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Methodology for oil pipeline critical infrastructures safety and resilience to climate change analysis

Keywords

critical infrastructure, oil pipeline, safety, climate change, resilience, unnatural threats, natural hazards

Abstract

In the paper there are described the oil pipeline network as the critical infrastructure. The basic definitions concerned with oil pipeline critical infrastructure are given. Moreover the climate and weather impacts on oil pipeline critical infrastructure safety and resilience are described.

1. Introduction

To ensure compatibility in the usage and communication of key terms across the work packages of EU-CIRCLE project the common “working terminology” should be fixed at the first steps of the project activity.

The critical infrastructure network which is a set of interconnected and interdependent critical infrastructures interacting directly and indirectly at various levels of their complexity and operating activity, the interconnected critical infrastructures that are critical infrastructures in mutually direct and indirect connections between themselves and the interdependent critical infrastructures that are critical infrastructures in mutually dependant relationships between themselves interacting at various levels of their complexity [7].

Considering above definitions concerned with critical infrastructures and their networks and the nature and features of the industrial installations at the Baltic Sea Region, we are convinced to distinguish the following 8 main critical infrastructure networks operating in this region:

- port critical infrastructure network;
- shipping critical infrastructure network;
- oil rig critical infrastructure network;
- wind farm critical infrastructure network;
- electric cable critical infrastructure network;
- gas pipeline critical infrastructure network;
- oil pipeline critical infrastructure network;
- ship traffic and operation information critical infrastructure network.

We classify the above distinguished shipping critical infrastructure network to the class of so called dynamic installations and the remaining distinguished 7 critical infrastructures to the class of so called static installations.

We also distinguish, in our opinion, the most natural and important in this region the network of networks composed of the port critical infrastructure network, the shipping critical infrastructure network and the ship traffic and operation information critical infrastructure network.

The present existing and planned natural oil pipeline networks in the Baltic Sea region, are particularly described in [6].

2. State of art

Before the considerations on critical infrastructure at Baltic Sea Region taxonomy, we refer to definitions of selected basic notions concerned with critical infrastructures and climate and weather impacts on their safety included in the report [7].

2.1. Oil pipeline critical infrastructure terminology – general terms

Critical infrastructures are those physical and information technology facilities, networks, services and assets which, if disrupted or destroyed, would have a serious impact on the health, safety, security or economic well-being of citizens or the effective functioning of government [13].

Oil pipelines are part of the energy infrastructure. *Energy infrastructure* is a total system of generation, transport, distribution, trade, supply and consumption of energy. This means not only the physical network (e.g. power plants, gas and oil pipes, heat delivery stations), but also the social (economic and institutional) network that manages and controls the physical system. Together, these networks form a socio-technical infrastructure system. It is a complex system in which the technological, economic, and institutional domains are strongly interdependent [16].

In a narrower meaning, oil pipelines are part of the energy branch called g*as and oil production, storage and transportation infrastructure*. It is a critical infrastructure consisted of the production and holding facilities for natural gas, crude and refined petroleum, and petroleum-derived fuels, the refining and processing facilities for these fuels and the pipelines, ships, trucks, and rail systems that transport these commodities from their source to systems that are dependent upon gas and oil in one of their useful forms [34].

Crude oil transported by oil pipelines is a *primary energy* (also referred to as *energy sources*) i.e. the energy embodied in natural resources (e.g., coal, crude oil, natural gas, uranium) that has not undergone any anthropogenic conversion. It is transformed into secondary energy by cleaning (natural gas), refining (oil in oil products) or by conversion into electricity or heat. When the secondary energy is delivered at the end-use facilities it is called final energy (e.g., electricity at the wall outlet), where it becomes usable energy (e.g., light) [7].

Critical infrastructure has to have assured safe operation. *System safety* is an ability of the system such that during fulfilling its operational objective it does not affect destructively on itself and other objects in its operating environment and does not degrade its natural operating environment [7].

2.2. Climate change terminology appropriate for oil pipelines critical infrastructure network

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. *Climate change* may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Influence on the oil pipelines can come from c*limate extreme (extreme weather or climate event)* which is an *extreme weather* event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called *extreme weather* may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an *extreme climate* event, especially if it yields an average or total that is itself extreme (e.g., drought or heavy rainfall over a season) [19].

Hydro-meteorological hazard is a process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage [20], [30]. Comment: Hydro-meteorological hazards include tropical cyclones (also known as typhoons and hurricanes), thunderstorms, hailstorms, tornados, blizzards, heavy snowfall, avalanches, coastal storm surges, floods including flash floods, drought, heat waves and cold spells. Hydro-meteorological conditions also can be a factor in other hazards such as landslides, wild land fires, locust plagues, epidemics, and in the transport and dispersal of toxic substances and volcanic eruption material [30].

Considering oil pipelines through the sea, or oil terminals at the coast, important factor for proper operation of such facility can be *extreme cold*. It may be very important in the regions of the world where temperature drops well below zero during winter, causing sea surface to freeze. What constitutes *extreme cold* and its effects can vary across different areas of the country. In regions relatively unaccustomed to winter weather, near freezing temperatures are considered “extreme cold” [27].

2.3. Resilience terminology appropriate for oil pipelines critical infrastructure network

Critical infrastructure resilience is an ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions [28].

Very similar term connected to resilience is *robustness*. *Robustness* signifies that a system will retain its system structure (function) intact (remains unchanged or nearly unchanged), when exposed to perturbations and can be measured as the probability that a system will not go into the critical state or worse in time shorter than assumed level T, due to some external factors [7].

Important feature that is tied with infrastructure resilience is its *vulnerability*. *Vulnerability* is the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity [4].

Valuable term which allows us to describe particular system resilience is *reliability*. *Reliability* can be defined as a degree of performance according to imposed standards or expectations [7]. From a mathematical point of view reliability is a Complement of the failure probability (www.inrisk.ubc.ca).

Reliability analysis address risk by providing the probability that a consequence measure exceeds a specific threshold (www.inrisk.ubc.ca). There are few more terms connected to resilience. First of them is c*ritical infrastructure risk management framework*. It is planning and decision-making framework that outlines the process for setting goals and objectives, identifying infrastructure, assessing risks, implementing risk management activities, and measuring effectiveness to inform continuous improvement in critical infrastructure security and resilience [31].

Risk management in general is the systematic approach and practice of managing uncertainty to minimize potential harm and loss. Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks. It is widely practiced by organizations to minimise risk in investment decisions and to address operational risks such as those of business disruption, production failure, environmental damage, social impacts and damage from fire and natural hazards. Risk management is a core issue for sectors such as water supply, energy and agriculture whose production is directly affected by extremes of weather and climate [30].

Preparedness defines the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions [30].

3. Oil pipeline critical infrastructure networks at Baltic Sea region taxonomy

Considering definitions of main notions from the above methodology concerned with oil pipeline critical infrastructures and their networks and the nature and features of the industrial installations at the Baltic Sea Region, we define the Baltic Oil Pipeline Critical Infrastructure Network (BOPCIN) composed of 9 following pipelines connected with the oil terminals near the Baltic seaside:

1. Oil piping system (OP_1 , 1 pipeline) transporting oil from oil rig installation in Russian Baltic EEZ to Baltic seaside Oil Terminal in Baltyisk near Kaliningrad;
2. Oil piping system (OP_2 , 2 pipelines) transporting oil from Skrudaliene (Russia-Latvian border) to Latvian Baltic Port Terminal in Ventspils;
3. Oil piping system (OP_3 , 1 pipeline) transporting oil from Mazeikiai Rafinery (Lithuania) to Butinge Oil Terminal (Latvia Baltic seaside);
4. Oil piping system (OP_4 , Pomeranian Pipeline, 1 pipeline) transporting oil from Oil Terminal in Płock (Central Poland) to Oil Terminal in Gdańsk (Poland Baltic seaside);
5. Oil piping system (OP_5 , 2-3 pipelines) transporting oil between the pier of Gdynia Port (Poland Baltic seaside) and Oil Terminal in Dębogórze (near Poland Baltic seaside);
6. Oil piping system (OP_6 , Friendship/Drushba Pipeline, 1 pipeline) transporting oil from Oil Terminal in Płock (Central Poland) to Oil Terminal in Schwedt-Rostock (Germany, near Baltic seaside);
7. Oil piping system (OP_7 , Pomeranian Pipeline, 1 pipeline) transporting oil from Oil Terminal in Timan-Pechora (Russia, West Siberia) to Oil Terminal in Primorsk (Russia, Gulf of Finland Baltic seaside);
8. Oil piping system (OP_8 , 1 pipeline) transporting oil from Oil Terminal in Unecha (Russia, Briansk

Region) to Oil Terminal in Ust-Luga (Russia, Gulf of Finland Baltic seaside);

9. Oil piping system (OP_9 , 1 pipeline) transporting oil from offshore platform Gorm "E"(located in North Sea) to Oil Terminal in Fredericia (Denmark Baltic seaside).

The Baltic Oil Pipeline Critical Infrastructure Network (BOPCIN) is described in details in [6].

First of all, the BOPCIN is interacting with the oil terminals associated with it. It is involved in cooperation with and dependent on the BSCIN (Baltic Shipping Critical Infrastructure Network), the BORCIN and other Baltic Industrial installations activity. The BOPCIN also cooperates and interacts with train and trucks European land oil transportation network and with other European and Asian land oil piping transportation critical infrastructures.

In the EU-CIRCLE project we analyse in details the oil piping transportation system OP_5 , which is part of BOPCIN [6].

3.1. Oil pipeline critical infrastructure taxonomy

In the EU project critical infrastructure (including pipeline systems) is described precisely and modeled. There are few terms closely related to the described critical infrastructure. One of them is *critical infrastructure integrated safety model*. It means modelling complex system operation process including its outside dependencies and operating environment hazards. Modelling complex system safety including inside dependencies between its components and subsystems. Constructing integrated critical infrastructure safety model composed of a complex system operation process model and its safety model including its inside and outside dependences and operating environment hazards [7].

Another concept related to the oil pipelines in the Baltic Sea region is c*omplex system* is a multistate ageing system composed of interacting components and subsystems related to its operation process having significant influence on its safety through changing its structure and its components' safety parameters in the different operation states [7]. Term strictly connected with above one is *complex system outside dependencies*. External dependencies and interactions coming from the complex system operating environment, including changes of the complex system structure and its components' safety parameters in different operation states and resulting in the complex system safety state changing caused by outside this system operational conditions related to changes of its functionality, location and other objects activity [7].

Definition related to our exemplary oil pipeline is *marine (liquid) bulk terminal*. It is large terminal located on a waterway. Generally, its receives and distributes petroleum via pipeline, barge, or marine tanker from either domestic or import suppliers. Liquid bulk terminals tend to deal with liquid fuels such as petroleum oil and Liquid Natural Gas (LNG) [33].

3.2. Climate change taxonomy

Climate change that is in progress nowadays is closely connected with global warming. And global warming cause a *sea-level rise.* That process will last in the future and will impact on the port oil terminals at the ends of oil pipelines. *Sea-level rise* means an increase in the mean level of the ocean. Eustatic sea-level rise is a change in global average sea level brought about by an increase in the volume of the world ocean. Relative sea-level rise occurs where there is a local increase in the level of the ocean relative to the land, which might be due to ocean rise and/or land level subsidence. In areas subject to rapid land-level uplift, relative sea level can fall [4]. Another factor that may have influence on the oil pipelines and terminals is a s*torm surge*. It is a temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place [18]. Important for an oil pipeline operation is *short-term climate-weather change prediction*, which can be defined as a climate-weather change prognosis for the nearest future time in the fixed area/environment. Similar influence come from *hazard caused by weather change*. It is an event associated with extreme weather that may cause the loss of life or severe injury, property damage, social and economic disruption or environmental degradation. For instance: a dangerous chemical release (spill) into the sea water as a result of ship accident cause by severe storm. In the Baltic Sea area winters can be severe occasionally. But even during "average" winter a c*old waves/spells* may occur. Cold spell is a series of an extremely cold days or a succession of frost days with minimum temperatures well below 0°C [5].

3.3. Resilience taxonomy

One of the most important matters regarding *critical infrastructure* is its *robustness (in climate change context)*. It is an inherent strength or ability of infrastructure to withstand external demands coming from climate change without degradation or loss of functionality [7].

For safe operation of an oil pipeline the most important thing is *prevention*. It can be described in various way which are listed below

1. The outright avoidance of adverse impacts of hazards and related disasters [20].
2. Those capabilities necessary to avoid, prevent, or stop a threatened or actual act of terrorism [25]
3. The systematic application of recognized principles to reduce incidents, accidents, or the accident potential of a system or organization. [17]

During proper planning of prevention *technological hazards* have to be taken into account. *Technological hazard* is range of hazards emanating from the manufacture, transportation, and use of such substances as radioactive materials, chemicals, explosives, flammables, agricultural pesticides, herbicides and disease agents; oil spills on land, coastal waters or inland water systems; and debris from space [33].

4. Conclusion

In the paper there are given the basic definitions concerned the Baltic Oil Pipeline Critical Infrastructure Network (BOPCIN). All of those definitions are taken from EU-CIRCLE taxonomy document and divided into separate subsets. Those subsets are: oil pipeline general terms, climate change and resilience.

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