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Risk Analysis Methods for Pipelines in Niger Delta *(pp.94 -106)*

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Abstract: This paper focuses on all possible risks, which may occur when carrying out a pipeline operation on an existing pipeline within the Niger Delta region of Nigeria. Risk analysis methods for pipeline in Nigeria Niger Delta region were evaluated using A Failure Modes Effects and Criticality Analysis (FMECA) method. A Failure Modes Effects and Criticality Analysis (FMECA) of the complete pipeline process were carried out which identified most of the project's possible failure modes. Two specific methods of risk assessment – Risk matrix graph and Risk Priority Numbers (RPN) were then employed to verify the analysis and define the risk involved in each activity. The FMECA assessment process identified many intolerable risks. However, by identifying control measures that can be incorporated into the activity's procedure, the levels of risk were reduced to a satisfactory level. The application of this mitigation strategy resulted in only eight activities remaining at the medium risk level. Not one of these residual medium level risks would stop a typical pipeline project from proceeding.

Key words: legislation, regulation, pipeline system, financial loss, financial efficiencies

1 INTRODUCTION

Oil and gas sector is considered as the backbone of Nigeria economy, as industrialization, agriculture, transportation and even domestic utilization of energy depends on oil and gas sector. The necessity to move these products to their use points economically, efficiently, reliably, responsibly and safely has given rise to pipelines and pipeline networks. For efficient energy production there is a need of efficient transportation system (main and distribution network of pipelines) in the country, which is not sufficient to fulfill the country's requirement. Due to the growing demands, pipeline networks are expanding vigorously.

Pipelines are subjected to several risks, which can cause failure of the line. These risks can be divided into 6 groups: Installation- and design failures, Material failures, Failures caused by maintenance, Corrosion, Weather-conditions and buckling, and Failure caused by third parties (commonly referred to as Sabotage).

Unlike other hazardous plant, the transmission pipelines carrying hydrocarbon are not within a secure industrial site, but are routed across land not owned by the pipeline company. If the hydrocarbon is accidentally released and ignited, the hazard distance associated with these pipelines to people and property is known to range from under 20m for a smaller pipeline at lower pressure, up to over 300m for a large pipeline at high pressures. Therefore pipeline operators and regulators must address the associated public safety issues.

There should be legislations in Nigeria requiring pipeline operators to demonstrate that the risks associated with constructing and operating their oil and gas transmission pipelines have been assessed and are being managed. To meet this requirement, operators need to have their pipeline records (construction, operation, maintenance and inspection) under proper control, and they need a means of assessing the risks, particularly to those sections that lie within high consequence areas.

For most effective risk management it is recommended to plan, analyze and manage risk in all phases of a pipeline project life cycle i.e. initializing, concept clearance and feasibility, design, construction and operation. To limit the scope of this paper the discussion is confined to the risks occurring during construction and operation phase of the pipeline project. The notion of project risk involves two concepts: The Likelihood that some problematical event will occur and the impact of the event if it does occur.

Risk is a joint factor of two variables expressed as

Risk = f (likelihood, impact)

For risk assessment, expected value represents the average outcome of project, if it were repeated many times, accounting for the possible occurrence of risk.

Expected value = summation [(Outcomes) x (Likelihoods)]

The Likelihood of Failure (LOF) threats are grouped into nine threat type categories, which are as follows: Third-Party Damage (TP), External Corrosion (EC), Equipment (EQ), Incorrect Operations (IO), Construction (CONS), Manufacturing (MFG), Internal Corrosion (IC), Weather and Outside Forces (WOF), Stress Corrosion Cracking (SCC). Similarly, the outcomes of these likelihoods (the consequence of the Failure) could be an impact on the population, the business or the environment, as shown in the typical pipeline risk tree of Figure 1.

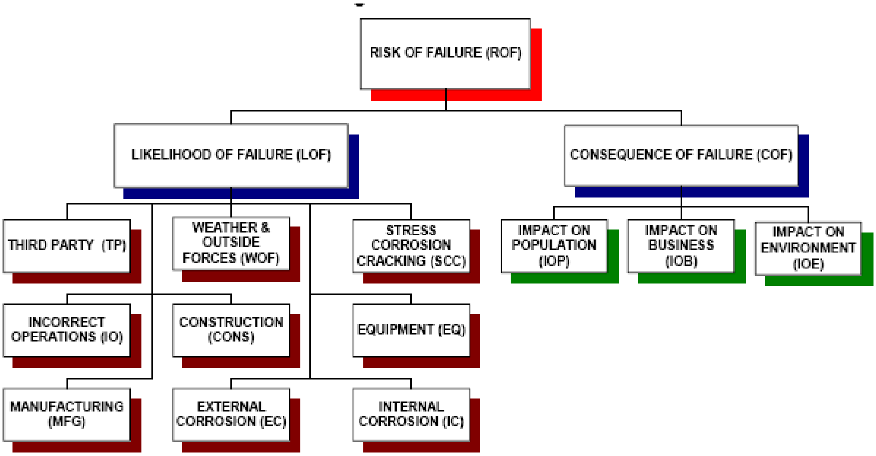

Figure 1: A Typical Pipeline Risk Tree.

The probability and consequence of failure profile (Maria *etal*, 2009) could be summarized as shown in Figure 2. It shows the 5 threats that contribute to the probability of failure and the 5 Effects contributing to the Consequence of failure.

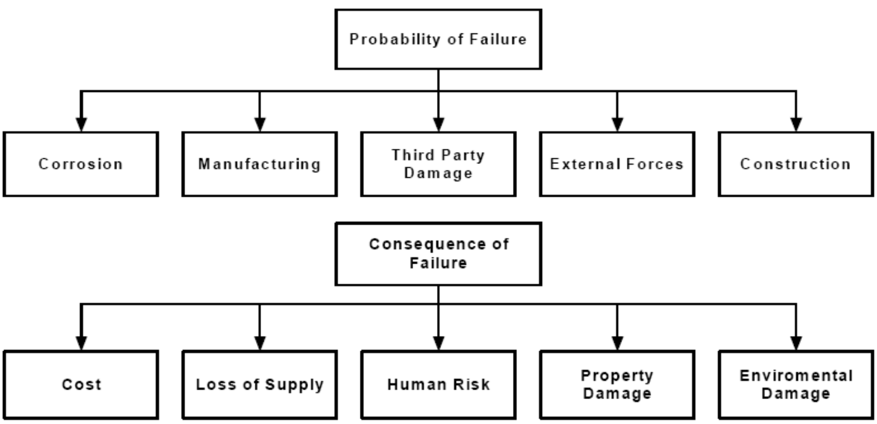

Figure 2: Probability and Consequence of Failure.

Robert (1998) enumerated the various elements of Risk Assessment and Risk control under the following headings:

Identify Uncertainties: Explore the entire project plans and look for areas of uncertainty.

Analyze Risks: Specify how those areas of uncertainty can impact the performance of the project, either in duration, cost or meeting the users' requirements.

Prioritize Risks: Establish which of those Risks should be eliminated completely, because of potential extreme impact, which should have regular management attention, and which are sufficiently minor to avoid detailed management attention.
Risk Control has three elements, as follows:

Mitigate Risks: Take whatever actions are possible in advance to reduce the effect of Risk. It is better to spend money on mitigation than to include contingency in the plan.

Plan for Emergencies: For all those Risks, which are deemed to be significant, have an emergency plan in place before it happens.

Measure and Control: Track the effects of the risks identified and manage them to a successful conclusion.

1.1 Aims and Objectives of Risks Management

The aim of project risk management is to guide the project successively from decision to completion, and to secure it from failure or time and cost overruns due to multidimensional risk factors. So with all the risks surrounding a typical pipeline project, one cannot afford not to use Risk analysis methods as we put the project at risk by not taking advantage of the following benefits: Risk analysis and evaluation, Comparison of variety of risk reactions and strategies, Optimizing and deciding the best strategy, Provision of early warning and Ability to be flexible and responsive to changes. The objective of this paper is then to determine the risk the pipeline poses to the public population along the pipeline Right-of-Way (route). This will require the completion of four major tasks.

Task 1: Determine potential pipeline accidents that could create life-threatening hazards to persons located near the pipeline.

Task 2: Derive the frequency of occurrence (probability) of each accident identified in the first task.

Task 3: Determine the consequences of each accident identified in the first task.

Task 4: Combine the consequences and the probability of occurrence of each accident to arrive at a measure of public risk created by the pipeline network.

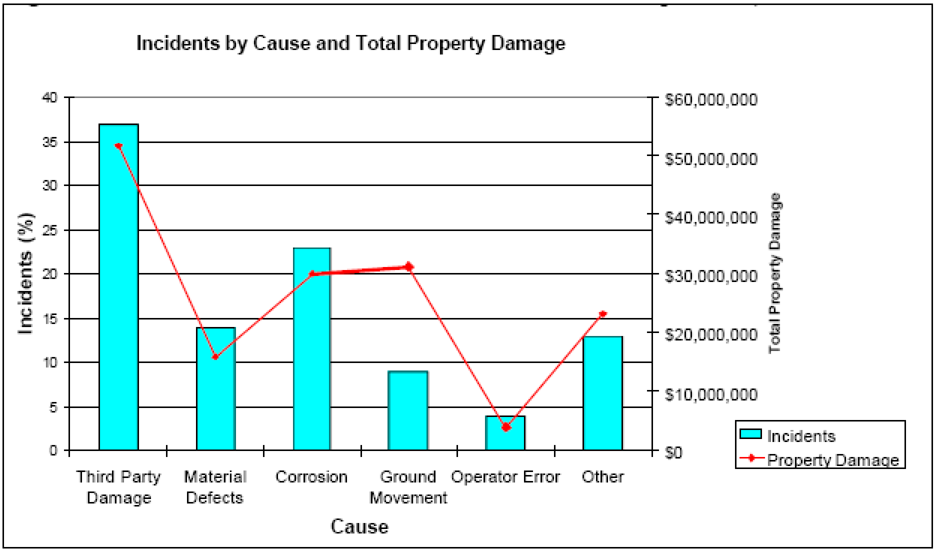

Figure 3: Incident Data for Gas Transmission Pipeline.

These tasks were carried out on two Independent Oil Companies (IOCs), operating in the Nigeria Niger delta, and the values obtained for the likelihood of failure were plotted against the Incidents (Frequency) and total property damage (consequence) as shown in Figure 3.

Risk is defined as the product of the likelihood of a failure of pipeline integrity and the consequence of such a failure; the overall business goals are to prevent the failure from occurring and to minimize the consequences if failure does occur. These business goals have been established for several reasons, which according to (Thorne, 2005; and Martin, 1992) include: To comply with legislation or Regulation (as per Directorate of Petroleum Resources-DPR), to avoid financial loss and *to achieve financial efficiencies.*

If a pipeline experiences a leak or a rupture, the financial loss suffered by a company can be considerable. The potential cost elements include: Cost of compensation for death or injury, Cost of compensation for damage to property, Loss of product, Cost of repair and re-commissioning, Loss of capacity during repair, Cost of environmental cleanup, Fines by regulatory bodies, Effect on investor confidence and stock price (to provide the maximum return on investment).

Based on the causes, the failure of a pipeline can lead to leaks or ruptures (Niederbaumer et al, 2000). The failure mode is determined by the length, depth and type of defect, and is dependent on the pipe diameter, wall thickness, material properties and operating pressure.

1.2 Threats to Pipeline Integrity

Although pipelines are generally buried and incidents are relatively rare, they cannot be considered as "fit and forget". Unless inspected and maintained, all pipelines may eventually suffer from leaks or ruptures.

Line rupture

Due to the pressure at which transmission pipelines are operated, a failure of a pipeline leads to a turbulent and complex fluid release. Following a rupture, or large puncture, there will be rapid depressurization in the vicinity of the failure. The various risk mitigation measures considered (Thomson, 1987) at specific sections of a pipeline as per increasing cost are: Increasing depth of cover, Concrete slab covering, Sleeving, Increasing pipe wall thickness and Reducing the distance (inventory) between sectionalizing valves

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2 METHODS OF ASSESSING PIPELINE RISK

There are several methods of assessing the risks associated with pipeline systems. Some of these methods are: Qualitative Methods (Relative Assessment) – the ranking approaches are based on the concept of risk scoring against a number of relevant parameters, with weighting applied to each of the parameters to reflect their perceived contribution to the overall level of risk. It requires much of the engineering knowledge. Quantitative methods of risk assessment are based on an understanding of the mechanisms causing pipeline failure, and consideration of the consequences of such an event.

The method incorporates information on: Loads applied, likely damage mechanisms (random and time dependent), variations in geometry and material parameters, and the effects of risk mitigating activities (such as in-line inspection, surveillance, pressure testing, and maintenance). But the method that is adopted in this paper will be an integration of both qualitative and quantitative method, which is referred in this paper as the Failure Modes Effects and Criticality Analysis.

2.1 Failure Modes Effects and Criticality Analysis

Failure Modes Effects and Criticality Analysis (FMECA) or simply Failure Modes Effect Analysis (FMEA) is a simple analysis method to reveal possible failures and to predict the failure effects on the system as a whole. The method is inductive; for each component of the system, we investigated what happens if this component fails. The method represents a systematic analysis of the components of the system to identify all significant failure modes and to see how important they are for the system's performance. Only one component is considered a time, and the other components are then assumed to function perfectly. Table 1 shows elements of FMECA table.

Table 1: Sample of a typical FMECA Table (McEwen, 2007)

ITEM NO.	COMPONENT OR OPERATION	FAILURE MODE	CAUSE OF FAILURE	FAILURE EFFECT	DETECTION METHOD	S	P	D	RPN

A Failure Modes Effects and Criticality Analysis (FMECA) on various sections of the pipeline were performed. From this, all possible risks were identified and each assigned a severity of failure (S), probability of occurrence (P) and detection of failure value (D). These values were used in two ways to analyze the operation's risk:

- To calculate a Risk Priority Number for each risk
- To plot all the actions and the threats they present to the operation on a risk matrix.

Risk Priority Number (RPN)

The RPN is used to compare the individual issues raised though the FMECA and quickly prioritizes the possible failure modes. Depending on the value of the RPN Table 2, the activity to which it corresponds will fall into one of the three risk categories; low, medium or high. The RPN is calculated simply by finding the product of the S, P and D values in (1).

$$RPN = Severity \times Probability \times Detection = S \times P \times D \quad (1)$$

Table 2: Color Assignment for RPN Risk Ranking

RISK LEVEL	COLOUR ASSIGNED	RPN VALUE RANGE
LOW		0 - 58
MEDIUM		59 - 479
HIGH		480 - 1000

Risk Matrix

A risk matrix pictorially represents how the consequence of each potential failure relates to another (Fig. 4). They are also a method of qualitative criticality analysis used to evaluate and prioritize activities which present risks. This is done by plotting the probability that the failure will occur (P) on the Y-axis against the severity of the failure (S) on the X axis.

Table 3: Colour Assignment for Risk Matrices Risk Categories

RISK LEVEL	COLOUR ASSIGNED
LOW	
MEDIUM	
HIGH	

The objective of this paper was to carry out a risk analysis of a Pipeline system in the Niger Delta region of Nigeria. Each activity involved in the Design, Construction, Operating and Maintenance procedures is assigned to one of three categories (Table 3); low, medium or high risk. From research and the organization of the data gathered from the FMECAs, RPN value rankings and risk matrices, control measures must now be put in place to reduce high and medium risks in order to ensure the pipeline operation system presents as low a risk as possible.

Evaluation of High Risks

The high risks identified by this evaluation are:

- Pipeline rupture due to high pressure

- Pipeline properties and its operating condition.
- Weld defects during Pipeline construction.
- Dropped Object
- Burn through or rupture from welding activity
- Welds do not meet set specifications

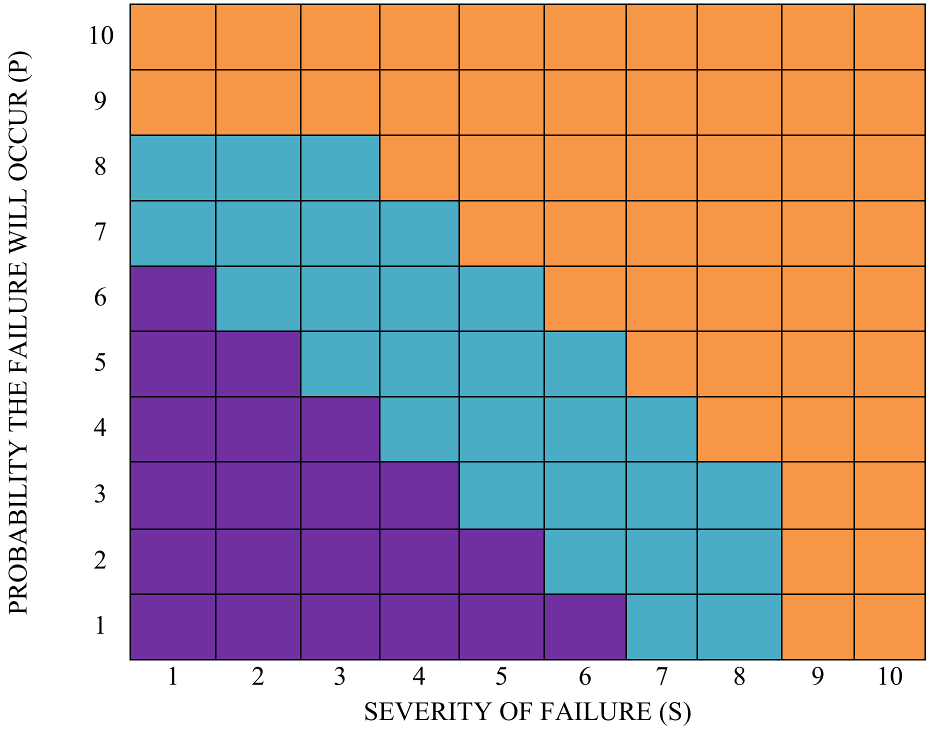

Figure 3: Typical Risk Matrix Graph for Pipeline

According to the RPN value ranking scale all potential risk activities were reduced to the low risk category once the control measures were in place.

A Pipeline procedure cannot proceed if any high risk items remained in the operations sequence of events. As none exist any longer the procedure will not be cancelled due to a high risk activity. The events which are rated as medium risks though may still hold the project back and present the Projects Manager with two choices:

- Allow the operation to proceed with extra caution as each item's risk has been made as low as reasonably possible.
- Delay or cancel the operation until time is spent to find other control measures to make the risk as low as reasonably possible or identify a different way of proceeding with the task, which presents a lower risk.

3 EVALUATION OF THE RISK ASSESSMENT METHODS

Risk assessments use "past experience and engineering judgment to rate each potential problem". Therefore our initial review of the processes involved in the Design, Construction, Maintenance and Operations of a Pipeline system is perhaps more open minded than that of someone with less Pipeline Engineering and Constriction experience. This means that the average S, P and D values assigned (as obtained from various respondents) are probably higher than those that would be assigned by a person who had been previously involved in a pipeline project. This is not necessarily a negative influence on the study as once we reevaluated the high and medium risks and identified appropriate control measures the S, P and D values were more in line with what could be anticipated. The reason for using two methods to analyze the assessment generated by the FMECA was to verify the outcome and identify any anomalous results that might be produced.

Generally the results gained from the RPN value ranking method and the risk matrices agree with which activities present the most risk, but there are a few discrepancies. On some occasions an activity which was categorized as a high risk on a risk matrix was only considered to be a low risk by its RPN value. This shows why the two methods are used to ensure no potentially harmful activity goes unnoticed.

By applying the RPN value ranking method it was easy to compare the issues, which arose for each different stage of the pipeline procedure. This method ranks the activities and allows the project team to prioritize which activities require immediate attention and which are considered to present a tolerable risk. The problem with this method arose in the grouping of the values into low, medium and high risks. The value brackets for these categories are too broad and no activities were defined as high risks. For this reason the categorization of risk by this method is not favored over the categorization by the risk matrix method.

The risk matrices immediately group the activities into the high, medium and low risk groups. This illustrates which group of events requires attention to lower their potential risk but the method does not rank the items in decreasing value of threat as the RPN value method does.

Where an activity lies on the grid in a risk matrix is based on two factors: severity and probability of occurrence. For this reason a risk matrix may be seen as a coarser risk analysis technique but it is widely used in industry. The RPN value method takes in the additional probability of detection factor (D) in an effort to further refine the process. As the D value is not considered in the creation of the risk matrices it is understandable that this value would influence the ranking of the results. This is why several discrepancies in the results can be seen.

Both methods present slightly different results with respect to the order of which activities present a higher or lower risk to the operation. The general overview of which activities require more attention than others is on the whole consistent.

4 CONCLUSION

The first conclusion to be drawn from this paper relate to the methods used to carry out the risk assessment of the pipeline procedure. FMECA was used to identify all potentially threatening activities, and then RPN and Risk Matrix methods were applied to analyze the FMECA results. Conclusions reached after application of the two methods, RPN value ranking and Risk Matrices, are identified below:

- The methods produced quite similar results.
- The RPN method is a convenient way to rank all the activities.
- The Risk Matrix categorizes all the activities into one of the three risk groups.
- The RPN method is a three-dimensional refined method of assessing risk.
- The Risk Matrix is a two dimensional coarse method of assessing risk.
- The Risk Matrix should be applied at the initial stage of the risk assessment.

From the information gathered and risk assessments carried out, the following conclusions about the risks involved in Pipeline operation systems are detailed below:

- No operation is void of risks.

- All the events that were identified as high risk presented the greatest threat to the project proceeding.

- Risk identification methods can help ensure an event is identified early in the life of a project and mitigation measures applied.

- The level of risk can be lowered by application of control measures.

- There is likelihood of having activities which will pose medium risks to the operation after the mitigation measures have been applied. Careful consideration should be given to such activities to evaluate whether the project can proceed or not.

However, some of these are not unique to pipeline operations and are common to general oil and gas activities. These are - impact with a parent pipeline during excavation, an object being dropped, and a valve failing to seal.

- Activities performed prior to the cutting of the hole in the pipeline present a lower level of risk than after the hole is cut. Prior to the hole being cut, the operation can be stopped, any weld repaired, if necessary, and equipment recovered.

- After the stage when the hole is cut, the implications if an event occurs are more severe.

- A worst-case scenario would require the project to make the site safe, abandon the location and find a new site for the operation.

Pipeline operation systems are now almost a routine operation in the Niger Delta region of Nigeria, as there is at least a pipeline crossing every village and with each one completed the experience of this technique grows. With the knowledge gained, from the experience, the risk that a failure will occur is reduced. However, oil and gas companies must not allow complacency to develop and strive to apply risk assessment techniques to all projects to ensure each activity presents as low a risk as possible to the complete pipeline operation.

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