Implementation of Petri Nets in the Analysis of Pipeline Accidents

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This paper aims to demonstrate the implementation of Petri net modeling of the National Environmental Council Resolution, CONAMA, which is responsible for the Emergency Plan, triggered in case of pipeline accidents to identify process characteristics such as fluidity, dynamics, and identify potential bottlenecks and critical stages of the process. The Petri Net is a mathematical representation that can be simulated in software such as PIPE. It was identified through the simulations that the discrete system modeled from the emergency plane is fluid and lively, without any abnormal concentration in places, also called transitions inputs. It has been able to describe the process steps and characteristics in detail and can serve as a basis for future implementation of an algorithm for simulation study and automation project design in this area. It can be concluded that the Petri net has extensive utilization and great implementation potential both in emergency action and in other areas. Using it in the described situation allowed us to identify the crucial points of the emergency plan and analyze it broadly, identifying its main points of activity.

Keywords: oil, pipeline, Petri Net

INTRODUCTION

The oil production process consists of prospecting, drilling, extraction, and transportation. The latter is done through pipelines, gas pipelines, oil tankers and marine terminals to the refineries and industries (BRASIL, 2015). Through oil and gas pipelines, transportation becomes more efficient and safer.

Given the growing offshore exploration in the country, which in 2012 reached the mark of 90 rigs operating off the Brazilian coast, the use of pipelines for moving oil, oil products and natural gas are essential points in the logistics of the oil industry process; an incident can lead to losses, operational disorders, environmental contamination, fires, and explosions (Almeida, 2017). One should consider that pipeline transport is designed to travel long distances, through areas where they are subject to environmental variations, soil movement and the action of third parties, further intensifying the risks (ANP, 2015).

With a high history of failures occurring both in Brazil, as is the case of the leaks in the PE-II pipeline, which connects the Duque de Caxias Refinery (REDUC) to the facilities of the Southeast Pipelines and Terminals-DTSE / Ilha D'Água (GEGUA); Gas Pipeline PCR-01 / Lubnor; and the P-55 platform that is 2.3 km away in the Roncador field; as in other countries such as the United States, which with statistics released by PHMSA point to an average of 521 accidents per year in pipelines in the country; (ANP, 2015).

The ANP has requirements for authorization and/or permission for construction and operation of subsea systems, where in article 44 of Law 9.478/1997 there is provision for concessionaires to adopt "measures necessary for the conservation of reservoirs and other natural resources, the safety of people and equipment and environmental protection. However, it was identified that despite this, the regulatory provisions are insufficient to obtain the desired results in relation to operational safety and environmental protection (ANP, 2015).

With the need for initiatives that aim to reduce the rates of incidents on pipelines, this work has as its prerogative the implementation of the Petri Net System in the process of executing post-incident emergency plans.

Petri nets are a mathematical model with graphical representation that has been widely used for over 30 years in various fields, among which are manufacturing systems, communication, transportation, information, logistics and, in general, all discrete event systems. To specify, analyze the logical behavior, evaluate the performance and implement these types of systems are the main motivations for the use of Petri Net (Cardoso; Valette, 1997).

Thus, with the Petri Net System, an improvement and agility in the decision-making process is sought with the mechanization of this process in the operational scope of pipeline safety, bringing a discrete, but commendable, reduction of risks in these operations.

Information was collected from theoretical bibliographic surveys. Norms and technical notes on pipeline safety made available by the ANP (National Petroleum, Natural Gas and Biofuels Agency) and CONAMA (National Environment Council) resolutions were used as base material for modeling.

The method proposed in this research for modeling is characterized as a case study, since it addresses the situational environment of compliance with technical standards in cases of accidents and implementing them in Petri net simulation systems. The modeling and analysis developed in this paper were developed in the "PIPE" editor (Nakamura et al., 1997). A graph will be made through PIPE where the software will simulate the whole process from the accident to the study of cause and consequence through Petri net analysis of discrete events. The modeling of the Petri net system will follow the implementation model proposed by Cardoso and Valette (1997). With this, the research methodology will consist of: theoretical study, process description, elaboration of the flowchart, development of the Petri net, as well as network analysis and process evaluation.

METHODOLOGY

Petri Net

A Petri Net is a representation for discrete events that has a strong mathematical basis. Unlike traditional data processing, it can hold more than one token. The graphical representation of a basic Petri net consists of two components: an active one called a transition, and a passive one called a place. The places are the states and the and transitions are the activities performed.

The main concepts worked in the Petri Net are: events, which are observation instants of state change in the system; the concept of activities, called black boxes because they are used to recover and hide the evolution of the physical system between two events; and the concept of processes, which are sequences of interdependent events and activities. One can exemplify that a process provokes an activity, which provokes an end-of-activity event, which in turn can provoke another activity, and so on (Cardoso; Valette, 1997).

A Petri net consists of positions, transitions, and directed arcs. Arcs connect transitions and positions. The entry positions of a transition are those to which an arc is intended; while the exit positions are those from which an arc originates. You cannot connect positions and positions or transitions and transitions (Cardoso; Valette, 1997).

In the analysis the discrete event definition will be used, as consisting of modeling and operating a system as a sequence of discrete events in time. Each event occurs at a given instant of time and marks a change of state in the system. Between consecutive events, it is considered that the system does not undergo any change, so the simulation can jump directly from the instant of occurrence of one event to the next (Cardoso; Valette, 1997).

The use of these simulations allows you to have a general idea of the process without having to put your entire system into practice, consequently reducing costs and allowing an overview of the activity and its problems. To get more information about the activities and events of the dynamic behavior of the interpreted network it is necessary to simulate it. Through simulation you can analyze the behavior of the predicted possibilities (Cardoso; Valette, 1997).

Accidents on Pipelines

The movement of oil, natural gas and their derivatives is a hazardous activity due to the volatile and non-biodegradable nature of the products. Spills can occur as a result of structural failures in the installations, third party failures, human failures in the execution of procedures, errors in environmental, geological and geotechnical analysis (Cardoso, 2007).

The absence or inadequacy of safety procedures can cause meltdowns, explosions, fires and other accidents involving the workforce, which cause environmental damage, damage to life and limb and financial loss. In short, accidents with oil pipelines are unexpected events that directly or indirectly affect the safety and the company, and can cause significant impacts to the environment, with high associated costs, with release of significant quantities of fluids into the sea, dispersed by sea currents and air currents. In addition, they may directly or indirectly harm the population living on the coast of the affected areas (ANP 2015).

MODEL DEVELOPMENT PROCESS

From the resolution of CONAMA no 398, June 11, 2008, one can view the emergency plan chain after the disaster as, (Brasil, 2008):

1. Identification of the installation: should contain basic information about the installation;
2. Accidental scenarios: this section must contain the definition of the accidental scenarios with the indication of the spill volume and the probable behavior and destination of the spilled product;
3. Information and procedures for response: this section should contain all the necessary information and procedures for response to an oil pollution incident;
    1. Oil spill warning systems: In this section, the procedures and equipment used for oil spill warning should be described;
    2. Reporting the incident: This section should contain the list of individuals, organizations, and official institutions that should be reported in the event of an oil pollution incident;
    3. Response Organizational Structure: This section should include the oil pollution incident response organizational structure for each considered accidental scenario, including in-house and contracted personnel;
    4. Response equipment and materials: In this section, the oil pollution incident response equipment and materials should be listed;
    5. Operational Response Procedures: In this section, all response procedures planned for oil spill control and cleanup should be described for each accidental scenario considered.
4. Closing of operations: Should be included in this section:
    a. criteria for deciding on the closure of operations;

b. procedures for demobilizing personnel, equipment, and materials used in response actions;
c. procedures for defining supplementary actions

5. Maps, nautical charts, plans, drawings and photographs: all maps, nautical charts, plans, drawings and photographs must be included in this section;

Annexes: in this section, complementary information to the Individual Emergency Plan should be included.

RESULTS AND DISCUSSION

From these, they will be simulated by means of software to obtain the entire simulated process in order to bring information about its liveness. Figure 1 shows a flowchart of the process.

FIGURE 1
PROCESS FLOWCHART

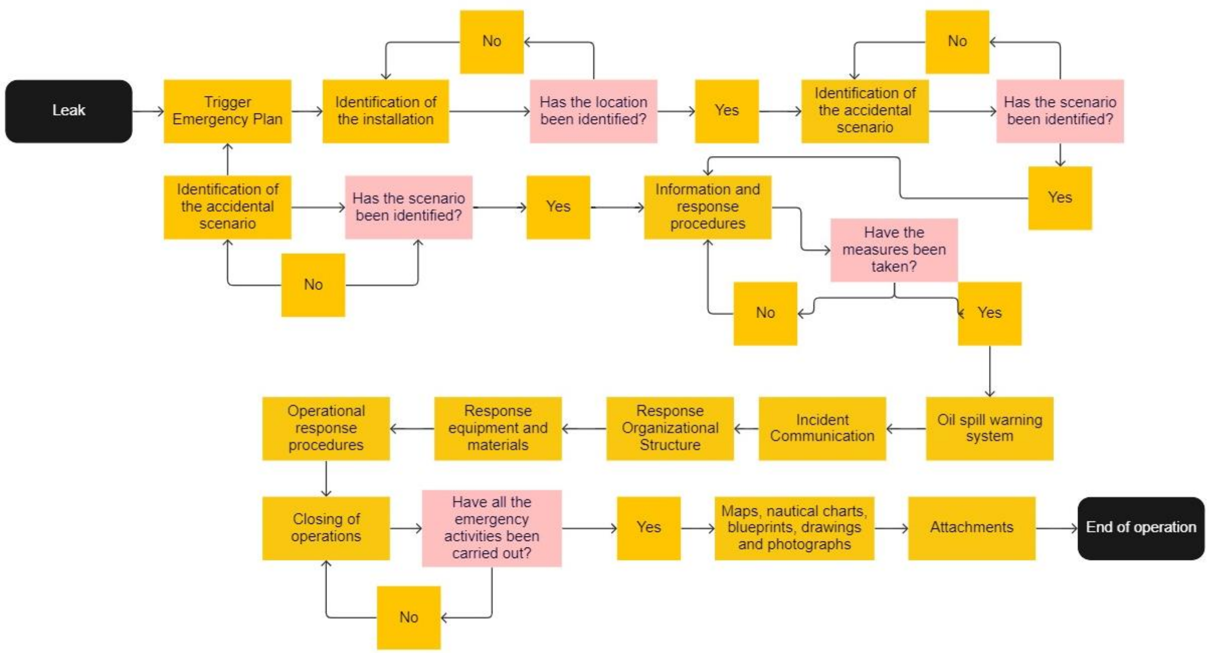


Figure 1 shows the schematic flowchart of the entire procedure from the leak to the final documentation post emergency standard procedures. Tables 1 and 2 identify each location and transition, respectively, used in the simulation.

TABLE 1
IDENTIFICATION OF THE PETRI NET LOCATIONS

P0	Leak
P1	Identification of the installation
P2	Accidental Scenarios
P3	Accidental Scenarios
P4	Information and response procedures
P5	Oil spill warning systems
P6	Incident Communication

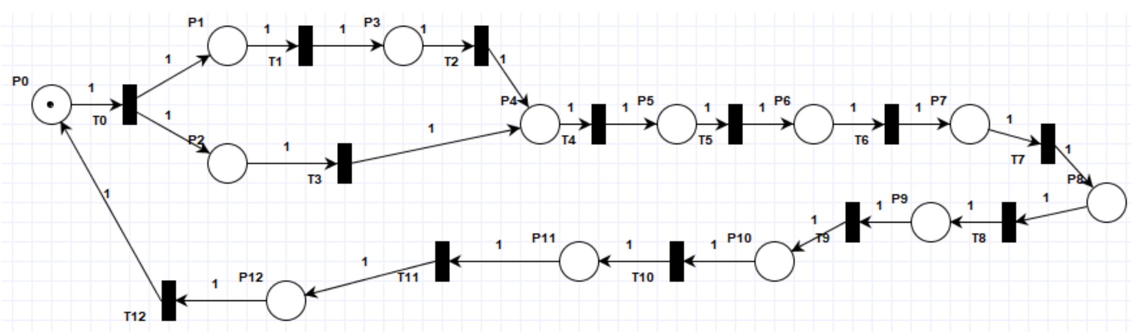
P7	Response Organizational Structure
P8	Response equipment and materials
P9	Operational response procedures
P10	Closing of operations
P11	Maps, nautical charts, blueprints, drawings and photographs
P12	Attachments

TABLE 2
IDENTIFICATION OF PETRI NET TRANSITIONS

T0	Individual Emergency Plan Triggering
T1	Basic installation information
T2	Identification of the accidental scenario
T3	Identification of the accidental scenario
T4	Response to the accident
T5	Oil Spill Alert Procedures
T6	Communicate in case of an oil pollution incident
T7	Response procedures for each accidental scenario
T8	Use of response equipment and materials
T9	Response Procedures
T10	Closing the Response Action
T11	Formulation of topographic maps
T12	Conclusive documents of the accident

Table 1 shows the places following the CONAMA emergency plan, in which twelve places are identified and simulated. In Table 2 the transitions are identified, having twelve transitions according to the transcription of the emergency plan for the Petri net structure. The structure of the simulated Petri net is shown in Figure 2:

FIGURE 2
PROCESS PETRI NET



It can be concluded from the Petri Net shown in Figure 2 that the installation identification step and accidental scenario can occur simultaneously, but never in isolation. Table 3 shows the simulation results for the average number of tokens and the confidence interval of the presence of tokens at each place in the Petri Net:

TABLE 3
SIMULATION RESULTS

Place	Average number of Tokens	Confidence interval of 95% (+/-)
P0	0,11881	0,19421
P1	0,25743	0,30771
P2	0,23762	0,17156
P3	0,19802	0,04526
P4	0,59406	0,33848
P5	0,50495	0,19498
P6	0,40594	0,76571
P7	0,38614	0,10657
P8	0,58416	0,30952
P9	0,37624	0,17383
P10	0,19802	0,11355
P11	0,13861	0,20994
P12	0,51485	0,35222

In Table 3 it is shown that the average number of tokens per place varies along the network; besides showing that the value of the confidence interval for the presence of tokens in each place in the network tends to be 0 (zero) in 95% of the simulation iterations, this demonstrates that there is no overload in any of the places modeled in the Petri Net. Thus, showing that the system is fluid, lively and without overloads in its process.

CONCLUSIONS

This work presented a discrete event model of the Emergency Leak Plan in Petri Nets that, besides being able to describe in detail the steps and characteristics of the process, will serve as a basis for future studies in the area of algorithm, simulation, flexible manufacturing system, and automation projects.

The Petri Net allows a schematic and systemic visualization for monitoring the dynamics of the decision-making process for emergency activities, localization, response procedure, and closing activities, for example, which have predominantly discrete characteristics. For objects of hybrid nature, with strong human influence, as is the case of transitions, the Petri net can represent them globally, inserted in the context of discrete systems.

From the information previously presented, it can be concluded that the Petri net has wide use and great potential for implementation. Using it in the described situation allowed us to identify the crucial points of the emergency plan and analyze it in a broad way, identifying its main points of activity. This work has the initiative of spreading the wide use of the Petri net for all the demands of processes that can be described in discrete events, thus helping all the productive chains.

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