A PROJECT REPORT
ON

RISK ASSESSMENT FOR NATURAL GAS PIPELINE

UNDER THE GUIDENCE OF

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SUBMITTED
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SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR AWARDING THE DEGREE OF M.Tech (Pipeline Engg)

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CERTIFICATE

This is to certify that the project work entitled **"RISK ASSESSMENT FOR NATURAL GAS PIPELINE "** submitted by **Tegala Bharadwaj** in partial fulfillment of the requirements for the award of the degree of Master of Technology (Pipeline Engineering), at University of Petroleum and Energy Studies, is a record of the work carried by under the guidance of "**Mr. R.P. Shriwas**, Sr Fellow, Coordinator M.Tech (Pipeline Engineering), COE, UPES".

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Abstract

Risk is most commonly defined as the probability of an event that causes a loss and its magnitude. Through Risk Assessment one can know the probability of failure in the pipeline.

Hence a pipeline that is being operated would be subjected to some amount of risk due to its surrounding environment. Hence in a present day scenario risk assessment has become an essential part to assess the health of a pipeline to prevent it from any kind of accident.

Risk assessment process is carried out by assessing the risk included with the third-party index, corrosion index, Design index and incorrect operations index.

For this risk Assessment study, under the Project work, Mora-Sajod Natural Gas Pipeline has been considered.

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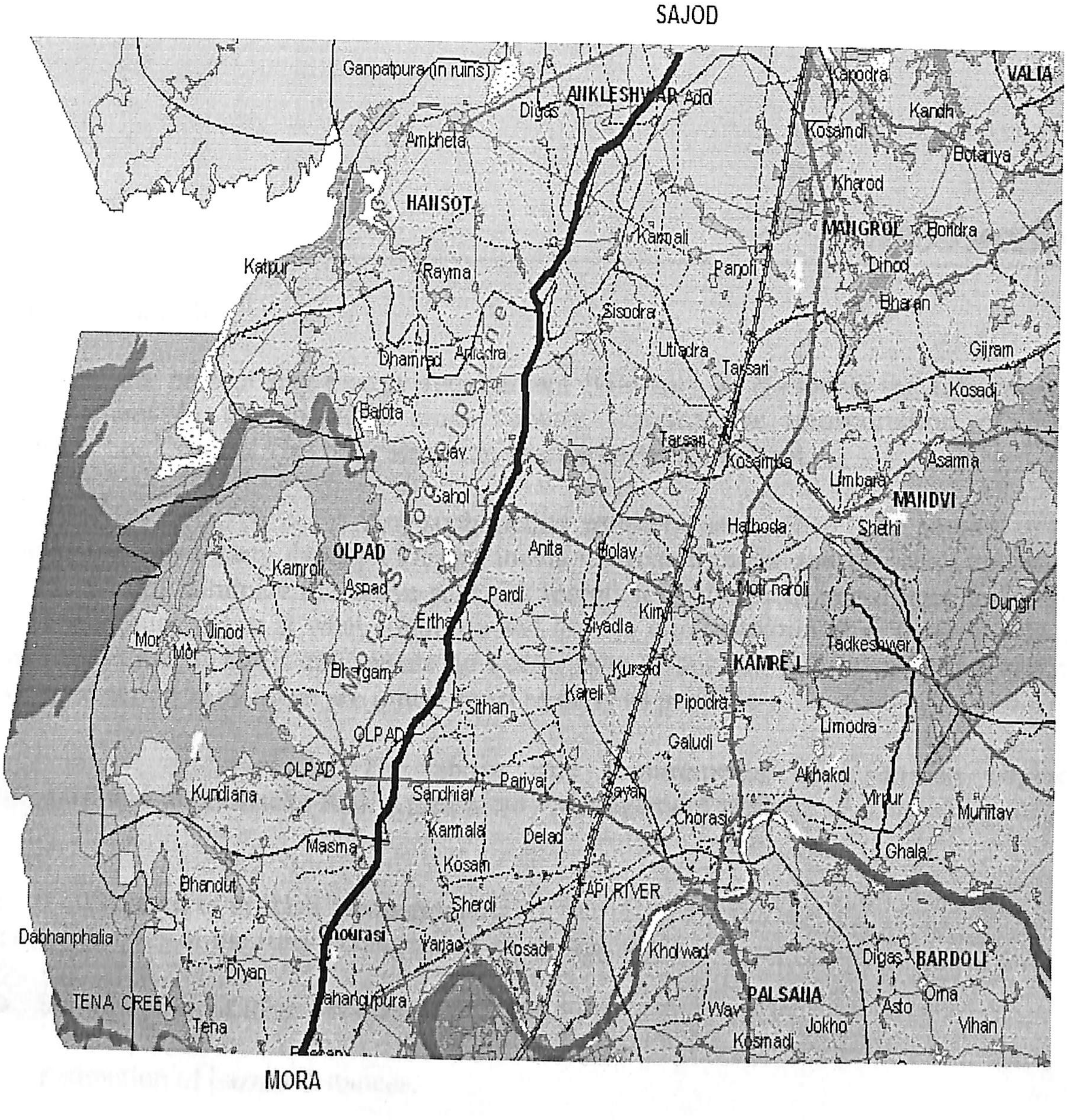
LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
CI	Corrosion Index
DI	Design Index
IOI	Incorrect Operations Index
ILI	Inline Inspection Technique
HAZID	Hazard Identification
LIF	Leak Impact Factor
LV	Leak Volume
MOP	Maximum Operating Pressure
O & M	Operation and Maintenance
PH	Product Hazard
ROW	Right of Way
ROU	Right of Use
SCADA	Supervisory Control and Data Acquisition
TPDI	Third Party Damage Index



MAP SHOWING MORA – SAJOD PIPELINE ROUTE

Chapter 1

Introduction

1.1 Preamble

To cater the present day energy requirement (Globally & National) the infrastructure development in the form of cross country pipeline for transportation of liquid hydrocarbon /Natural Gas has gained top most priority throughout.

Any such facility would be ascertained to an amount of risk due to the Third party damage, Design index, Corrosion index and incorrect operations index. And to minimize the above said risk threats it is of utmost importance to identify as to what may occur at what condition and how to eliminate/minimise these events. At the same time, if at all any events do occur, how to act and how to mobilise and the required action to be taken are jotted down as early as possible

The above said requirements drive to an engineer /organisation to undertake Risk Assessment / Management study.

1.2 Objectives of Risk Management:

The objectives of the Risk Management are as follows:

- Identification of Risk hot-spots.
- Estimation of hazard distances.
- To act as a decision-support tool
- To allocate the necessary resources to reduce the failure probability
- To act as an Information Repository for reference purpose
- To improve the Overall Risk Picture.

1.3 Approach

The study was carried out as follows:

- Selection of a risk assessment model.
- Data collection and preparation
- Segmentation
- Risk Assessment
- Risk Management

1.4 Scope of work

The work undertaken consists of the following stages:

- Collection of relevant data on operating conditions.
- Resolution of those data so that it would act as a critical risk Indicator.
- Priority-based segmentation of the entire pipeline to assess the relative magnitude of risk.
- Risk quantification
- Calculation of damage distances for various operating conditions.
- Risk Analysis
- Risk management

Chapter 2

Project Setting and Process Description

2.1 Project Setting

The Risk Assessment study made was for a Natural Gas pipeline. The details of the Pipeline are mentioned below.

2.1.1 Pipeline Details

2.1.1.1 Location: State of Gujarat (India).

Operating Company: Gujarat State Petronet Limited (GSPL).

Pipeline Traversing From: Mora to Sajod.

2.1.1.2 Other Details

Pipeline Length: 58.097 Km

Maximum Operating Pressure: 95 bar

Design Temperature: -20 deg.c to 60 deg.c

2.1.1.3 Pipeline Route

While Traversing from Mora to Sajod it crosses various rail lines, roads, canals, rivers, drains, etc.
(Total no. of crossings: 53)

Some of the major crossings are:

1. Khadi River crossing at 2.87 km. (Length- 100 m app.)
2. Tena River crossing at 4.76 km. (370 m app.)
3. SH-65 at 34.046 km.
4. Kim River crossing at 36.286 km. (234 m app.)

5. Asphalted road crossings.
6. River/Nalla Crossings.

2.1.1.4 Construction Details

As constructed including testing, compliance codes etc.
(Details mentioned in the Annexure)

2.1.1.5 Service

- The Soil along the route is mainly alluvial black cotton soil or yellow soil.

(Details included in the Annexure)

- The type of Terrain along the pipeline is Flat and Cultivated Land

Composition of Natural Gas

S. No.	Components	Volume, %
1.	Nitrogen	0.72
2.	Methane	94.74
3.	Carbon Dioxide	0.25
4.	Ethane	2.65
5.	Propane	1.08
6.	Iso-Butane	0.29
7.	n-Butane	0.17
8.	n-Pentane	0.07
9.	Hexane	0.01

Gross Cal. Value (Kcal/m^3)	:	9367-9679
Net Cal. Value (Kcal/m^3)	:	8449-8460
Specific Gravity	:	0.5915-0.5925

2.1.1.6 Climatic Conditions

The annual climate is characterised by three seasons and the temperature range between these seasons are mentioned below:

Summer: 15^0c to 50^0c

Winter: 7^0c to 25^0c

Monsoon: 10^0c to 20^0c

Wind and Cyclones

The predominant wind directions during summer, monsoon and winter seasons are SW, SW, and NE-SW for Mora-Sajod section. The wind speed was observed to be predominantly in the range of 10-20 kmph throughout the year except during winter season in which stronger winds dominated the wind pattern. The cyclonic activities are infrequent in the region with hardly one cyclone striking the West Coast annually.

(The wind profile is given in the Annexure)

2.1.1.7 Facilities

- **Block Valve Stations and Pig Traps**

Block Valve Stations have been provided in accordance with the requirements of ANSI/ASME Code B31.8 at intervals corresponding to location classes.

- **Power Requirement**

The Power Requirement for the operation of the pipeline is very small. Power generation is not envisaged along the pipeline system.

- **External Protection, Hydraulic Testing**
- **External/Internal Corrosion Coating**
- **Insulating Joints**
- **Cathodic Protection**
- **Leak Tests before Operation**
- **Hazardous Substances Handling**
- **Identification of Risk Prone Locations**

Chapter 3

Introduction to Pipeline Risk Assessment

The chief objective of this activity is to make pipelines safer. The transportation of large quantities of sometimes very hazardous products over great distances through a pressurized pipeline system, often with zero-leak tolerance, is not a trivial thing. It is useful to occasionally step back and re-assess what a pipeline really is.

The pipeline is a very complex and carefully engineered structure. It is subjected to a variable, ever-changing and usually hostile environment. A pipeline is indeed a complex system which must co-exist with all of nature's and man's frequent lack of hospitality.

Out of the several variations "Risk signals" are the most sought after. The risk measurement must therefore identify and consider all of the variables in such a way that risk signals can be effectively picked out from all of the background "noise" created by the variability.

The purpose of "Pipeline Risk management" is to provide frameworks in which a given set of evidence consistently leads to a specific degree of belief regarding the safety of a pipeline.

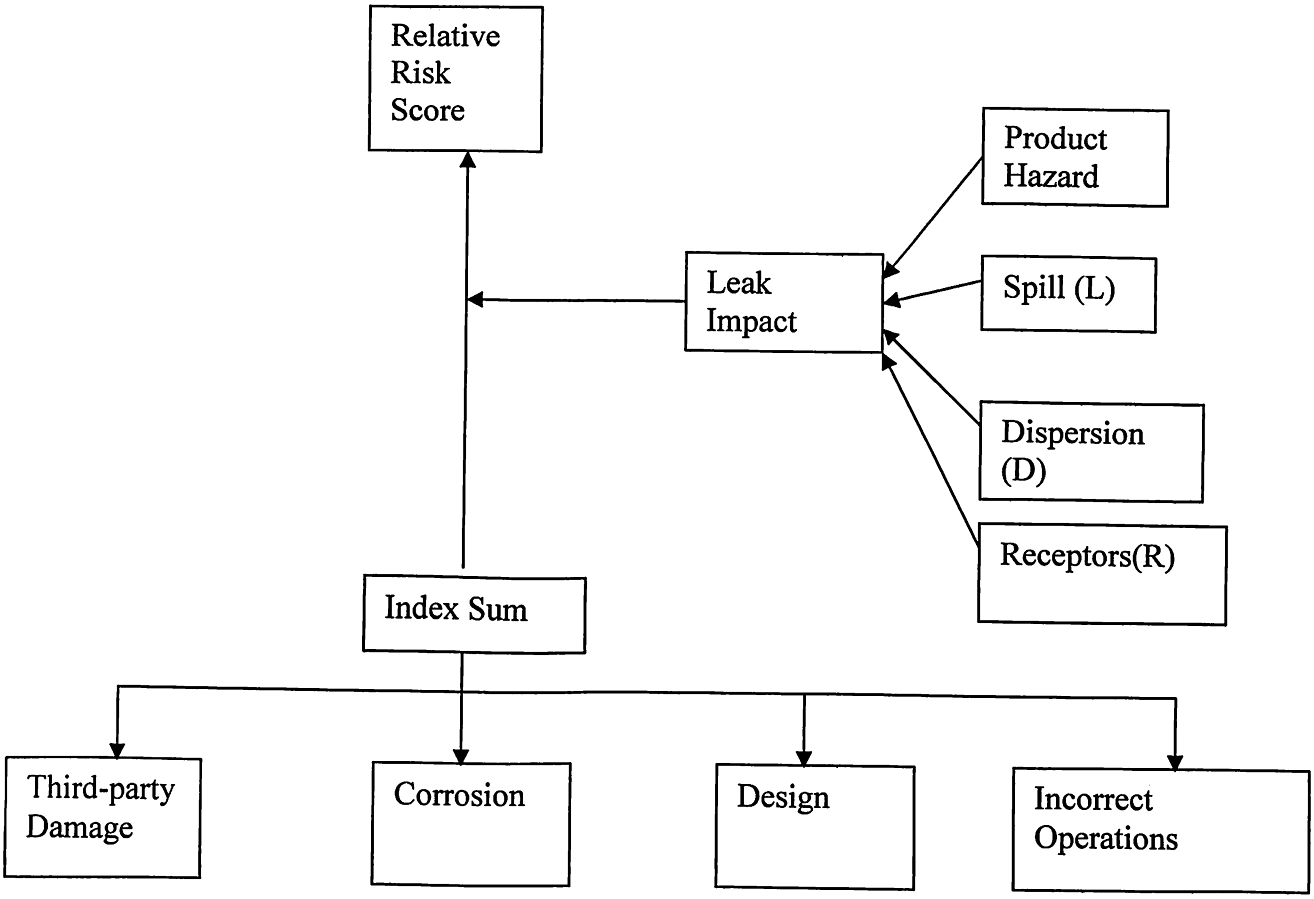
The most critical belief underlying this topic is that all available information should be used in a risk assessment.

All risks should be reassessed at definite intervals. If the new assessment yields different results than the previous assessments, then some valuable knowledge can be gained. This new knowledge is obtained by finding the basis of the differences- and learning the reasons for the deviation. Thus, the Overall risk picture will improve.

3.1 For Assessment of risk in respect of mora-sajod gas pipeline the following steps were followed

1. Risk Modelling is carried out using Kent Muhlbauer Model
2. Data collection and preparation
3. Segmentation
4. Risk Assessment
5. Risk Analysis

3.2 RISK ASSESSMENT MODEL (Kent Muhlbauer Model)



- **Relative Risk Rating = (Index Sum)/ (Leak Impact Factor)**
- **Index Sum = [(Third Party)+ (Corrosion)+(Design)+ (Incorrect Operations)]**
- **Relative Risk Score = [(Index Sum) / LIF]**
- **Relative Probability of Failure = 1- (Third Party damage Score/100 * Corrosion Score/100 * Design Score/100 * Incorrect Operation Score/100)**

NOTE : While Assigning the Weightage and points against various indices, the values have been taken from Pipeline Risk Management Manual (Third Edition) by W.kent Mahulbauer (Page no 21 to Page no 176).

3.2.1 Third-Party Damage Index

1. Minimum Depth of cover.........0-20 pts..........20%
(Soil Cover, Type of Soil, Warning Tape/Mesh)

2. Activity Level.......................0-20 pts...........20%
(Population density, Stability of the Area, Other buried utilities)

3. Above ground Facilities...........0-10 pts...........10%
(Vulnerability, threats)

4. One-call System.................. 0-15 pts...........15%
(Mandated, Response by owner)

5. Public Education.................... 0-15 pts.......... 15%
(Methods, Frequency)

6. ROW Condition........................0-5 pts..........5%
(Signs, Markers, Overgrowth)

7. Patrol.....................................0-15 pts.......15%
(Type, Frequency, Effectiveness)

0-100 pts 100%

3.2.2 Corrosion Index

1. Atmospheric corrosion................0-10 pts............10%
   - Atmospheric Exposures....0-5 pts...............5%
   - Atmospheric Types.........0-2 pts...............2%
   - Atmospheric coating........0-3 pts...............3%

2. Internal corrosion........................0-20 pts............20%
   - 2.1 Product Corrosivity..........0-10 pts............10%
   - 2.2 Preventions...................0-10 pts............10%

3. Subsurface corrosion.....................0-70 pts...........70%
   - 3.1 Subsurface Environment.....0-20 pts.............20%
     - Soil corrosivity.................0-15 pts...........15%
     - Mechanical corrosion.........0-5 pts...............5%
   - 3.2 Cathodic Protection..........0-25 pts.............25%

Effectiveness..................0-15 pts...........15%
Interference Potential........0-10 pts............10%

3.3 Coating..............................0-25 pts.............25%
Fitness..........................0-10 pts...........10%
Condition.......................0-15 pts...........15%

0-100 pts	100%

- Corrosion Threat = 1+2+3 = 100%

3.2.3 Design Index

1. Safety Factor.............................0-35 pts..............35%
(Maximum Pressure, Normal pressure, Material strength, Pipe wall thickness, External loading, Diameter)

2. Fatigue.....................................0-15 pts..............15%
(Material toughness, D/t Ratio, Pressure cycle Magnitude and Frequency)

3. Surge Potential...........................0-10 pts..............10%
(Fluid bulk modulus, Pipe modulus of elasticity, Rate of flow stoppage, Flow rates)

4. Integrity Verification.......................0-25 pts..............25%
(Date, Pressure test level, ILI Technique, ILI Accuracy)

5. Land Movements..........................0-15 pts..............15%
(Seismic shaking, fault movements, Subsidence, Land slide)

0-100 pts	100%

3.2.4 Incorrect Operations Index

1. Design.................................. 0-30 pts....................30%

1.1 HAZID.......................0-4 pts.......................4%
1.2 MOP Potential...............0-12 pts.....................12%
1.3 Safety Systems...............0-10 pts.......................10%
1.4 Material Selection...........0-2 pts.........................2%
1.5 Checks.......................0-2 pts.........................2%

2. Construction..............................0-20 pts.........................20%

2.1 Inspection....................0-10 pts..........................10%
2.2 Materials.....................0-2 pts...........................2%
2.3 joining.......................0-2 pts...........................2%
2.4 Backfill......................0-2 pts...........................2%
2.5 Handling......................0-2 pts...........................2%
2.6 Coating.......................0-2 pts...........................2%

3. Operations.................................0-35 pts.........................35%

3.1 Procedures...................0-7 pts...........................7%
3.2 SCADA.......................0-3 pts...........................3%
3.3 Drug testing................0-2 pts...........................2%
3.4 Safety programmes.........0-2 pts...........................2%
3.5 Surveys/Maps/Records....0-5 pts...........................5%
3.6 Training....................0-10 pts.........................10%
3.7 Mechanical error preventors...0-6 pts.......................6%

4. Maintenance..............................0-15 pts........................15%

4.1 Documentation..............0-2 pts...........................2%
4.2 Schedule.......................0-3 pts...........................3%
4.3 Procedures...................0-10 pts..........................10%

0-100 pts 100%

- Incorrect operations Index = 1+2+3+4 = 100%

3.2.5 Leak Impact Factor

1. Product Hazard (PH).....................0-22 pts

1.1 Acute Hazards

1.1. a. Nf........................0-4 pts
1.1. b. Nr........................0-4 pts
1.1. c. Nh........................0-4 pts

Total (Nf+Nr+Nh).........0-12 pts

1.2 Chronic Hazard (RQ)........0-10 pts

- PH = 1.1 + 1.2 = 12 +10 = 22 pts

2. Leak Volume (LV)..............................0-1 pts

3. Dispersion (D)..................................0-10 pts

4. Receptors(R)....................................0-5 pts

4.1 Population density (Pop.)
4.2 Environmental considerations (Env.)
4.3 High Value Areas (HVA)

- Total Receptors = (Pop.+Env.+ HVA)

- LIF = 1 * 2* 3* 4 = PH * LV * D * R

Chapter 4

Risk Scoring Details for the First Segment

4.1 Third Party Damage Potential

4.1.1. Minimum depth of cover (weighting: 20%)

The minimum depth of cover is the amount of earth, **or** equivalent cover, over the pipeline that serves to protect the pipe from third-party activities. A schedule or simple formula can be developed to assign point values based on depth of cover. In this formula, increasing points indicate a safer condition

A sample formula for depth of cover is as follows:
Amount of cover in inches ÷ **3** =point value up to a maximum of **20** points

For example,
2 in. of concrete coating =8 in. of additional earth cover
4 in of concrete coating = **12** in. of additional earth cover
Pipe casing = **24** in. of additional cover
Concrete slab (reinforced) = **24** in. of additional cover.
Therefore for Minimum depth of cover considering 24 in of additional cover
We get
28'' + 24 + 1.62 = 53.62
53.62 ÷ 3 = 17.54 Points

4.1.2. Activity level (weighting: 20%)

High activity level (0 points)

This area is characterized by one **or** more of the following:

- Class 3 population density
- High population density as measured by some other scale
- Frequent construction activities
- High volume of one-call **or** reconnaissance reports

- Rail or roadway traffic that poses a threat
- Many other buried utilities nearby
- Frequent damage from wildlife
- Normal anchoring area when offshore
- Frequent dredging near the offshore line.

Medium activiy level (8 points)

This area is characterized by one **or** more of the following:

- Class 2 population density (as defined by DOT)
- Medium population density nearby, as measured by some
- No routine construction activities that could pose a threat
- Few one-call or reconnaissance reports *(<5* per month)
- Few buried utilities nearby
- Occasional wildlife damage.

LOW activity level (I5 points)
This area is characterized by all of the following:

- Class 1 population density (as defined hy DOT)
- Rural, low population density as measured by some other
- Virtually no activity reports (<lo per year)
- No routine harmful activities in the area (agricultural activities
- where the equipment cannot penetrate to within 1 ft of
- the pipeline depth are sometimes considered harmless).

None (20 points)
The maximum point level is awarded when there is virtually no chance of any digging **or** other harmful
Third-party activities near the line..

- **Based on the above assumptions and the class levels the Activity level has been given 5 points.**

4.1.3. Aboveground facilities (weighting: I00 %)

This is a measure of the susceptibility of aboveground facilities to third-party disturbance. Aboveground pipeline components have a different type of third-party damage exposure compared to the buried sections. Included in this type of exposure are the threats of vehicular collision and vandalism.

No aboveground facilities 10 pts

Aboveground facilities	0 pts
(plus any of the following that apply (total not to exceed **10** pts)	

Facilities more than 200 ft from vehicles	5 pts
Area surrounded by 6-ft chain-link fence	2 pts
Protective railing (4-in. steel pipe or better)	3 pts
Between vehicles and facility	
Trees (12 in. in diameter), wall, or other substantial	4 pts
Ditch (minimum 4-ft depth width) between vehicles	3 pts
Signs ("Warning," "No Trespassing," "Hazard" etc.)	1 pt

4.1.4. Line locating (weighting: 15%)

A line locating program or procedure-the process of identifying the exact location of a buried pipeline in order for third parties to safely excavate nearby-is central to avoiding third-party damages. A one-call system is a service that receives notification of upcoming digging activities and in turn notifies all owners of potentially affected underground facilities. It is the foundation of many pipeline-locating programs.

The effectiveness of a one-call system depends on several factors:

Effectiveness	6 pts
Proven record of efficiency and reliability	2 pts
Widely advertised and well known in community	2 pts
Meets minimum ULCCA standards	2 pts
Appropriate reaction to calls	5 pts
Maps and records	4 pts

4.1.5. Public education program (weighting: 15%)

Public education programs are thought to play **a** significant role in reducing third-party damage to pipelines. Most third-party damage is unintentional and due to ignorance. This is ignorance not only of the buried pipeline's exact location, but also ignorance of the aboveground indications of the pipeline's presence and of pipelines in general. **A** pipeline company committed to educating the community on pipeline matters will almost assuredly reduce its exposure to third-party damage. Some of the characteristics of an effective public education program are shown in the following list,

Mail outs	2 pts
Meetings with public officials once per year	2 pts
Door-to-door contact with adjacent residents	4 pts
Meetings with local contractors/excavators once per year	2 pts
Regular education programs for community groups	2 pts
Mail outs to contractors/excavators	2 pts
Advertisements in contractor/utility publications once per year	1 pts

4.1.6. Right-of-way condition (weighting: 5%)

This item is a measure of the recognizability and inspectability of the pipeline corridor. A clearly marked, easily recognized ROW reduces the susceptibility of third-party intrusions and aids in leak detection.
The evaluator can establish a point schedule with clear parameters. The following example schedule is written in paragraph form where interpolations between paragraph point values are allowed.

Excellent 5 pts
Clear and unencumbered ROW route clearly indicated; signs and markers visible from any point on ROW or from above, even if one sign is missing; signs and markers at all roads, railroads, ditches, water crossings; all changes of direction are marked; air patrol markers are present.

Good 3 pts
Clear route (no overgrowth obstructing the view along the ROW from ground level or above); well marked: markers are visible from every point of ROW or above if all are in place; signs and markers at all roads, railroads, ditches, water crossings.

Average 2 pts
ROW not uniformly cleared; more markers are needed for clear

Below average 1 pt
ROW is overgrown by vegetation in some places; ground is not always visible from the air or there is not a clear line of sight along the ROW from ground level; indistinguishable as a pipeline ROW in some places; poorly marked. Identification at roads, railroads, waterways.

Poor 0 pt
Indistinguishable as a pipeline ROW no (or inadequate) markers present.

The point values are selected corresponding to the closest description of the actual ROW conditions observed in the section.

4.1.7. Patrol frequency (weighting: 15%)

Patrolling the pipeline is a proven effective method of reducing third-party intrusions. The frequency and effectiveness of the patrol should be considered in assessing the patrol value. Patrolling becomes more necessary where third-party activities are largely unreported.

An example point schedule is as follows:

Daily	15 pts

Four days per week	12 pts
Three days per week	10 pts
Two days per week	8 pts
Once per week	6 pts
Less than four times per month more than once per month	4 pts

4.2 CORROSION INDEX

Atmospheric corrosion (weighting: 10% of corrosion threat)

Atmospheric corrosion is basically a chemical change in the pipe material resulting from the material's interaction with the atmosphere. Most commonly this interaction causes the oxidation of metal

4.2.1. Atmospheric exposure (weighting: 50% of atmospheric corrosion)

Air/water interface	0 pts
Casings	1 pts
Insulation	2 pts
Supports/hangers	2 pts
Ground air interface	3 pts
Other exposures	4 pts
None	5 pts

4.2.2. Atmospheric type (weighting: 20% of atmospheric corrosion)

Certain characteristics of the atmosphere can enhance or accelerate the corrosion of steel. They are thought to promote the oxidation process. Oxidation is the primary mechanism evaluated in this section. Some of these atmospheric characteristics and some simplifying generalities about them are as follows

- Chemical and marine — 0 pts
- High humidity and high temperature — 1.2 pts
- Low humidity and low temperature — 2 pts
- No exposures — 2 pts
- Chemical and high humidity — 0.5 pt
- Marine, swamp, coastal — 0.8 pt
- Chemical and low humidity — 1.6 pts

4.2.3. Atmospheric coating (weighting: 30% of atmospheric corrosion)

The third component in this study of the potential for atmospheric corrosion is an analysis of the preventive measures taken to minimize the threat.

An evaluation scale could look like this:

Good	3pts
Fair	2pts
Poor	1pt
Absent	0pts

Good	A high-quality coating designed for its present environment.
Fair	An adequate coating but probably not specifically designed for its specific environment.
Poor	A coating is in place but is not suitable for long-term service in its present environment.
Absent	No coating present.

4.3. Internal corrosion (weighting: 20% of corrosion threat)

4.3.1. Product corrosivity (weighting: 50% of internal corrosion potential)

This is an assessment of the relative aggressiveness of the pipeline contents that are in immediate contact with the pipe wall. The greatest threat exists in systems where the product is inherently incompatible with the pipe material. Another threat arises when corrosive impurities can routinely get into the product. These two scenarios can be scored separately and then combined for an assessment of product corrosivity:

Simplified scoring of product corrosivity

A simple schedule can be devised to assign points to the product corrosivity if a more generalized approach is appropriate:

Strongly corrosive	0 pts
Mildly corrosive	3 pts
Corrosive only under special conditions	1pts
Never corrosive	10 pts

4.3.2. Preventions (weighting: 50% of internal corrosion)

It is often economically advantageous to transport corrosive substances in pipe that is susceptible to corrosion by the substance. In these cases, it is prudent to take actions to reduce the damage potential.

Anti corrosion activities being performed:

None	0 pts
Internal monitoring	2 pts
Inhibitor injection	4pts
Not needed	10pts
Internal coating	5pts
Operational measures	3pts
Pigging	3pts

4.4. Subsurface corrosion (weighting: 70%)

4.4.1. Subsurface environment (weighting 20% of corrosion threat)

Soil corrosivity	15 pts
Mechanical	5 Pt

4.4.2. Cathodic protection (weighting 25% of corrosion threat)

Using these concepts, a coarse point schedule can be developed based on general criteria such as:

All buried metal in the vicinity of the pipeline is monitored directly by test leads, and test lead spacing is no greater than 1 mile throughout this section	Best
Test leads are spaced at distances of 1 to 2 miles apart (maximum) and all foreign pipeline crossings are monitored via test leads; not all casings are monitored; there may be other buried metal that is not monitored	Fair
Test lead spacing is sometimes more than 2 miles; not all potential interference sources are monitored	Poor

The frequency of readings at test leads is rated as follows

<6 months	Best
6 months-annually	Fair
>annually	Poor

Interference potential (weighting 10% of corrosion threat)

In terms of risk exposure, one of three possible scenarios can exist and be scored from a risk perspective:

No AC power is within 1000 ft of the pipeline	3 pts
AC power is nearby, but preventive measures are being used to protect the pipeline	1-2 pts
AC power is nearby, but no preventive actions are being taken	0 pts

4.4.3. Coating (weighting: 25% of corrosion threat)

Coating fitness

The evaluation should assess the coating's resistance to all anticipated stresses including a degree of abuse at initial installation, soil movements, chemical and moisture attack, temperature differentials, and gravity.

Good - a high-quality coating designed for its present environment

Fair - an adequate coating but probably not specifically designed for its specific environment

Poor - a coating in place but not suitable for long-term service in its present environment
Absent - no coating present.

Coating Condition
The evaluator should satisfy himself that the operator understands the technique and can demonstrate some success in its use for coating inspection.
Good - A formal, thorough inspection is performed specifically for evidence of coating deterioration. Inspections are performed by trained individuals at appropriate intervals (as dictated by local corrosion potential). Full use of visual inspection opportunities in addition to one or more indirect techniques being used.
Fair - Inspections are informal, but performed routinely by qualified individuals. Perhaps an indirect technique is used but maybe not to its full potential.
Poor - Little inspection is done; reliance is on chance sighting of problem areas. Informal visual inspections when there is the opportunity.
Absent -No inspection done

4.5. Design Index
4.5.1. Safety factor

Point schedule based on extra wall thickness

T	Points
‹ 1.0	10.0
1.0 – 1.1	3.5
1.11 – 1.20	7.0
1.21 – 1.40	14.0
1.41 – 1.60	21.0
1.61 – 1.80	28.0
› 1.81	35.0

4.5.2. Fatigue

Fatigue scores based on various combinations of pressure magnitudes and cycle.

	Lifetime cycles				
% MOP	*<10³*	*10³–10⁴*	*10⁴–10⁵*	*10⁵–10⁶*	*>10⁶*
100	7	5	3	1	0
90	9	6	4	2	1
75	10	7	5	3	2
50	11	8	6	4	3
25	12	9	7	5	4
10	13	10	8	6	5
5	14	11	9	7	6

4.5.3. Surge potential

The point schedule can be set up with three general categories and room for interpolation between the categories. For instance, evaluate the chances of a pressure surge of magnitude greater than 10% of system MOP:

High probability	0 pts
Low probability	5 pts
Impossible	10 pts

4.5.4. Integrity verifications

Confirm proper test methods and assess the impact on risk on the basis of time since the last test and the test level (in relation to the normal maximum operating pressures).
An example schedule follows:
(1) Calculate **H,** where **H** = (test pressure/MOP)

H< 1.10(1.10=test pressure l0%aboveMOP)	0 pts
1.11 <**H**< 1.25	**5** pts
1.26<**H**< 1.40	10 pts
H> 1.41	**15** pts

(2) Time since last test: Points = 10 - (years since test)
(Minimum = 0 points)

A test 4 years ago	6pts
A test 1 year ago	0pts

Points from (1) and (2) are added above to obtain the total hydrostatic test score. In this schedule, maximum points are given to a test that occurred within the last year and that was conducted to a pressure greater than 40% above the maximum operating pressure.

4.5.5. Land movements

Evaluating land movement potential

Potential for significant (damaging) soil movements:

High	0 pts
Medium	5 pts
Low	10 pts
Unknown	0 pts
None	15 pts

High Areas where damaging soil movements are common or can be quite severe. Regular fault movements, landslides, subsidence, creep, or frost heave are seen. The pipeline is exposed to these movements.
Medium Damaging soil movements are possible but rare or unlikely to affect the pipeline due to its depth or position.
Low Evidence of soil movements is rarely if ever seen. Movements and damage are not likely
None No evidence of any kind is seen to indicate potential threat due to soil movements.

Unknown In keeping with an "uncertainty = increased risk" bias, having no knowledge should register as high risk, pending the acquisition of information that suggests otherwise.

4.6 In correct Operations Index

4.6.1. Hazard Identification

Here, the evaluator checks to see that efforts were made to identify all credible hazards associated with the pipeline and its operation. A hazard must be clearly understood before appropriate risk reduction measures can be employed.

4.6.2. MOP Potential

Routine 0 pts Where routine, normal operations could allow the system to reach MOP. Overpressure would occur fairly rapidly due to incompressible fluid or rapid introduction of relatively high volumes of compressible fluids.
Unlikely 5 pts Where overpressure can occur through a combination of procedural errors or omissions, and failure of safety devices (at least two levels of safety).
Extremely Unlikely 10 pts Where overpressure is theoretically possible (sufficient source pressure), but only through an extremely unlikely chain of events including errors, omissions, and safety device failures at more than two levels of redundancy.
Impossible 12 pts Where the pressure source cannot, under any conceivable chain of events, overpressure the pipeline.

4.6.3. Safety systems

A. No safety devices present	0pts
B. On site, one level only	3pts
C. On site, two or more levels	6pts
D. Remote, observation only	1pt
E. Remote, observation and control	3pts
F. Non-owned active witnessing	-2pts
G. Non-owned no involvement	-3pts
H. Safety systems not needed	10pts

4.6.4. Material selection

The evaluator should look for evidence that proper materials were identified and specified with due consideration to all stresses reasonably expected.

4.6.5. Checks

Here, the evaluator determines if design calculations and decisions were checked at key points during the design process.

4.6.6. Construction

Ideally, construction processes would be well defined, invariant from site to site, and benefit from a high pride of workmanship among all constructors. This would, of course, ensure the highest quality and consistency in the finished product and inspection would not be needed.

Variables that can be scored in the assessment are as follows:

B1. Inspection	10 pts
B2. Materials	2 pts
B3. Joining	2 pts
B4. Backfilling	2 pts
B5. Handling	2 pts
B6. Coating	2 pts

4.7. Operation

4.7.1 Procedures

The evaluator should be satisfied that written procedures covering all aspects of pipeline operation exist. There should be evidence that these procedures are actively used, reviewed, and revised.

4.7.2. SCADA/ Communications

The following are selected as indicators of SCADA effectiveness as an error reducer:

1. Monitoring ofall critical activities and conditions
2. Reliability of SCADA system
3. Enforced protocol requiring real-time communications between field operations and control room; two sources involved in critical activities; an adequate real-time communications system is assumed
4. Interlocks or logic constraints that prevent incorrect operations; critical operations are linked to pressure, flow, temperature, etc.

4.7.3. Drug testing

Government regulations in the United States currently require drug and alcohol testing programs for certain classes of employees in the transportation industry.

4.7.4. Safety programs

Safety program evidence may take the form of some or all of the following:

- Written company statement of safety philosophy
- Safety program designed with high level of employee participation
- Strong safety performance record (recent history)
- Good attention to housekeeping
- Signs, slogans, etc., to show an environment tuned to safety
- Full-time safety personnel.

4.7.5. Training

Documented minimum requirements

Testing	2pts
Topics covered:	2pts
Product characteristics	0.5pts

Pipeline material stresses	0.5pts
Pipeline corrosion	0.5pts
Control and operations	0.5pts
Maintenance	2pts
Emergency drills	1pts
Job procedures (as appropriate)	0.5pts
Scheduled retraining	0.5pts

4.7.6. Mechanical error preventers

Three-way valves with dual instrumentation	4 pts
Lock-out devices	2 pts
Key-lock sequence programs	2 pts
Computer permissives	2 pts
Highlighting of critical instruments	1 Pt

4.7.7. Maintenance

Documentation	0-2 pts
Schedule	0-3 pts
Procedures	0-10 pts

- **Risk Assessment for Segment 1**

Segment-1 (0 m. – 2870 m.)

1.	**2.**	**3.**	**4.**	**5.**
A. 15.74	A. 3	A. 11.27	A. 17	PH = 9
B. 5	B. 15	B. 10	B. 8	L = 0.07
C. 3	C. 29.5	C. 8	C. 15	D = 2
D. 5		D. 17.125	D. 4	R = 2.12
E. 5		E. 2.5		
F. 2				
G. 3				
TPDI= 38.74	CI= 47.5	DI= 48.895	IOI= 44	LIF= 2.67

- **Risk Assessment Results for Segment 1**

Index Sum = 38.74 + 47.5 + 48.895 + 44 = 179.135

Relative Risk Score = 179.135 / 2.67 = 67.091

Relative Probability of Failure = 1 – (0.3874 * 0.475 * 0.48895 * 0.44) = .9604

= 96.04 %

Chapter 5

Pipeline Risk Assessment

5.1 Introduction

To carry out the Pipeline Risk Assessment the Pipeline has been divided in to 30 segments. The Procedure adopted and given at Page 13 to Page 24 was applied for calculating the Risk scores and Risk assessment results for all the 30 segments and are given segment wise here-in-after.

5.2 Segment wise Scoring

5.2.1 Segment-1 (0 m. – 2870 m.)

1. A. 15.74	**2.** A. 3	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 5	B. 15	B. 10	B. 8	L = 0.07
C. 3	C. 29.5	C. 8	C. 15	D = 2
D. 5		D. 17.125	D. 4	R = 2.12
E. 5		E. 2.5		
F. 2				
G. 3				
TPDI= 38.74	CI= 47.5	DI= 48.895	IOI= 44	LIF= 2.67

5.2.2 Segment-2 (2870 m. – 3000 m.)

1.	2.	3.	4.	5.
A. 19	A. 4	A. 11.27	A. 15	PH = 9
B. 8	B. 15	B. 9	B. 5	L = 0.07
C. 9	C. 29.5	C. 8	C. 12	D = 2
D. 7		D. 17.125	D. 3	R = 1.56
E. 5		E. 1.5		
F. 2				
G. 0				
TPDI= 50	CI= 48.5	DI= 46.895	IOI= 35	LIF= 1.965

5.2.3 Segment-3 (3000 m. – 4760 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 8	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 54.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.4 Segment-4 (4760 m. – 5130 m.)

1.	2.	3.	4.	5.
A. 19	A. 4	A. 11.27	A. 15	PH = 9
B. 8	B. 15	B. 9	B. 5	L = 0.07
C. 9	C. 29.5	C. 8	C. 12	D = 2
D. 7		D. 17.125	D. 3	R = 1.56
E. 5		E. 1.5		
F. 2				
G. 0				
TPDI= 50	CI= 48.5	DI= 46.895	IOI= 35	LIF= 1.965

5.2.5 Segment-5 (5130 m. – 6610 m.)

1. A. 13.12	**2.** A. 8	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 44.12	CI= 54.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.6 Segment-6 (6610 m. – 6700 m.)

1. A. 19	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 50	CI= 48.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.7 Segment-7 (6700 m. – 8320 m.)

1. A. 13.12	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 44.12	CI= 48.5	DI= 48.895	IOI= 44	LIF= 1.965

5.2.8 Segment-8 (8320 m. – 9606 m.)

1. A. 13.12	**2.** A. 8	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 44.12	CI= 54.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.9 Segment-9 (9606 m. – 11240 m.)

1. A. 13.12	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.95
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 44.12	CI= 48.5	DI= 48.895	IOI= 44	LIF= 2.457

5.2.10 Segment-10 (11240 m. – 16030 m.)

1. A. 13.12	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 5	B. 15	B. 8	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 2
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 41.12	CI= 48.5	DI= 46.895	IOI= 44	LIF= 2.52

5.2.11 Segment-11 (16030 m. – 17600 m.)

1. A. 13.12	**2.** A. 8	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 44.12	CI= 54.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.12 Segment-12 (17600 m. – 20465 m.)

1. A. 13.12	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 44.12	CI= 48.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.13 Segment-13 (20465 m. – 21140 m.)

1. A. 14.43	**2.** A. 3	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 3	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 3				
TPDI= 42.43	CI= 47.5	DI= 48.895	IOI= 44	LIF= 1.965

5.2.14 Segment-14 (21140 m. –24655 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 4	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 48.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.15 Segment-15 (24655 m. –28145 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 4	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.95
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 48.5	DI= 48.895	IOI= 44	LIF= 2.457

5.2.16 Segment-16 (28145 m. –31643 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 4	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 3	C. 29.5	C. 8	C. 15	D = 2
D. 8		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 3				
TPDI= 44.74	CI= 48.5	DI= 48.895	IOI= 44	LIF= 1.965

5.2.17 Segment-17 (31643 m. –34000 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 8	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 54.5	DI= 48.895	IOI= 44	LIF= 1.965

5.2.18 Segment-18 (34000 m. –34100 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 4	A. 20.02	A. 17	PH = 9
B. 5	B. 15	B. 8	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 2
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 48.5	DI= 55.645	IOI= 44	LIF= 2.52

5.2.19 Segment-19 (34100 m. -36286 m.)

1.	2.	3.	4.	5.
A. 15.74	A. 8	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.9
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 54.5	DI= 48.895	IOI= 44	LIF= 1.134

5.2.20 Segment-20 (36286 m. -36520 m.)

1.	2.	3.	4.	5.
A. 19	A. 4	A. 11.27	A. 15	PH = 9
B. 8	B. 15	B. 9	B. 5	L = 0.07
C. 9	C. 29.5	C. 8	C. 12	D = 2
D. 7		D. 17.125	D. 3	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 50	CI= 48.5	DI= 46.895	IOI= 35	LIF= 1.965

5.2.21 Segment-21 (36520 m. - 38646m.)

1.	2.	3.	4.	5.
A. 15.74	A. 3	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 3	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 3				
TPDI= 43.74	CI= 47.5	DI= 48.895	IOI= 44	LIF= 1.965

5.2.22 Segment-22 (38646 m. - 40780m.)

1.	2.	3.	4.	5.
A. 15.74	A. 8	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.9
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 54.5	DI= 48.895	IOI= 44	LIF= 1.134

5.2.23 Segment-23 (40780 m. - 45630m.)

1. A. 15.74	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 48.5	DI= 48.895	IOI= 44	LIF= 0.705

5.2.24 Segment-24 (45630 m. - 47900m.)

1. A. 15.74	**2.** A. 8	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 0.9
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 54.5	DI= 48.895	IOI= 44	LIF= 1.134

5.2.25 Segment-25 (47900 m. - 49040m.)

1. A. 15.74	**2.** A. 8	**3.** A. 28.455	**4.** A. 17	**5.** PH = 9
B. 5	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 43.74	CI= 54.5	DI= 66.08	IOI= 44	LIF= 1.965

5.2.26 Segment-26 (49040 m. - 51046m.)

1. A. 15.74	**2.** A. 8	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 7	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 0		
F. 2				
G. 0				
TPDI= 45.74	CI= 54.5	DI= 46.395	IOI= 44	LIF= 1.965

5.2.27 Segment-27 (51046 m. - 52656m.)

1. A. 15.74	**2.** A. 4	**3.** A. 11.27	**4.** A. 17	**5.** PH = 9
B. 7	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 0		
F. 2				
G. 0				
TPDI= 45.74	CI= 48.5	DI= 46.395	IOI= 44	LIF= 1.965

5.2.28 Segment-28 (52656 m. - 53314m.)

1. A. 15.74	**2.** A. 8	**3.** A. 28.455	**4.** A. 17	**5.** PH = 9
B. 0	B. 15	B. 10	B. 7	L = 0.07
C. 9	C. 31.5	C. 8	C. 15	D = 2
D. 5		D. 17.125	D. 3	R = 2
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 36.74	CI= 54.5	DI= 66.08	IOI= 42	LIF= 2.52

5.2.29 Segment-29 (53314 m. - 56139m.)

1.	2.	3.	4.	5.
A. 15.74	A. 4	A. 11.27	A. 17	PH = 9
B. 8	B. 15	B. 10	B. 8	L = 0.07
C. 9	C. 29.5	C. 8	C. 15	D = 2
D. 7		D. 17.125	D. 4	R = 1.56
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 46.74	CI= 48.5	DI= 48.895	IOI= 44	LIF= 1.965

5.2.30 Segment-30 (56139 m. - 58097m.)

1.	2.	3.	4.	5.
A. 15.74	A. 3	A. 28.455	A. 17	PH = 9
B. 0	B. 15	B. 10	B. 8	L = 0.07
C. 3	C. 29.5	C. 8	C. 15	D = 2
D. 5		D. 17.125	D. 4	R = 2.12
E. 5		E. 2.5		
F. 2				
G. 0				
TPDI= 33.74	CI= 47.5	DI= 66.08	IOI= 44	LIF= 2.67

5.3 Segment wise risk assessment results

- Index Sum = [(TPDI)+(CI)+(DI)+(IOI)]
- Relative Risk Score = [(Index Sum)/ LIF]
- Relative Probability of Failure = 1- (third Party damage Score/100 * Corrosion Score/100 * Design Score/100 * Incorrect Operation Score/100)

Segment	Index Sum	Relative Risk Score	Relative Probability of Failure(%)
1	179.135	67.091	96.04
2	180.395	91.8	96.01
3	194.095	275.078	94.52
4	180.395	91.8	96.01
5	191.515	271.42	94.82
6	191.395	271.25	94.78
7	185.515	94.409	95.39
8	191.515	271.42	94.82
9	185.515	75.5	95.39
10	180.515	71.63	95.88
11	191.515	271.42	94.82
12	185.515	262.918	95.39
13	182.825	93.04	95.66
14	194.135	275.13	94.51
15	188.135	76.57	95.12
16	186.135	94.725	95.33
17	194.135	98.796	94.51
18	191.885	76.144	94.8
19	194.135	171.194	94.51
20	180.395	91.8	96.01
21	184.135	93.7	95.53
22	194.135	171.194	94.51
23	188.135	266.63	95.12
24	194.135	171.194	94.51
25	207.32	105.474	93.22
26	190.635	96.985	94.91
27	184.635	93.933	95.47
28	199.32	79.09	94.44
29	188.135	95.713	95.12
30	191.32	71.655	95.34

Risk Analysis

- Based on the segment wise risk assessment results obtained from chapter 5, a graph has been plotted between the segments and risk scores.

- The following figure shows the bar-chart of the 30 segments:

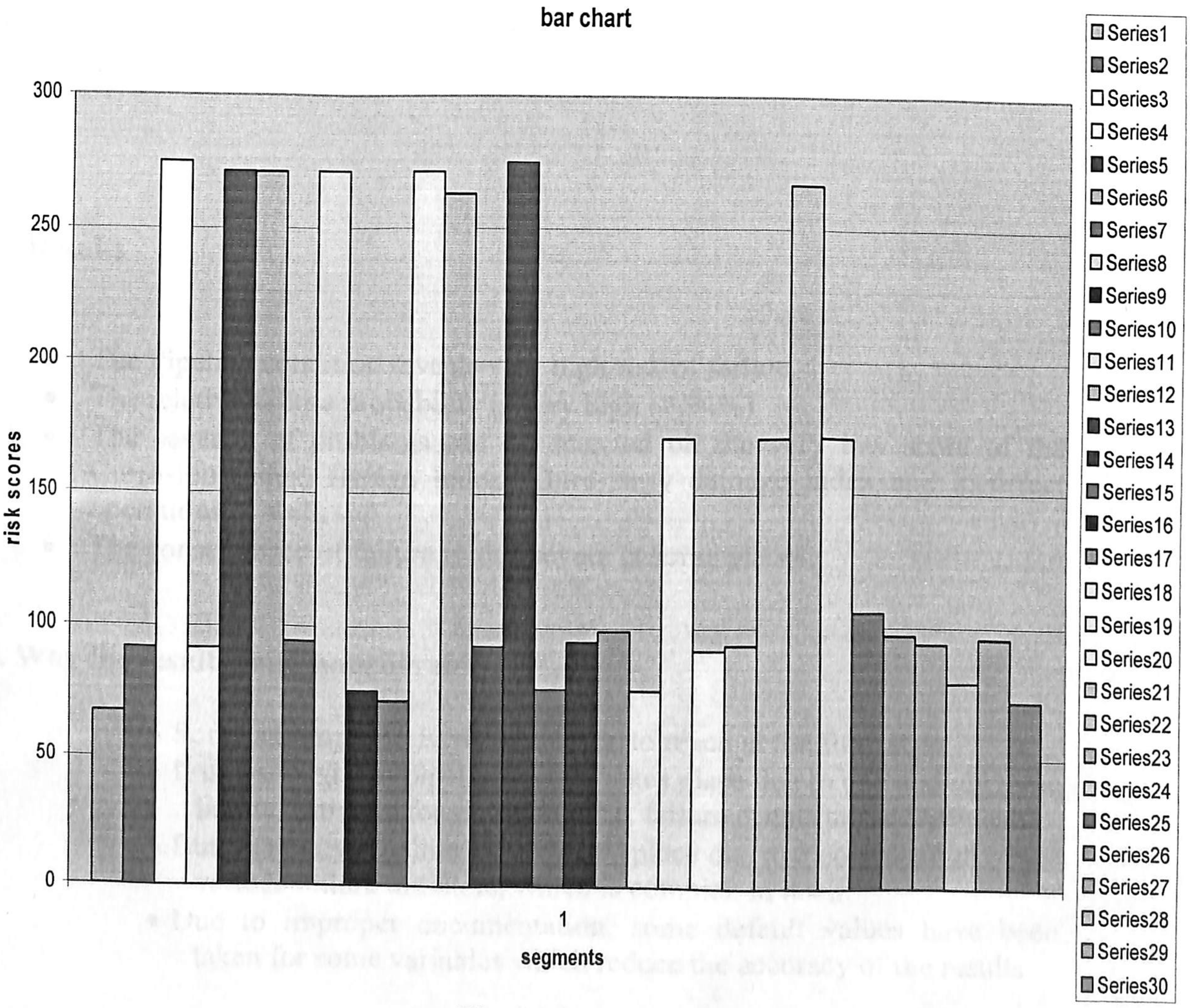


Fig. 5.4.1

- The results indicate that if the risk score is less, then the pipe segment has high probability of failure.

Chapter 6

Results and Discussions

6.1 . Results

- The Pipeline condition reveals very high risk of failure.
- The relative failure probability is very high (> 94%)
- The severity of problems can be detected on the very low score of the Corrosion Index, Design Index, Third-party damage Index and incorrect operations as well.
- The consequence of failure is also severe at some places.

6.2. Why the result seems unbelievable

- Some assumptions have been taken to reach at the final score.
- It is assumed that pipeline failure takes place due to one and only one failure initiators for simplicity.(i.e. failure events are independent)
- But, in reality pipeline failure takes place due to a combination of the various failure initiators, which is complex in itself.
- Due to improper documentation, some default values have been taken for some variables which reduce the accuracy of the results.

6.3. Conditions for a good risk assessment

- Evaluation by one evaluator to reduce variability
- Consistency in Scoring various segments

- Availability of all relevant information, Expert judgement based on engineering knowledge.

6.4. How to use this result

- The results should be put in a professional risk assessment model.
- As new information is available it should be put into the previous data and the risk scores should be re-assessed.
- It should be used as an information repository for reference purpose.
- It should be updated each time any activity is taken which will affect the risk score.

6.5. Recommendations

- Based on the relative risk score, the risk score of the 18 most risky segments should be improved, to improve the Overall risk picture.

6.5.1. How to improve third-party damage index

- Response time to one-calls should be reduced to a reasonable level.
- Approach to the public education programme needs a close scrutiny.(Door-to-door contact with the people nearby the pipeline is the most effective way to reduce third-party- damage.)
- ROW condition needs improvement. (Any type of encroachment on the ROU should be effectively prevented.)
- Patrolling frequency should be increased.(At least once weekly)

6.5.2. How to improve Corrosion index

- Subsurface corrosion should be prevented by:

    1. Watching carefully the current requirements from time to time
    2. SCADA system should be effective such that it should monitor all the important activities.
    3. Assessing the coating condition at regular intervals and taking necessary action.

6.5.3. How to improve Design index

- Integrity verification tests (Hydrotesting, ILI) should be done at pre-determined intervals.
- Land movements should be monitored (lateral movement of the pipeline during certain time period) and suitable action should be taken.

6.5.4. How to improve Incorrect Operations index

- The O & M activities are more prone to human errors as it is a major dependent upon the human activities.
- HAZID should be done for all critical activities
- Safety systems should be in good working conditions at any time
- Mechanical error preventers should be provided for the critical activities
- Proper documentation of all the associated activities
- Increasing the awareness of the employees through proper training and orientation.

6.5.5. How to reduce Leak impact factor

- The LIF can be reduced by:

    1. Effective containment of the released product
    2. Increasing distance between the source and receiver.
    3. Isolating the receiver.

- Out of the three points as the effective containment of a product like natural gas is very difficult, the inventory to be released in case of a leak should be reduced by providing Shut-off valves at suitable distances which will reduce the inventory, thus reducing the severity of damage.
- Whenever it is impossible to increase the distance between source and receiver, the thickness of the pipeline section should be increased during design and construction phase.
- Isolating the observer is an auxiliary option.

CONCLUSION

The Pipeline condition reveals very high risk of failure and the relative failure probability is greater than 94%.

The main contributors towards higher risks are based on the relative risk score. The risk score indicates that 18 segments have very high risk of failure.

Continuous updating of the results is required as conditions keep varying with time.

"RECOMMENDATIONS"

- The Recommendations to improve the Various indices with a view to reduce the probability of failures have been given vid. clauses 6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.5.5.
  (Pages 39-40).

Information Resources

- Pipeline risk management Manual, 3rd Edition, W. Kent Muhlbauer
- www.google.com
- www.heavens-above.com
- www.epa.gov
- www.naturalgas.com
- Office of pipeline safety.
- Gas Research Institute
- www.pipelinerisk.com
- www.riskworld.com
- Office of Gas Safety.
- Internet

ANNEXURE

- **Construction Details**

The pipeline has been designed, engineered, constructed and tested in accordance with the provisions of ASME code B 31.8 for Gas Transmission and Distribution piping systems. OISD 141 part 11, and other relevant codes and standards. The design parameters of buried pipeline are as follows:

- Pipeline diameter : 24"
- Maximum operating pressure : 95 bar
- Design temperature : -20 deg. C to 60 deg. C

- **Engineering Details and Operating Parameters**

Section Name	Diameter	Length (Km)	Pressure	Temperature
Mora-Sajod	24"	58.097	55 bar	35 deg. C

- **Soil along the Proposed Natural Gas Pipeline**

The soil along the route is mainly alluvial black cotton soil or yellow soil as per details given below:

Route	**Soil Type**
Mora-Sajod	Black Cotton Soil
	Silty Soil
	Sandy Soil
	Gravelly Soil

[illegible]

Duration	**Predominant wind direction**	**Predominant wind speed Km/hr**
March – June	SW	10 - 20
July – October	SW	5 - 20
November - February	NE – SW	5 - 10