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# Risk analysis of offshore pipeline due to third party damages

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**Abstract.** The third party damage also known as external factor that contributed to pipeline failure was an unexpected event that considered as threats to human safety. In this work, two risk assessment approaches namely qualitative and quantitative were adopted to predict and measure the causes of offshore pipeline failure due to the third party damages. Qualitative analysis involving causal and consequences of an event was developed using Bow-tie (BT) model to determine the contributing parameter of an event. The parameters obtained were then converted to Bayesian Network (BN) for a quantitative approach. Based on the qualitative analysis, the major threats identified in third party damage were categorized into “anchor impact” and “impact” meanwhile the consequences were human safety, marine life ecosystem and economical loss. Statistical data from PARLOC 2012 were utilized for BN model and transformed into conditional probability table (CPTs). the results generated indicate that the major contribution to pipeline damage was “trawling”. The utilization of Bow-tie and BN analysis may complement the risk analysis of offshore pipeline due to third party damage for more informed pipeline maintenance decisions.

## 1. Introduction

The Pipeline is an essential carrier in oil and gas industries. Since it is carrying hazardous material for the global use, safety precaution is crucial to avoid any failure that could lead to fatalities. There are lot of causes lead to pipeline failure which will gives impact to industrial oil and gases around the world. Oil spillage happened due to pipeline leakage or ruptured will arouse world’s concern. Many party will involve directly and indirectly. Meanwhile, accidents involving fire or explosion and carbon dioxide emission gives number of severe consequences, including loss of lives, injuries, environmental damage and various economic costs [1-2]. For the company itself, they will have bad reputation among society. In fact, the company also will experience with great losses in term of costing considering of product lost, public, private, and operator property damage along with clean-up and recovery costs. Therefore, maintaining pipeline integrity become the main priority in offshore pipeline because the consequences may result in catastrophic event.

From the literature, with 38% occurrence, third party damage giving the most contributing factor to pipeline failure due to anchoring activities and impact comprises with dropping object and fishing activities [3]. An extensive length of offshore pipeline become the major obstruction to detect or inspecting any problem regarding to the pipeline. In fact, the maintenance planning of oil and gas pipelines is a challenging task because of the complexity and high cost of maintenance operations



[4]. An extensive length of offshore pipeline become the major obstruction to detect or inspecting any problem regarding to the pipeline. Other than that, limited data availability become the main concern for the risk assessment.

Risk assessment is a tool designed to establish a proactive safety strategy by investigating potential risks [5]. Risk assessment was developed to overcome common problem faced in offshore pipeline. Risk assessment of pipeline failure can be a challenging task whereby scenarios leading to failure, the probability of a failure and the consequences of a failure have to be assessed in a risk assessment process. A number of qualitative and quantitative techniques have been implemented for risk assessment of oil and gas pipeline [6–10]. Fault tree analysis (FTA) and Event tree analysis (ETA) are two well established and most commonly used techniques for risk and reliability studies. Bow-tie, on the other hand, is a common platform which couples ETA and FTA by considering the common top-event named as critical event and reflects a corresponding relationship between reasons and consequences. The concept of a fault tree or event tree is following the Boolean logic, which in some circumstances may not reflect the reality. Fault tree is as well difficult to be used for quantitatively assessing system reliability because of its limited expressive power. In addition, fault tree and event tree allow the one-way inference that limits their applicability in the field of systematic risk mitigation and management.

Bow-tie (BT) is a graphical method that is broadly utilized in process industry accident modelling. Bow-tie diagram comprises of an integration of a FTA and ETA on a same platform. This method is able to portray a complete accident occurrence scenario from the causes, hazards and the consequence [11]. This bow-tie model however is limited to model mutual cause failures and conditional dependencies due to the static characteristic [12].

Another method so called the Bayesian Network is different from bow-tie method. It is an inference probabilistic method, that can overcome the static limitation of bow-tie method due to its updating mechanism. Furthermore, this method can also carry out a forward and backward prediction as well as diagnosis analysis [13]. The adaptation of Bayesian networks approaches in safety and risk assessment is due to several features offered by Bayesian network. In addition, communication of the model is strongly facilitated by means of transparent graphical representation of the undesired events and their causal relationships. Based on the above criteria, the Bayesian network is often implemented it can take full advantage of its flexible structure to fit a wide variety of accidents [14].

The Bayesian theory also is coupled with bow-tie model in order to use new evidence precursor data in updating the prior failure probability of primary events and safety barriers [15]. Qualitative analysis involving causal and consequences of an event was developed using Bow-tie model to determine the contributing parameter of an event. The parameters obtained were then proceed to quantitative analysis using by mapping bow tie model into Bayesian Network [16]. This work implements the last approach in developing a risk assessment used to predict and measure the root of offshore pipeline failure, qualitative and quantitatively.

## 2. Methodology

### 2.1. Bow-Tie method

A Bow-tie model was developed under few steps using BowtieXP software. The first step was to identify the top event. Top event is basically known as an incident that occurs when a hazard is released. In this work, the top event is the pipeline failure due to the third party damages. The next step was the assessment of the threats and consequences where the threats were positioned on the left hand side in the Bow-tie diagram. Meanwhile, the consequences were positioned on the right hand side of the diagram as the result from the top event. Barriers were then introduced in order to control the threats. For each threat, barriers were assessed to control the escalation factor from resulting to the top event.

### 2.2. Bayesian Network development

Bayesian Network is mapped from the proposed Bow Tie model. Each node established represents a variable while each arc representing a causal relation among two variables [17]. Conditional probability tables were assigned to the nodes denote conditional dependencies. Each CPT holds conditional probabilities of a child node being in a specific state of its parent's nodes. The conditional probability

table (CPT's) can be elicited from the domain expert [18], by conversion of Boolean operations [3-19] or through the framework, literature, or observational experience [20]. In this study, the best available source to carry out the CPT elicitation is from the Pipeline and Riser Loss of Containment PARLOC 2001 [21]. Once the information (evidence) available obtained, a software programme HUGIN provide the parameter learning algorithms was utilized [3], [18]. Lastly, the essential steps in performing the probability assessment is to prove the model to help assess whether the model selected is reliable or not.

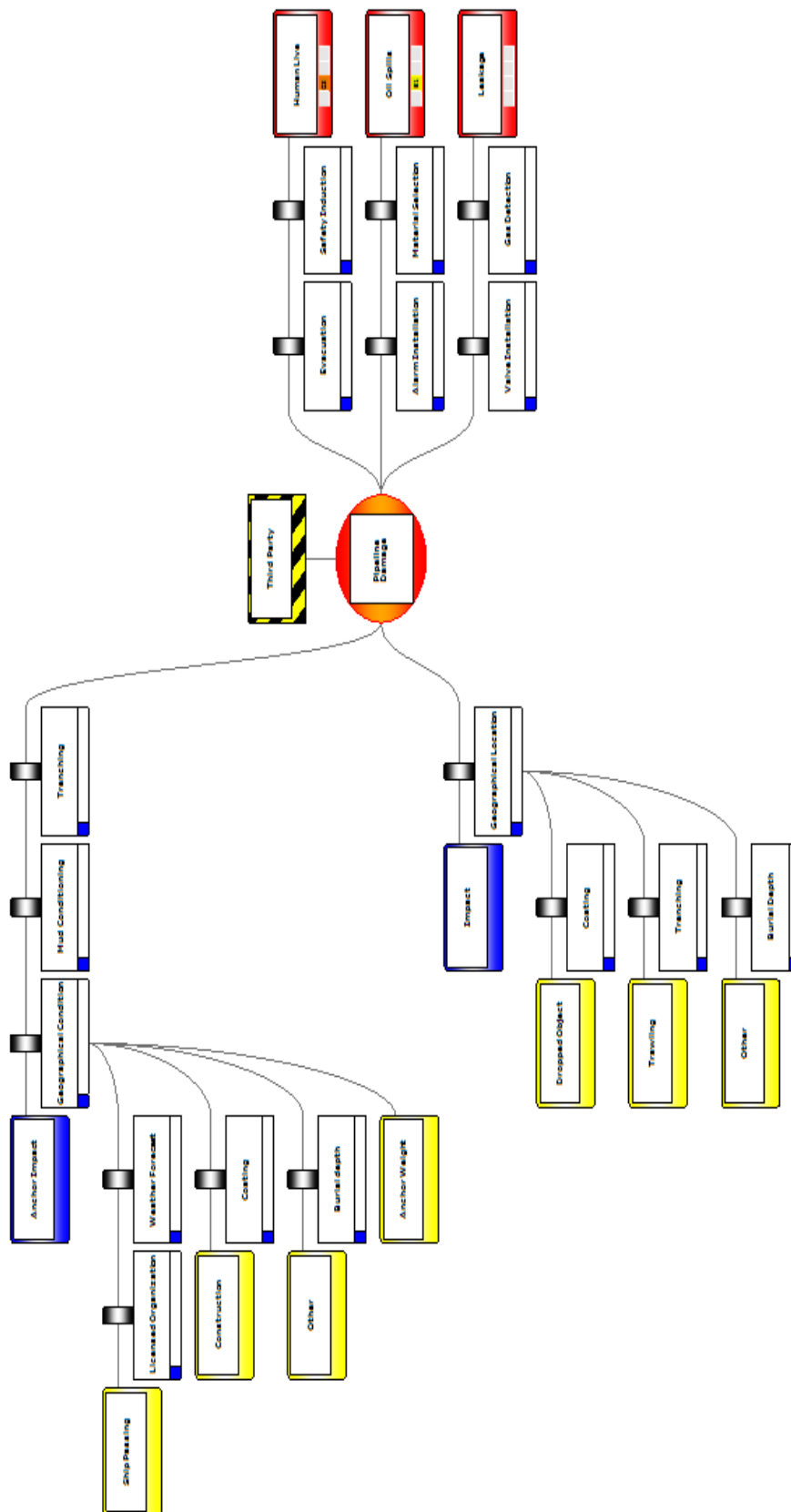
### 3. Results and discussions

#### 3.1. *Qualitative analysis*

Third party damage is known as damages due directly to the acts of man and includes all activities not directly related to the pipeline of study. As reported in [21], the scenarios that lead to the third party damages are categorized into two main factors namely impact and anchor smash. Impact on the pipeline may be caused by the trawling activities and dropped object. Meanwhile anchor smash impact are due to ship passing and construction activities. Due to the third party activities, three consequences that are human loss, oil spill and economical loss can be envisaged for the accident scenario depending on the success or failure of the safety barriers. Based on the collected data, a BT was developed as shown in figure 1.

#### 3.2. *Quantitative analysis using Bayesian Network*

3.2.1. *Risk analysis.* The BT diagram was converted and mapped into a BN as shown in figure 2. Once the network model was developed, Conditional Probability Tables (CPTs) are elicited for further analysis. In this work, CPTs were assigned based on the data gathered from various existing reports and literatures. Table 1 shows example of data collected from [21]. Other than that, the consequences of failure data are collected from various existing literature [22-23]. The proposed BN model is then analyzed using HUGIN.



**Figure 1.** Qualitative Analysis by Bow-Tie Model

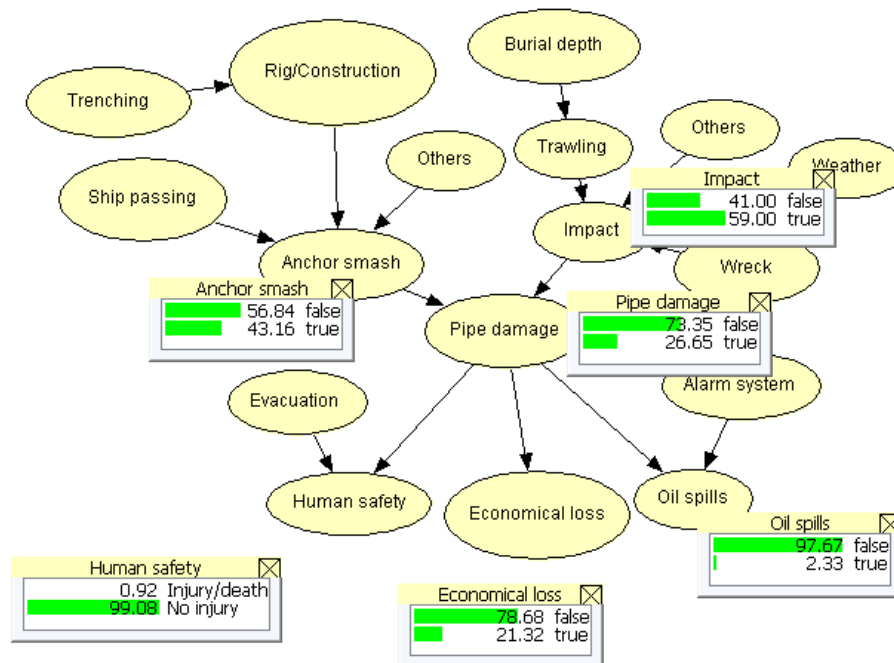
**Table 1.** Data of incidents happen [21].

Parameter	Sources	Number of incidents
Anchor	Ship/Supply Boat	6
	Rig or Construction	3
	Other/Unknown	10
	Total	19
Impact	Ship on Riser	-
	Trawl	23
	Dropped Object	-
	Wreck	1
	Construction	-
	Other/Unknown	9
	Total	33

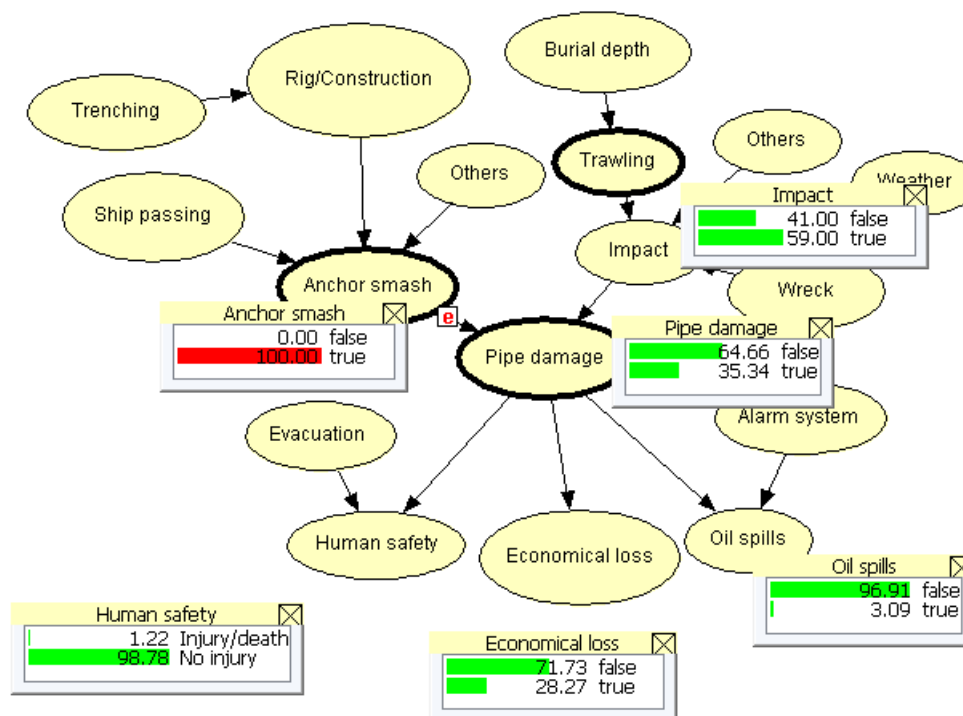
### 3.2.2. Probability analysis

The Bayesian Network model is used to revise the prior probabilities by taking into account the evidence which is a task not supported by BT. Entering the probabilities, the BN is now available to perform different types of analysis. In this study, the most significant purpose is in updating probabilities in the light of actual observations of events. In BN modelling, these are called evidences for the third party damages BN. By running the proposed model for this third party damages scenario, as can be seen in figure 2, the conditional probability that “death” happened from pipeline failure is 0.92% given 95% evacuation success. Meanwhile the “oil spill” is 2.33% given alarm is 95% work and probability of “economical loss” is 21.32%.

Entering pieces of evidence and using them to revise the probabilities in this way is called propagation. figure 3 shows the results with “*evidence*” node for anchor impact represented by an *evidence bar* with 100% occurrence. As would be expected, the probability of occurrence for pipeline damaged increases from 26.65% to 35.34% when anchor impact has been observed.



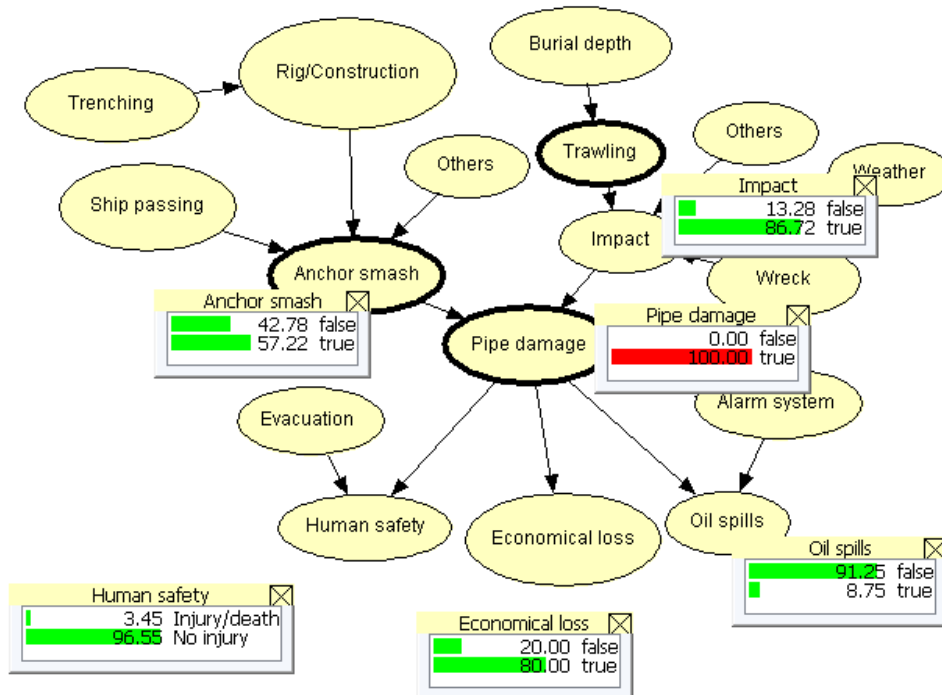
**Figure 2.** BN showing results for Pipeline Damage



**Figure 3.** BN showing propagated result when anchor impact is 100% occurred.

From figure 4, it shows that propagation of 100% pipeline damage happened will affect the results of its dependence variables. Based on “*human safety*” node, the significant effect is “*injury*” where it increased to 96.55% with 95.0% evacuation success. While for “*oil spills*” and “*economical loss*” are 3.09% with and 28.27% loss probability, respectively. Considering the after-event consequences,

pipeline failure gives significant effect towards human safety compared to economy and oil spillage. Furthermore, from the result obtained, “*impact*” node gives the higher probability risk factor compared to “*anchor smash*” and the major factor that causing the higher probability of impact is trawling activities. Thus the authorities may monitor the trawling activities to be in a safe area and away from the buried pipeline.



**Figure 4.** BN showing propagated result when pipeline damages is 100% occurred

#### 4. Conclusions

The Bow-tie model applied in figure 1 may help to determine the activities that could prevent and control pipeline damages from happened. The proposed model shown in figure 2 explicitly represent dependencies of events, updating probabilities and representation of uncertain knowledge. There is major difference between BT and BN analysis but both of the method complementing each other in risk assessment. In addition to generating a numerical value that can be employed in estimation of pipeline damage due to the third party activities, a BN model also provides the means to access how the underlying factors may affect the pipeline condition probability. The scenario analysis was able to assess the impact of evidence or knowledge for probability updating. Diagnosis analysis was conducted to determine the critical risk factor that may lead to catastrophic accident occurrence. It was found that the most contributing factor lead to pipeline damage due to third party was “*trawling*” activities. These analyses are appropriate to be used during model construction to gain detailed insight of the accidental occurrence. It is envisaged that this risk analysis approach may assist the operator by prioritizing the major contributor of pipeline failure, thus making the monitoring and inspection process of offshore pipeline at the right place and right time.

#### Acknowledgement

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