EASTERN AFRICA CRUDE OIL PIPELINE (EACOP)

THE GIS ROUTING EXPERIENCE

ENERGY SECTOR GIS WORKING GROUP

By
Florence N Nkalubo

SKY HOTEL, KAMPALA
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EACOP Routing: The GIS Experience

- Introduction
- Overview of the oil and gas sector in Uganda
- Background: Pipeline in Uganda
- Criteria for Pipeline Routing
- Data collection and Analysis
- Results
- Conclusions
INTRODUCTION

THE PETROLEUM VALUE CHAIN

- LICENSING
- EXPLORATION
- DEVELOPMENT
- PRODUCTION

UPSTREAM

- TRANSPORTATION
- REFINING
- GAS PROCESSING

MIDSTREAM

- DISTRIBUTION
- MARKETING
- SALES

DOWNSTREAM
• Changed from small independent companies to large International oil companies after first commercial discovery

• 4 licenses with Three companies; CNOOC, Total and Tullow.

• New Licensees – Armour Energy, Oranto Petroleum
OVERVIEW OF THE OIL AND GAS SECTOR IN UGANDA

- **2006 – Commercial Discovery**
- **21 Discoveries; 88% drilling success rate**
- **6.5 BBLs STOIIP; 1.4 billion reserves**
- **9 production licenses over 14 discoveries**
- **10% of Albertine Graben Licensed**
- **3 New exploration licenses issued in 2017**
OVERVIEW OF THE PIPELINES

FACILITIES

Feeder Pipelines
- Northern 97km long from Tilenga CPF
- Southern 47km long from KFDA CPA

Refinery
- 60k barrels of oil refinery in Hoima

Product Pipelines
- 205km long Products pipelines

East African Crude Oil Pipeline
- 1445km long Hoima to Tanga Port pipeline (EACOP)
MAIN OBJECTIVE: Identify and select the preferred pipeline route and alternatives.

3 PHASES

- **PHASE 1**: GIS Risk Based Pipeline Routing Study (Scale 1:200,000)
- **PHASE 2**: Manual Routing Improvement Using High Resolution Satellite Imagery (Scale 1:50000) and Lidar Data.
- **PHASE 3**: Ground Truthing / Field based investigations
PHASE 1: GIS Risk Based Pipeline Routing Study

- Identification of area of interest (AOI)
  From Hoima to the Indian ocean coastline excluding areas with slopes above 45 degrees, Main Cities, Lake crossing, Elevation above 2500m, Active Volcanoes, 1km from Archaeological & Tourist sites, and Protected areas.
PHASE 1: GIS Risk Based Pipeline Routing Study

✔ Development of a GIS database at scale 1: 200000

Infrastructure, land use, environment, geo hazards (Volcanoes, Seismic, flooding, etc.), tourism, archeology and heritage, hydrology, population among others. Harmonizing data for Kenya, Uganda, Tanzania and Southern Sudan.

✔ Identification and prioritization risk factors and their impact on pipeline cost

Five thematic risks were considered

Construction, operational, socioeconomic, environmental and security
**PHASE 1: GIS Risk Based Pipeline Routing Study (thematic risks)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational</strong></td>
<td>7  Seismic activity damage in Ag</td>
</tr>
<tr>
<td></td>
<td>8  Active fault crossing and active rifting</td>
</tr>
<tr>
<td></td>
<td>9  Landslide threat</td>
</tr>
<tr>
<td></td>
<td>10 Extreme temperature in soil</td>
</tr>
<tr>
<td></td>
<td>11 Limited access to pipeline</td>
</tr>
<tr>
<td></td>
<td>12 High elevation</td>
</tr>
<tr>
<td></td>
<td>13 Volcanic activity damage</td>
</tr>
<tr>
<td></td>
<td>14 Flooding hazard damage</td>
</tr>
<tr>
<td></td>
<td>15 Liquefaction susceptibility</td>
</tr>
<tr>
<td><strong>Socio-Economic</strong></td>
<td>16 Agriculture impact</td>
</tr>
<tr>
<td></td>
<td>17 Pollution of populated areas</td>
</tr>
<tr>
<td></td>
<td>18 Cultural &amp; archaeological heritage</td>
</tr>
<tr>
<td></td>
<td>19 Touristic degradation</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td>20 Wetlands and rivers geothermal fields/springs pollution</td>
</tr>
<tr>
<td></td>
<td>21 Deforestation (of non protected forests)</td>
</tr>
<tr>
<td></td>
<td>22 Sensitive and protected areas damage</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>23 Area of conflict</td>
</tr>
<tr>
<td></td>
<td>24 Sabotage damage</td>
</tr>
</tbody>
</table>
Development of GIS tool to calculate least costly route using weighted index.

Analytical hierarchy Process (AHP) method was chosen as it uses pairwise comparison and each factor is characterized by an index according to the relative importance of that factor.

- Agreed end points at the Indian Ocean.
- Malindi / Lamu at the Kenyan coast
- Tanga along the Tanzanian coast
- Juba in South Sudan
- Lokichogio in Kenya
<table>
<thead>
<tr>
<th>Risk Factor Description</th>
<th>GEOTER</th>
<th>TOTAL</th>
<th>TULLOW</th>
<th>Common agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Building cost over high slopes</td>
<td>0.030</td>
<td>0.028</td>
<td>0.045</td>
<td>0.060</td>
</tr>
<tr>
<td>2 - Urban construction cost</td>
<td>0.060</td>
<td>0.060</td>
<td>0.033</td>
<td>0.024</td>
</tr>
<tr>
<td>3 - Crossing cost</td>
<td>0.119</td>
<td>0.060</td>
<td>0.103</td>
<td>0.121</td>
</tr>
<tr>
<td>4 - ROW distance from existing infrastructures</td>
<td>0.014</td>
<td>0.017</td>
<td>0.015</td>
<td>0.014</td>
</tr>
<tr>
<td>5 - Shallow or surface bedrock constructibility</td>
<td>0.119</td>
<td>0.060</td>
<td>0.103</td>
<td>0.060</td>
</tr>
<tr>
<td>6 - Wetlands crossing</td>
<td>0.060</td>
<td>0.060</td>
<td>0.057</td>
<td>0.060</td>
</tr>
<tr>
<td>9 - Seismic activity damage</td>
<td>0.014</td>
<td>0.017</td>
<td>0.010</td>
<td>0.012</td>
</tr>
<tr>
<td>10 - Active fault crossing and active rifting</td>
<td>0.119</td>
<td>0.114</td>
<td>0.103</td>
<td>0.121</td>
</tr>
<tr>
<td>11 - Landslide threat</td>
<td>0.036</td>
<td>0.114</td>
<td>0.057</td>
<td>0.060</td>
</tr>
<tr>
<td>12 - Extreme temperature in soil</td>
<td>0.014</td>
<td>0.017</td>
<td>0.013</td>
<td>0.013</td>
</tr>
<tr>
<td>13 - Limited access to pipeline</td>
<td>0.014</td>
<td>0.017</td>
<td>0.015</td>
<td>0.013</td>
</tr>
<tr>
<td>14 - Elevation</td>
<td>0.119</td>
<td>0.168</td>
<td>0.103</td>
<td>0.121</td>
</tr>
<tr>
<td>15 - Volcanic activity damage</td>
<td>0.014</td>
<td>0.017</td>
<td>0.010</td>
<td>0.013</td>
</tr>
<tr>
<td>16 - Flooding hazard damage</td>
<td>0.018</td>
<td>0.017</td>
<td>0.022</td>
<td>0.019</td>
</tr>
<tr>
<td>17 - Liquefaction susceptibility</td>
<td>0.024</td>
<td>0.028</td>
<td>0.033</td>
<td>0.018</td>
</tr>
<tr>
<td>18 - Agriculture impact</td>
<td>0.060</td>
<td>0.028</td>
<td>0.033</td>
<td>0.060</td>
</tr>
<tr>
<td>19 - Pollution of populated areas</td>
<td>0.014</td>
<td>0.017</td>
<td>0.033</td>
<td>0.012</td>
</tr>
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<td>20 - Cultural &amp; archaeological heritage</td>
<td>0.014</td>
<td>0.017</td>
<td>0.013</td>
<td>0.013</td>
</tr>
<tr>
<td>21 - Touristic degradation</td>
<td>0.014</td>
<td>0.017</td>
<td>0.013</td>
<td>0.013</td>
</tr>
<tr>
<td>23 - Wet lands and rivers geothermal fields/springs</td>
<td>0.018</td>
<td>0.017</td>
<td>0.033</td>
<td>0.033</td>
</tr>
<tr>
<td>24 - Deforestation</td>
<td>0.014</td>
<td>0.017</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>25 - Sensitive and protected areas damage (RAMSAR)</td>
<td>0.060</td>
<td>0.060</td>
<td>0.103</td>
<td>0.103</td>
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<tr>
<td>27 - Area of conflict</td>
<td>0.015</td>
<td>0.017</td>
<td>0.017</td>
<td>0.017</td>
</tr>
<tr>
<td>28 - Sabotage damage</td>
<td>0.015</td>
<td>0.017</td>
<td>0.017</td>
<td>0.017</td>
</tr>
</tbody>
</table>
Identification of 50km wide corridors
Hoima to Malindi
Hoima to Malindi

Hoima to Malindi – Corridor 1, North - Profile

FIGURE 13

Hoima to Malindi – Corridor 1, North - Profile

Distance (KP) - Total 3D length = 1156.8 Km

- Elevation (m)
- Slope (Degree)
- Soil thickness < 0.5 m
- Major faults with scarp
- Major river crossing

Route length (3D) = 1196.8 km
Max. elevation = 2432 m
Max. slope = 45°

Soil conditions (length km):

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>&gt; 1.5 m</th>
<th>0.5 - 1.5 m</th>
<th>&lt; 0.5 m</th>
<th>&lt; 0.5 m slope A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (km)</td>
<td>503</td>
<td>534</td>
<td>60</td>
<td>0</td>
</tr>
</tbody>
</table>

Altitude (length km):

<table>
<thead>
<tr>
<th>Altitude (m)</th>
<th>&lt;1500</th>
<th>1500-2000</th>
<th>2000-2500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (km)</td>
<td>943</td>
<td>702</td>
<td>52</td>
</tr>
</tbody>
</table>
Hoima to Tanga

Ministry of Energy and Mineral Development
Hoima to Tanga

Distance (KPI) - Total 3D length = 1408.2 Km

Soil thickness < 0.5 m

Major faults with scarps

No major river crossings

Route length (JD) = 1408.2 km
Max. elevation = 2004 m
Max. slope = 38.2°
Best routes considered for further evaluation
Risk Analysis

**General Routing Constraints**
- High slopes
- Crossings – hydrology and transport
- Shallow surface bedrock
- Wetlands (opt for seasonal)

**Operational Constraints**
- Active fault crossing and active rift
- Land slide threat
- Elevation

**Social Economic and Environmental Constraints**
- Forests
- Farms Mainly Tea And Coffee
Risk Maps
Risk Maps
Risk Maps

Risk map
ROW distance from existing infrastructures

Ministry of Energy and Mineral Development
Risk Maps

Ministry of Energy and Mineral Development
Risk Maps
Risk Maps

Active fault crossing and active rifting

Risk map

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Risk Maps
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Risk Maps

Area of conflict and Sabotage damage

Risk map

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Best route after optimization

LIDAR HD res. (20cm) Imagery

LIDAR 2m Digital Elevation Model
Best route after optimization

1445km – one of longest crude oil pipelines

- 216 kbopd design capacity
- Waxy Crude (up to 45°C PP) & Viscous Oil
- Insulated 24in pipeline
- Longest Trace Heated Pipeline in the World
- 6 Pumps Stations (PS)
- 2 Pressure Reduction Stations (PRS)
- Power Generation at PS 3 & 5 and Terminal
- Future Heating Facilities at PS
- Marine Storage and Export Terminal
- Interfacing Upstream (Tilenga/ Kingfisher) + Refinery
- Approx. 430,000 t of material & equipment
Conclusion

- Oil and gas facilities development needed for production
  - Tilenga project
  - KFDA project
  - Kabaale industrial park
- GIS used from project inception to decommission
- GIS for data management and decision making for the pipeline Routing
- Future prospects for GIS in facility management
THANK YOU

Questions/Comments ????

Contact: Directorate of Petroleum
Plot 21-29 Johnstone Road
Entebbe
Email: directorate@petroleum.go.ug
Web: http://www.petroleum.go.ug/