.00000266, 0.00000137, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.16446795, 0.0515394, 0.00091626, 0, 0.00801724, 0.00412315, 0.00061748, 0.0001935, 0.00000344, 0, 0.0000301, 0.00001548, 0, 0, 0, 0, 0, 0, 0.00005457, 0.0000171, 0.0000003, 0, 0.00000266, 0.00000137, 0.13574795, 0.0425394, 0.00075626, 0, 0.00661724, 0.00340315, 0.00061748, 0.0001935, 0.00000344, 0, 0.0000301, 0.00001548, 0, 0, 0, 0, 0, 0, 0.00005457, 0.0000171, 0.0000003, 0, 0.00000266, 0.00000137, 0.13574795, 0.0425394, 0.00075626, 0, 0.00661724, 0.00340315, 0.00061748, 0.0001935, 0.00000344, 0, 0.0000301, 0.00001548, 0, 0, 0, 0, 0, 0, 0.00005457, 0.0000171, 0.0000003, 0, 0.00000266, 0.00000137] \quad (1)$$

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

- the matrix $[p'q_{ij\,kl}]_{168x168}$ of the probabilities $p'q_{ij\,kl}$, $i, k = 1,2,\ldots,28, j, l = 1,2,\ldots,6$, of transitions of the piping operation process related to climate-weather change process $Z'C^1(t)$ from the operation state $z'c_{ij}$ into the operation state $z'c_{kl}$ could be found in [3];
- the matrix $[N'_{ij\,kl}(t)]_{168x168}$ of the mean values of the piping operation process related to climate-weather change process $Z'C^1(t)$ conditional sojourn times $\theta' C^1_{ij\,kl}$, $i, k = 1,2,\ldots,28, j, l = 1,2,\ldots,6$, 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 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 $Z'C^2(t)$ [3]:
- the vector

$$[p'q_{ij}(0)]_{1x168} = [0.32109361, 0.00203438, 0, 0.01186724, 0.00406877, 0, 0.00081442, 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, 0.00000091, 0, 0.04646361, 0.00029438, 0, 0.00171724, 0.00058877, 0, 0.00081442, 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, 0.00000091, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.21692361, 0.00137438, 0, 0.00801724, 0.00274877, 0, 0.00081442, 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, 0.00000091, 0, 0.17904361, 0.00113438, 0, 0.00661724, 0.00226877, 0, 0.00081442, 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, 0.00000091, 0, 0.17904361, 0.00113438, 0, 0.00661724, 0.00226877, 0, 0.00081442, 0.00000516, 0, 0.0000301, 0.00001032, 0, 0, 0, 0, 0, 0, 0, 0.00007197, 0.00000046, 0, 0.00000266, 0.00000091, 0] \quad (4)$$

of initial probabilities of the piping operation process including operating environment threats related to climate-weather change process $Z'C^2(t)$ staying at the initial moment $t = 0$ at the operation states $z'c_{ij}$, $i = 1,2,\ldots,28$, $j = 1,2,\ldots,6$;
- the matrix $[p'q_{ij\,kl}]_{168x168}$, of the probabilities $p'q_{ij\,kl}$, i, $k = 1,2,\ldots,28$, j, $l = 1,2,\ldots,6$, of transitions of the piping operation process related to climate-weather change process $Z'C^2(t)$ from the operation state $z'c_{ij}$ into the operation state $z'c_{kl}$ could be found in [3];
- the matrix $[N'_{ij\,kl}(t)]_{168x168}$ of the mean values of the piping operation process related to climate-weather change process $Z'C^2(t)$ conditional sojourn times $\theta' C^2_{ij\,kl}$, i, $k = 1,2,\ldots,28$, j, $l = 1,2,\ldots,6$, 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 $Z'C^3(t)$ [3]:
- the vector

$$[p'q_{ij}(0)]_{1x448} = [0.00406877, 0.04000955, 0, 0, 0, 0.26582618, 0.01186724, 0, 0, 0, 0.01729226, 0, 0, 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, 0, 0, 0.00000388, 0, 0, 0, 0, 0, 0.00058877, 0.00578955, 0, 0, 0, 0.03846618, 0.00171724, 0, 0, 0, 0.00250226, 0, 0, 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, 0, 0, 0.00000388, 0.00274877, 0.02702955, 0, 0, 0, 0.17958618, 0.00801724, 0, 0, 0, 0.01168226, 0, 0, 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, 0, 0, 0.00000388, 0, 0, 0, 0, 0, 0.00226877, 0.02230955, 0, 0, 0, 0.14822618, 0.00661724, 0, 0, 0, 0.00964226, 0, 0, 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, 0, 0, 0.00000388, 0, 0, 0, 0, 0, 0.00226877, 0.02230955, 0, 0, 0, 0.14822618, 0.00661724, 0, 0, 0, 0.00964226, 0, 0, 0, 0, 0, 0.00001032, 0.00010148, 0, 0, 0, 0.00067424, 0.0000301, 0, 0, 0, 0.00004386, 0,$$

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000091, 0.00000897, 0, 0, 0, 0.00005958, 0.00000266, 0, 0, 0, 0.00000388, 0, 0, 0, 0, 0] (7)

of initial probabilities of the piping operation process including operating environment threats related to climate-weather change process $Z'C^3(t)$ staying at the initial moment $t = 0$ at the operation states $z'c_{ij}$, $i = 1,2,\ldots,28$, $j = 1,2,\ldots,16$;

- the matrix $[p'q_{ij\,kl}]_{448x448}$ of the probabilities $p'q_{ij\,kl}$, $i, k = 1,2,\ldots,28$, $j, l = 1,2,\ldots,16$, of transitions of the piping operation process related to climate-weather change process $Z'C^3(t)$ from the operation state $z'c_{ij}$ into the the operation state $z'c_{kl}$ can be found in [3];
- the matrix $[N'_{ij\,kl}(t)]_{448x448}$ of the mean values of the piping operation process related to climate-weather change process $Z'C^3(t)$ conditional sojourn times $\theta' C^3_{ij\,kl}$, $i, k = 1,2,\ldots,28$, $j, l = 1,2,\ldots,16$, at the operation state $z'c_{ij}$, when the next operation state is $z'c_{kl}$ can be found in [3].

3. Piping operation process including operating environment threats related to climate-weather change prediction characteristics

The piping operation process including operating environment threats 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 including operating environment threats related to climate-weather change, we can predict basic characteristics of this process.

3.1. Transient probabilities of piping operation process including operating environment threats related to climate-weather change

<u>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</u>

The limit values of the piping operation process including operating environment threats related to climate-weather change process $Z'C^1(t)$ transient probabilities $p'q_{ij}$, $i = 1,2,\ldots,28$, $j = 1,2,\ldots,6$, at the particular operation states $z'c_{ij}$, are given in the vector [3]:

$[p'q_{ij}]_{1x168} \cong$ [0.35505166, 0.03428357, 0.00039406, 0, 0.00315251, 0.00118219, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023, 0.05321666, 0.00513857, 0.00005906, 0, 0.00047251, 0.00017719, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023, 0.00185966, 0.00017957, 0.00000206, 0, 0.00001651, 0.00000619, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023, 0.00095866, 0.00009257, 0.00000106, 0, 0.00000851, 0.00000319, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023, 0.17935666, 0.01731857, 0.00019906, 0, 0.00159251, 0.00059719, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023, 0.05141466, 0.00496457, 0.00005706, 0, 0.00045651, 0.00017119, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023, 0.25323866, 0.02445257, 0.00028106, 0, 0.00224851, 0.00084319, 0.00077486, 0.00007482, 0.00000086, 0, 0.00000688, 0.00000258, 0, 0, 0, 0, 0, 0.00006848, 0.00000661, 0.00000008, 0, 0.00000061, 0.00000023]; (10)

<u>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</u>

The limit values of the piping operation process including operating environment threats related to climate-weather change process $Z'C^2(t)$ transient probabilities $p'q_{ij}$, $i = 1,2,\ldots,28$, $j = 1,2,\ldots,6$, at the particular operation states $z'c_{ij}$, are given in the vector [3]:

$[p'q_{ij}]_{1x168} \cong$ [0.37790738, 0.00275845, 0, 0.00827534, 0.00512283, 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, 0.05664238, 0.00041345, 0, 0.00124034, 0.00076783, 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, 0.00197938, 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, 0.00007288, 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, 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, 0.00007288, 0.00000053, 0, 0.0000016, 0.00000099, 0]; (11)

<u>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</u>

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

$[p'q_{ij}]_{1x448} \cong$ [0.00039406, 0.01497443, 0, 0, 0, 0.34165349, 0.01221598, 0, 0, 0.0043347, 0.02049133, 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, 0.00000008, 0.00000289, 0, 0, 0, 0.00006589, 0.00000236, 0, 0, 0.00000084, 0.00000395, 0, 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, 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, 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, 0.00000008, 0.00000289, 0, 0, 0, 0.00006589, 0.00000236, 0, 0, 0.00000084, 0.00000395, 0, 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, 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, 0.00000008, 0.00000289, 0, 0, 0, 0.00006589, 0.00000236, 0, 0, 0.00000084, 0.00000395, 0, 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, 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, 0.00000008, 0.00000289, 0, 0, 0, 0.00006589, 0.00000236, 0, 0, 0.00000084, 0.00000395, 0, 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, 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, 0.00000008, 0.00000289, 0, 0, 0, 0.00006589, 0.00000236, 0, 0, 0.00000084, 0.00000395, 0, 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, 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, 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

<u>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</u>

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

$[\hat{M}'\hat{N}^1_{ij}]_{1x168} = [E[\theta' C^1_{ij}]]_{1x168} \cong [10.296498,$ $0.99422353, 0.01142774, 0, 0.09142279, 0.03428351, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 1.5432831, 0.14901853, 0.00171274, 0, 0.01370279, 0.00513851, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 0.05393014, 0.00520753, 0.00005974, 0, 0.00047879, 0.00017951, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 0.02780114, 0.00268453, 0.00003074, 0, 0.00024679, 0.00009251, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 5.2013431, 0.50223853, 0.00577274, 0, 0.04618279, 0.01731851, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 1.4910251, 0.14397253, 0.00165474, 0, 0.01323879, 0.00496451, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667, 7.3439211, 0.70912453, 0.00815074, 0, 0.06520679, 0.02445251, 0.02247094, 0.00216978, 0.00002494, 0, 0.00019952, 0.00007482, 0, 0, 0, 0, 0, 0, 0.00198592, 0.00019169, 0.00000232, 0, 0.00001769, 0.00000667];$ (13)

<u>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</u>

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

$[\hat{M}'\hat{N}^2_{ij}]_{1x168} = [E[\theta' C^2_{ij}]]_{1x168} \cong [10.959314,$ $0.07999505, 0, 0.23998486, 0.14856207, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 1.642629, 0.01199005, 0, 0.03596986, 0.02226707, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 0.05740202, 0.00041905, 0, 0.00125686, 0.00077807, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 0.02959102, 0.00021605, 0, 0.00064786, 0.00040107, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 5.536169, 0.04041005, 0, 0.12122986, 0.07504707, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 1.587007, 0.01158405, 0, 0.03475186, 0.02151307, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0, 7.816671, 0.05705605, 0, 0.17116786, 0.10596107, 0, 0.02391746, 0.00017458, 0, 0.00052374, 0.00032422, 0, 0, 0, 0, 0, 0, 0, 0.00211352, 0.00001537, 0, 0.0000464, 0.00002871, 0];$ (14)

<u>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</u>

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

$[\hat{M}'\hat{N}^3_{ij}]_{1x448} = [E[\theta' C^3_{ij}]]_{1x448} \cong [0.01142774,$ $0.43425847, 0, 0, 0, 9.9079512, 0.35426342, 0, 0, 0.1257063, 0.59424857, 0, 0, 0, 0, 0, 0.00002494, 0.00094772, 0, 0, 0, 0.02162298, 0.00077314, 0, 0, 0.00027434, 0.00129688, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0.00000232, 0.00008381, 0, 0, 0, 0.00191081, 0.00006844, 0, 0, 0.00002436, 0.00011455, 0, 0, 0, 0, 0, 0.00171274, 0.06508847, 0, 0, 0, 1.4850462, 0.05309842, 0, 0, 0.0188413, 0.08906857, 0, 0, 0, 0, 0, 0.00002494,$

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

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