

Implementation of Pipeline Integrity Management in a Large Pipelines Network in India



S S Gupta, A K Arya, P.Vijay

Abstract: Hydrocarbon pipelines are one of the key elements of the energy security system of a country, especially in a large country like India hydrocarbon pipelines are the backbone of the energy distribution system. While the operational reliability of such a system is important to ensure a sustained supply of hydrocarbon energy across the country, the continued structural integrity of the network is vital for public safety. Generally, pipelines are the safest mode of transportation of bulk hydrocarbon energy, but pipeline failure is not uncommon. Recent global databases on pipeline failure indicate that third party damage and corrosion are two major causes of pipeline failure though there are other reasons like poor construction quality; an incorrect operation etc., may also lead to pipeline failure. The extent of damage that a pipeline failure can cause depends on the extent of the release, for example, a small leak may not cause much damage if detected with a short period, while a rupture of the pipeline can release a significant amount of pipeline content and may cause significant damage to property and life. With a higher degree of public awareness and stricter regulatory regime, pipeline operators are having a relook into their integrity management system to prevent any untoward incident. Majority of the pipeline operator now realize that holistic approach taking together as much factor as possible could be a better approach to manage the integrity of the pipeline network especially a large network of pipeline spread across a vast country like India. This realization has led many pipeline operators to implement computer-based pipeline integrity management system. While this is a welcome change but implementation of PIMS across a vast network of pipeline built over a long period, with various technologies and having diverse engineering requirements have come of the challenges that the pipeline operator must overcome. This paper discusses one such case of implementation of the Pipeline Integrity Management System (PIMS) in a large and diverse network pipeline in India and the challenges faced in the course of implementation. Authors feel that the case could be a good learning ground for those operators who are contemplating implementation of PIMS in their respective pipeline network.

Key word: Pipeline, Integrity Management; corrosion; third-party damage; Cathodic Protection; GIS; risk

I. INTRODUCTION

Pipelines are important infrastructure responsible for the transportation of liquid and gaseous hydrocarbons. Even though pipelines are considered to be the safest mode of transportation, accidents pipelines are inevitable. Because of hazards and consequences related to pipeline transportation, API (American Petroleum Institute) came with its recommended practices API 1173 "Pipeline Safety Management System" (American Petroleum Institute, 2015). API 1173 provides a basic framework for the development of a pipeline safety management system. Apart from its critical aspects related to management, one of the key requirements is the maintenance of pipeline integrity through risk management, data collection & analysis, periodic review, operational controls and incident investigations. Pipeline accidents have always been a matter of grave concern as several of the reports are annually published for drawing attentions to pipeline-related failure. One of the reports has been published by UKOPA (United Kingdom Onshore Pipeline Operators' Association, 2019), which shows that the pipeline exposure is continually increasing. Similar trends are also seen in Indian conditions, where nearly 11377km of the pipeline is under construction. A general perception is longer the pipeline network more is the possibility of pipeline failure. However, with improvement in technology is it now possible to manage a large data bases related to pipeline network which has helped to reduce instances of pipeline failure. This is indicated by the UKOPA data for failure per year as detailed in figure 1.

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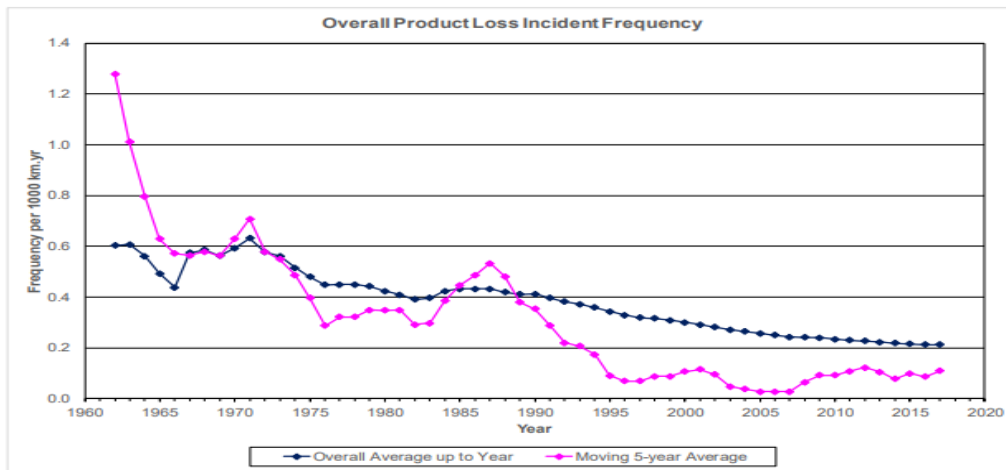


Figure 1: Failure Incidence frequency with time

II. BACKGROUND

Any integrity management system begins with a systematic & comprehensive identification of threats to a particular system & pipeline integrity management system is not different. API 1160 & ASME B31.8s provide a

comprehensive list of threats which can account for pipeline failure (API RP-1160, 2019) (ASME B31.8S, 2018). Several databases are available for pipeline-related failure such as EGIG. EGIG 10th report (EGIG, 2018) illustrates the distribution of pipeline failure per cause as shown in figure 2.

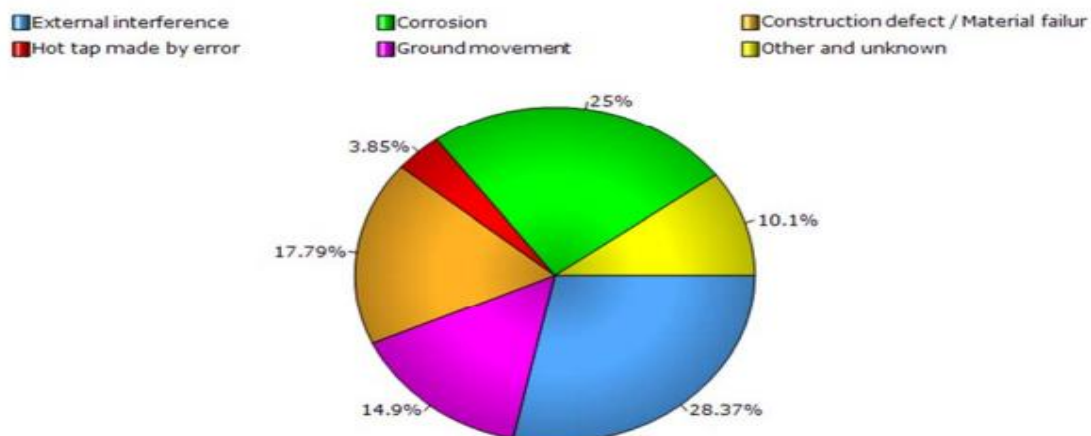


Figure 2: Distribution of Incidences - 10th report of EGIG

Identification and management of each type of threat require a specific approach. Several methodologies have been implemented over the past year to reduce the frequency of failures based on each type of threat. One such strategy for management of corrosion-related defect is inline inspection tools. (Ellineger, 2017). Today ultra-high-resolution corrosion detection tools with detection of 1 mm diameter Axial Magnetic Flux Leakage tools are available in the market which can detect very small pinholes. (Spille, 2019). Corrosion assessment by ultrasonic compression wave has also been advanced to greater accuracy for measurement of remaining wall thickness. Further, the crack inspection techniques have also been enhanced with advanced shear wave tools which are equipped with recent techniques such as pitch-catch type of ultrasonic measurement. In advancement in crack detection, phased array inspections have also been started. (A. Hugger, 2009).

The direct assessment has been widely accepted for integrity assessment of pipelines, both by the operators as well as the regulators, where, inline inspection is not feasible. Direct

assessment is divided into three parts known as External Corrosion Direct Assessment (NACE SP0502-2010-SG, 2010), Internal Corrosion Direct Assessment (NACE SP0116-2016-SG, 2016), Stress Corrosion Cracking Direct Assessment (NACE SP0204-2015-SG, 2015). Several calculations have been done to predict the location as well as the extent of the corrosion.

III. PIPELINE INTEGRITY MANAGEMENT SYSTEM

Pipeline integrity management systems PIMS offers the unified approach & a complete integrated framework towards effective pipeline asset management. A pipeline integrity management system starts with the policy of an operator with the central idea of asset management, within the regulatory framework, including an effective strategy for implementation and action to implement the system. PIMS scheme can be described in figure 3:



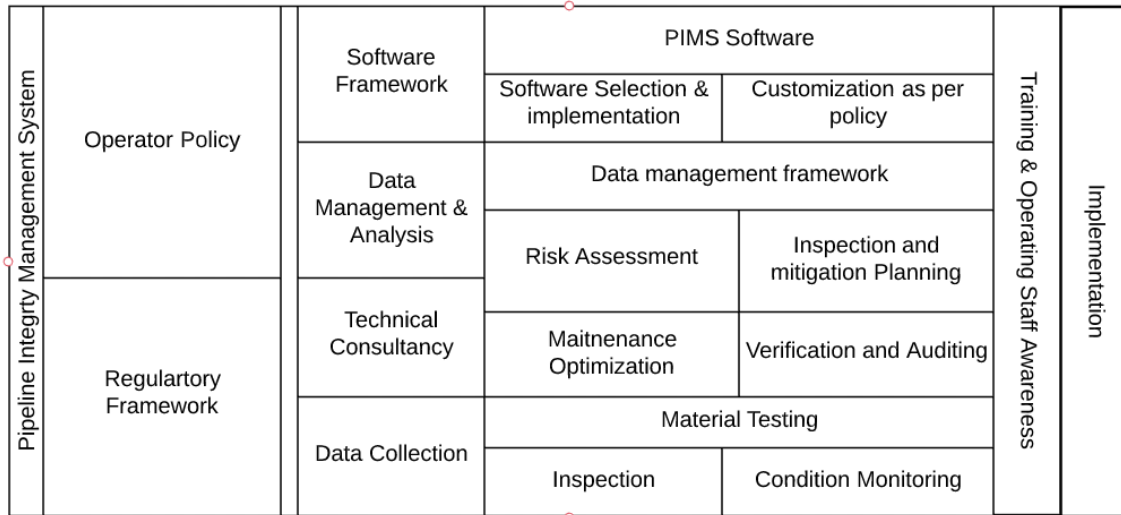


Figure 3: Schema for Pipeline Integrity Management System

IV. PIPELINE NETWORK DESCRIPTION

Any asset management system strategy and assessment depend on the type of the system as the failure modes as well as the impact of the failure changes based on the type of the system. The present paper discusses the implementation of PIMS on a large cross country pipeline network with a length of more than 5000 km. The network consists of crude oil, refined liquid product, highly volatile product as well as gas pipelines in the onshore pipeline system. The network also has offshore crude oil pipelines which are connected from an SPM system to a large storage tank farm. The network has pipelines more than half a century old to recently commissioned pipelines. The wall thickness of the network changes from less than 1/4 inch to 1 inch. Subject pipeline network passes through several types of geography as well as demography in India. The corrosion conditions, as well as the impact of the human population on the network, changes very rapidly.

V. DEVELOPMENT OF MODULES FOR PIPELINE INTEGRITY MANAGEMENT SYSTEM

A software suite was customised to tackle the need for pipeline integrity management. The software consisted of the following parts

VI. GIS MAPPING

The pipeline network navigates through various terrains, hence a comprehensive GIS was required to be inbuilt in the software. A pipeline is referenced on chainage basis. However, with recent development on inline inspection tools built-in with IMU (Inertial Measurement Unit) modules, these tools provide an accurate position of the pipeline. The GIS-based system was designed to take input data from various sources as listed below:

1. GIS mapping from an above-ground Survey
2. Maps & *.shp files available from pipeline constructions

3. GIS mapping from an inline inspection survey

Similarly, Pipeline attributes such as above-ground markers, cadastral, crossings etc. were also marked through a projection on the centreline of the pipeline. The system was designed to calculate the projections to avoid human errors. Any of the visualizations we're able to be displayed on 2D or a 3D map.

PODS Database

A standard Pipeline Open Database Standard PODS 7.0 was used for storage of data. PODS 7.0 is a unique combination of RDBMS platform, spatial data storage type and data editing paradigm. (PODS, 2019). The PODS 7.0 standard includes several modules to store the pipeline asset data, inspection data, crossings, work orders etc for both onshore as well as offshore pipelines. PODS standard has a mechanism to "extend" the core to manage data for defined work streams, business processes and reporting requirements. A typical snapshot of the data is as displayed in figure 4

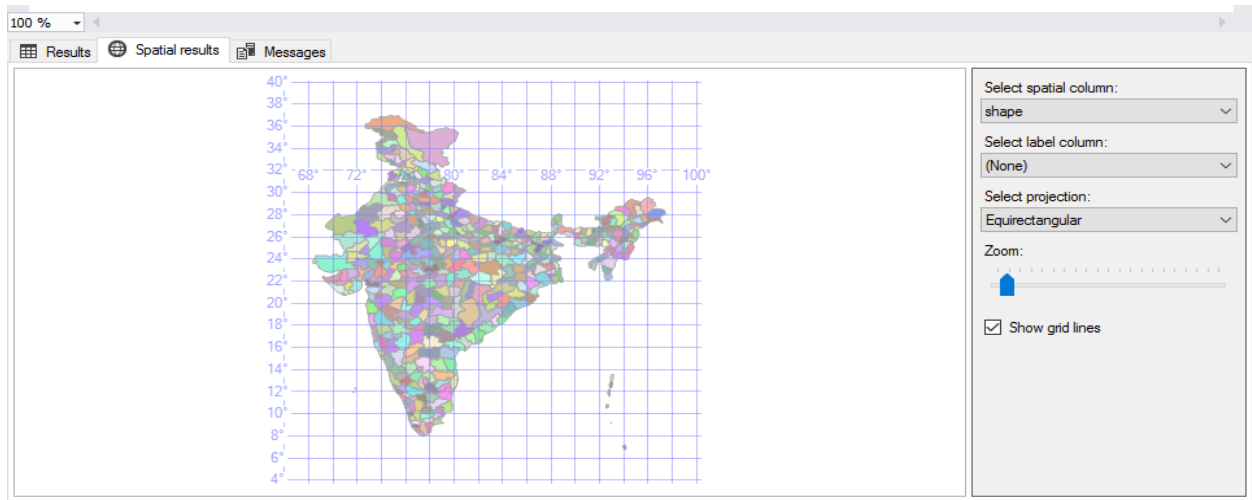


Figure 4: Spatial Database of PODS- Markers for districts in India

VII. IN-LINE INSPECTION

A key feature of any PIMS is the evaluation of an inline inspection data. Inline inspection data provides the details of several types of defects based on inspection technology used. ASME B 31G was used for determination of the remaining strength of the corrosion defects (ASME B31G, 2012), Empirical limits were used for evaluation of dents

(Cosham & Hopkins, 2010) and assessment of cracks was done using API 579 (API 579, 2016).

The system is designed to automatically identify the repairs as per API-1160 (API RP-1160, 2019). A prescript of the algorithm built-in inside for identification of repair is displayed in figure 5

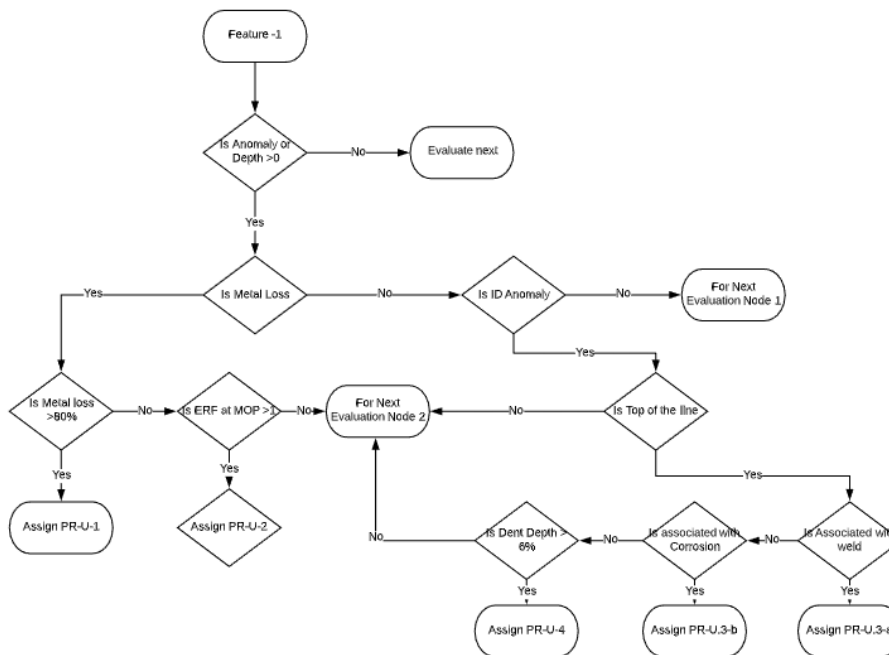


Figure 5: Prescript of the flow chart of the system for evaluation of inline inspection data

scheme was devised to understand the historical performance of a cathodic protection system and its impact on the external corrosion of the system. A typical system output for external corrosion along the chainage looks is provided in figure 6.

VIII. CATHODIC PROTECTION SYSTEM

The system was designed for the assessment of cathodic protection (CP) assessment. The changes of CP reading in various seasons can be compared and analysed to check the behaviours of a particular system and its dependence on dry and wet season. Accordingly, a comprehensive scoring

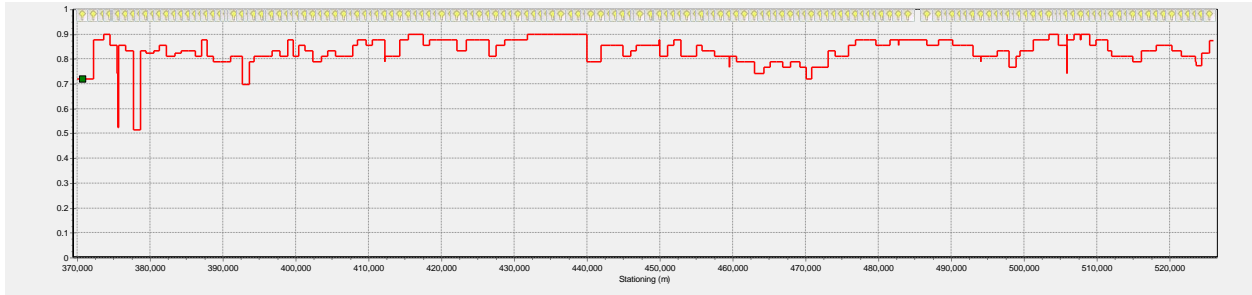


Figure 6: Performance of a Cathodic Protection System along pipeline Chainage

IX. RISK ASSESSMENT SYSTEM

Two important factors, namely the consequences of failures and failure chances, are a preliminary driving risk in an asset. Each risk assessment scheme has several phases, including hazard identification, potential consequences, risk assessment, risk evaluation and mitigation action implementation. Several engineering and management

industries use risk management to decide their strategies and plans in a new enterprise or keeping with their existing strategy. The General Risk Assessment Equation is (Muhlbauer, 2003)

$$\text{Risk} = \text{Probability} \times \text{Consequence}$$

A detailed procedure as shown in figure 7 was followed for implementation of PIMS:

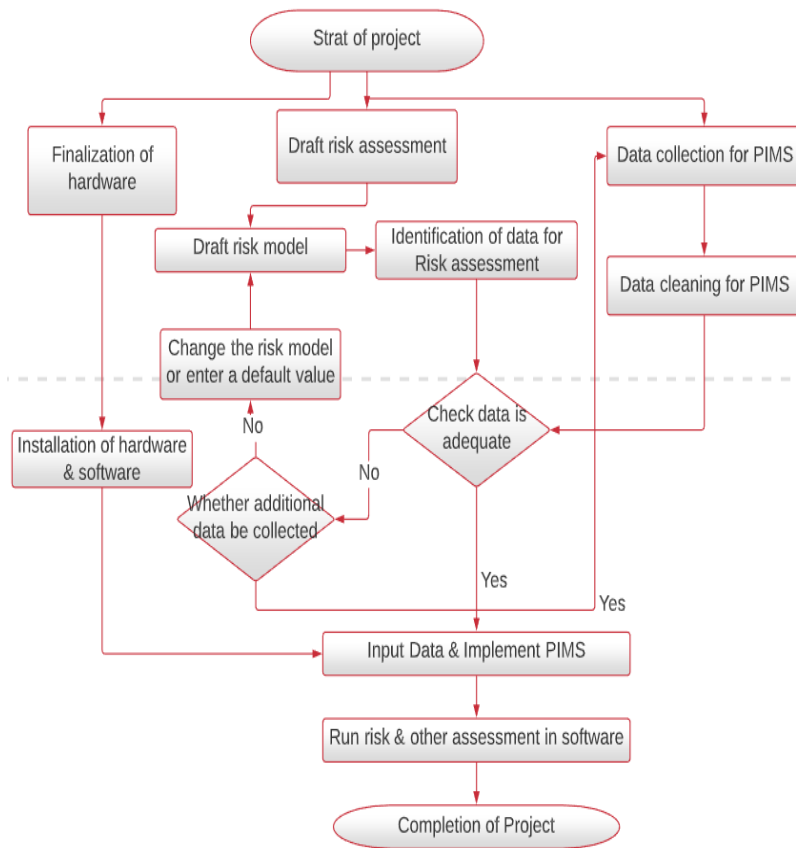


Figure 7: Strategy Adopted For The Implementation Of Pims

A semi-quantitative relative risk assessment method was used for the assessment of pipeline risk. Two separate models were prepared, one for onshore probability and

consequences and one for offshore pipelines. The outline of the onshore model is shown as in figure 8 & offshore in shown in figure 9.

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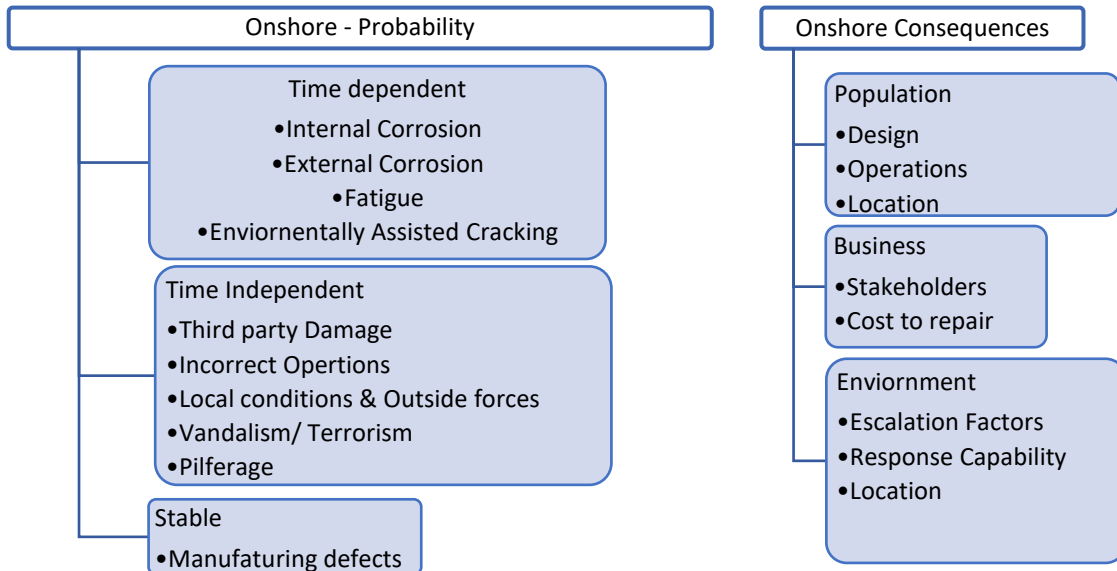


Figure 8: Outline of Onshore Risk Assessment model

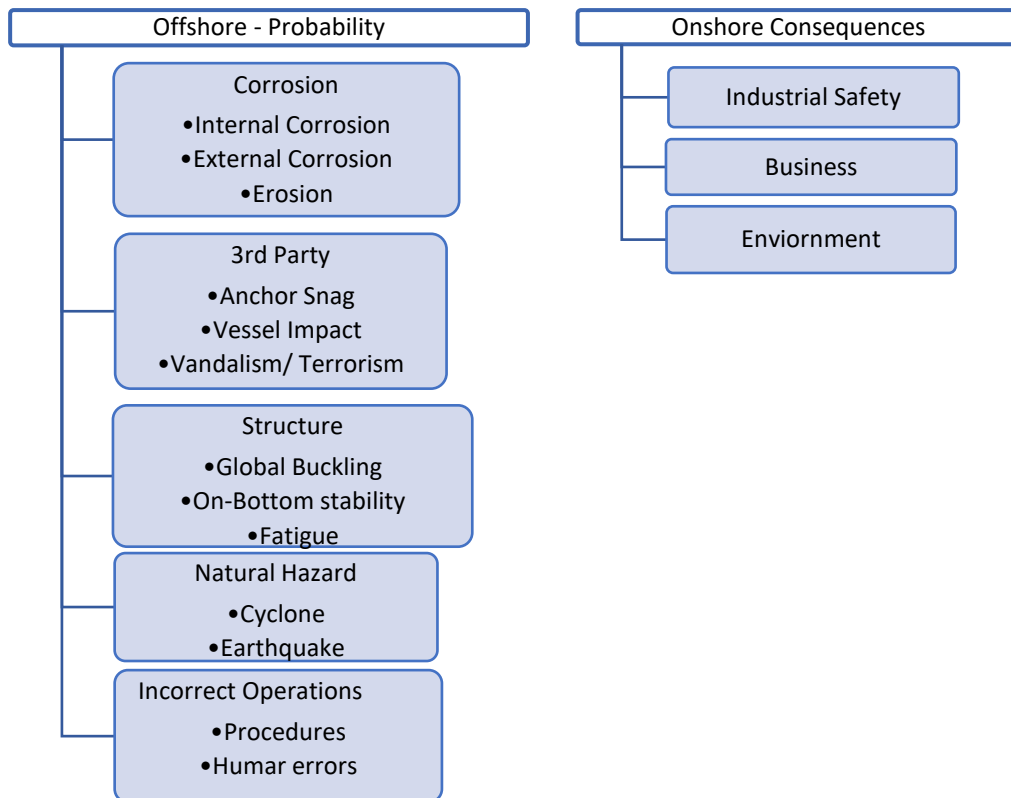


Figure 9: Outline of Offshore Risk Assessment model

The risk assessment system displayed the risk of individual section based on dynamic segmentation as shown in figure 10.

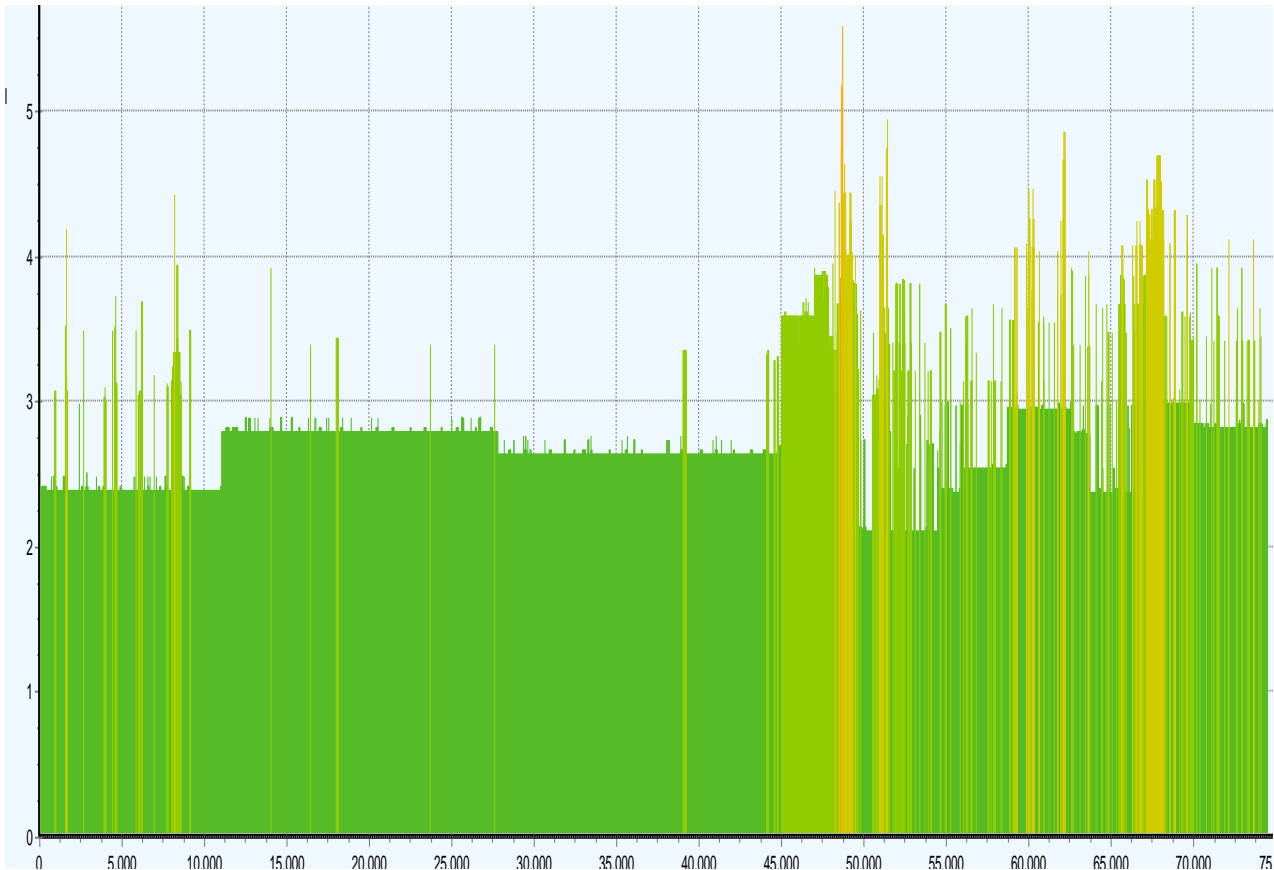


Figure 10: Risk of a pipeline along its chainage

Similarly, the risk level of various segments can also be compared as shown in figure 11.



Figure 11: Comparison of risk of an individual section across the network

X. CHALLENGES IN IMPLEMENTATION

Implementation of pipeline integrity management system in a large pipeline network was associated with several challenges. A few of the challenges are enlisted as:

XI. DATA COLLECTION

Pipeline Integrity Management system requires various type of data including inspection data such as inline inspection, cathodic protection, above-ground survey, dig verification data. Monitoring data includes pipeline cleaning data, product feed analysis, water testing data and operational parameters. Pipeline construction data includes route maps, cadastral maps, crossings, population, pipe manufacturing and fabrication data. Pipeline excavations, response capabilities, awareness programs, failure details and theft activities were also included for assessment of pipeline integrity. Collection of such data required data mining of records as old as 50 years as well as in some cases the fresh surveys were carried out.

XII. DATA FORMATTING

Collected data was in all forms of record-keeping such as hard copy records, pdfs, word, excel, CSV, access, kml, shp, oracle, SQL databases, AutoCAD files etc. The necessary records in hard copy, pdf or word were digitised in a tabulated format. Collected excel, CSV, access, kml or shp files were in many different formats due to diversity of the network as well as due to the collection period of data.

Apart from manual formatting, special algorithms were written in 'R' as well as in 'VBScript' for formatting tabulated data while ESRI & Qgis were used gis formatted data in kml and shapefiles. Existing database in oracle and SQL were directly connected to the PIMS system. Autocad files were converted in kml or shp files for further assessment

XIII. CHANGE OF MANAGEMENT

Implementation of a system in a large network also has administrative hurdles and requires the involvement of management. These hurdles were overcome with several appraisals & reviews by senior management as well as the persons directly involved in the change of management. Several training programs across the network were conducted first for familiarization of the system & then usage on a day to day analysis and work.

XIV. DEVELOPMENT OF RISK MODEL

The risk model was developed with the help of a consultant as well as internal experts. A detailed protocol was followed for the identification of internal experts. Long workshops were carried out for identification of real threats related to actual pipeline integrity as well as identification of relevant weighting schemes. Not all threats identified by the literature may apply to the pipeline network & hence the

phantom threats were also listed and either removed from the risk model or given very low weight.

XV. CONCLUSION

Saving pipelines from failure is one of the key responsibilities of a pipeline operator. With enhanced public awareness levels and a strict regulatory regime, a pipeline operator has to ensure that all the preventive measures against pipeline failure works in tandem and provides intended results in a cost effective manner. Pipeline Integrity Management is a tool that can help pipeline operators to attain the above objective by directing pipeline operators towards the areas where efforts are required to prevent incidences of failure. In a sense PIMS acts like an early warning system. Implementation of PIMS system in a large network of pipelines with multiple diameter, a variety of external coating, different design consideration could be a daunting task. A well thought out approach can assist the pipeline operators in cover coming some of the challenges that might be encountered while implementing PIMS in a large network of pipelines. Involvement of managers at all levels is essential for smooth implementation of the system. The system provides fundamental changes in policy for integrity management ultimately providing better management control on an integrity management program. Biography: S S Gupta is working with Indian Oil Corporation Ltd., as Chief General Manager. He is currently located at NOIDA. Dr. Arya and Dr Vijay are in the teaching faculty of Department of Chemical Engineering, University of Petroleum and Energy Studies, Dehradun

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