CEA-GIS BASED AUTOMATIC TOOL FOR SELECTION OF GAS PIPELINE CORRIDORS – SIGGAS PROJECT

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This paper describes a methodology developed to build Total Accumulated Surfaces in order to improve the selection of Gas Pipelines corridor alternatives. The methodology is based on the minimization of negative impacts and in the use of Geographic Information Systems (GIS), allowing an automatic method of construction, evaluation and selection of alternatives, contributing to the decision making process. Gas Pipelines, as for their linear characteristic, cross a variety of habitats and settlements, increasing the complexity of their environmental management. Considering this reality, this paper presents a methodology that takes into account different environmental dimensions (themes or layers). From the synthesis of the themes it is presented the Total Accumulated Surface. Using the Total Accumulated Surface, it is selected a region, formed by pixels, each pixel with an accumulated impact score lower than some arbitrary measure. This region is called “corridor”, and it is the final result obtained using the proposed methodology.

Keywords: Gas Pipeline Connection, Total Accumulated Surface, Corridor, Negative Impacts, Geographic Information System, linear projects, impact scores, layers, spatial features, environmental management.

1. Introduction

Part of this paper had been presented at IAIA Meeting on Cumulative Effects Assessment, at Calgary, Canada, on November 2008. It is a result of a research project on the development of a computerized decision support system, called SIGGAS, specialized on considering environmental issues in sitting gas pipelines. The research project is developed at CEPEL, the Electric Power Research Center of ELETROBRAS System. At the Center it is also developed a similar decision support system to choose best corridors for transmission lines regarding environmental issues, called AMBIENTRANS.

By using the methodology it is possible to bring together a spatial approach to the intersections between impacts, and not only analyze them separately. Also it is possible to insert layers considering implemented pipelines and planned pipelines, what add “time” to space approach, and improve the cumulative effects assessment analysis.

The figure below shows the net of gas pipelines in Brazil:

Pipelines in red plus pipelines in blue (the operating ones) represent more than 5.200 km. As can be seen in the figure, the yellow ones have bigger extension and go across different ecosystems of high importance and fragility (Brazilian Amazon rain forest, caatinga and cerrado). This shows the necessity of methodologies to minimize the environmental impacts of projects, acting in their planning process.

The methodology presented here is based on:

- Minimizing negative environmental impacts;
- Building Total Accumulated Surfaces;
- Implementing data to a Geographic Information System (GIS) – using in this case ARCGIS 9.0 version (ESRI).

The methodology is divided in five steps:

1. Selection of study area and environmental dimensions;
2. Definition of so called "impact scores";
3. Building the Total Accumulated Surface;
4. Proceed Directional Analysis, using the Total Accumulated Surface;
5. Perform Corridor Selection.

To make the selection of environmental dimensions and define the impact scores it is necessary to know a little more about gas pipelines projects, what is considered in next item.

2. Negative Environmental Impacts of Gas Pipelines

It is necessary to consider the potential environmental impacts of a hypothetical gas connection. CONAMA 001/86 Resolution defines environmental impact as: "any change on physical, chemical and biological properties of the environment, caused by any substance or energy resulting of human activities that, directly or indirectly affect:

I – health, safety of well being of the people;
II – social or economic activities;
III – flora and fauna;
IV - aesthetical or sanitary conditions of the environment;
V – environmental resources quality."[1]

The chain of natural gas can be divided in: extraction, processing, transport, storage and distribution. . In short, gas is extracted from the earth or the oceans by drilling from a well and then moved by pipeline or boats to a cleaning and processing plant and then to a gas grid or storage facility, to be distributed to the final users. Here are considered the negative impacts that occur on transportation by pipeline, an action that is only one possibility that takes place in one of the steps of natural gas chain.

The environmental impacts associated to transport of gas can be divided in two groups:

- environmental impacts that take place on construction phase; and
- environmental impacts that take place on operation phase.

During the construction of a gas pipeline the main negative impacts are over land use and communities around the facility, and during operation the main negative impacts are the occurrence of gas emissions and risks related to the presence of a gas transportation unity.

This study focuses on avoidance / minimization of negative environmental impacts that take place on the construction phase of gas pipelines, by inserting environmental-key considerations on the

[1] Freely traduced from Portuguese to English. Source: BRASIL, 1986. *Resolução CONAMA 001*, de 23 de Janeiro de 1986. Ministério do Meio Ambiente (MMA).

process of choosing the best location for it. It is considered that a good location choice also minimizes negative impacts during the operation of gas pipelines.

The list below presents the potential negative impacts of gas pipelines, as cited at the "Roteiro Metodológico para Análise de Grau de Impacto Ambiental" (IBAMA, 2003):

- Interference on communities ways of life;
- Increase of STD's and other endemism;
- Probability of increase on prostitution;
- Increase of violence occurrences;
- Pressure over infra-structure of essential services;
- Disordered urban occupation;
- Pressure over highway infrastructure;
- Noise and dust emissions;
- Accidents Risk;
- Aggradation of water bodies;
- Changes on water quality;
- Interferences on aquatic flora and fauna;
- Changes on land use;
- Loss of agricultural areas;
- Intensification / beginning of erosive processes;
- Fragmentation of forests;
- Increasing mortality of fauna individuals;
- Probability of selective extraction of vegetal species;
- Loss of habitats;
- Water and soil pollution.

These are potential impacts, listed considering gas pipelines projects in general. For each specific project some of these impacts can happen, others don't, and maybe there could happen some impact not listed above. This will be important on the definition of:

- environmental dimensions (themes or layers);
- categories of environmental dimensions (how to classify the spatial features that compound the environmental dimensions).

3. The Five Steps

A. Selection of study area and Environmental Dimensions

The selection of the study area is done considering the two points to be linked, plus a margin that makes possible to make turns at the end/beginning, imagining that there could be obstacles not allowing a straight connection.

Considering the environmental characteristics of the area to be crossed by the gas pipeline feature, some negative impacts are to be expected, and some environmental aspects appear to be more likely to be impacted. Having said so, the environmental dimensions normally gathered in this kind of study are: land use; declivity, Protected Areas (like National Parks and so on); Highways and Railways; Hidrography and Urban Areas.

These environmental dimensions, inside GIS software, take the form of themes. These themes overlaid produce a synthesis of the relevant spatial features to be crossed by the gas pipeline.

Each theme is compound by a set of spatial features. There are point-themes in which the spatial features are represented by points (like monitoring stations, schools); line-themes, in which spatial features are represented by lines (such as roads, rivers, etc) and polygon-themes, in which spatial features are represented by polygons (for example, land use, Protected Areas, etc.).

The set of spatial features that compound a theme can be classified, and often is. The environmental dimensions have classical ways of classifications, but sometimes they are not accurate enough, and other times, information is not available. Below it can be seen the main environmental dimensions considered in this kind of project, and some helpful ways to classify it.

Table 1: Examples of Themes Classification

Environmental Dimensions			
Land Use	**Declivity**	**Vegetation**	**Roads**
Agriculture	0 a 5%	Temperate broadleaf	Paved Roads
Pasture	5 a 15 %	Temperate steppe	Not-paved roads
Urban use	15 a 30 %	Subtropical rainforest	
Primary Vegetation	30 a 45%	Subtropical dry forest	
Secondary Vegetation	45 a 60%	Tropical rainforest	
Soil	> 60%	Grass savanna	
		Tree savanna	

All spatial features in a theme are classified, even if there is only one category. In this work the categories receive a value, named “impact score”. Impact scores are directly proportional to the potential of being negatively affected by the construction of the gas pipeline, the higher the potential, the higher the “impact score”.

B. Definition of Impact Scores

Impact Scores are values in a hierarchical scale, in our case they go from 0 to 1.000, 0 meaning a very low potential to negative impacts as a consequence of the gas pipeline installation, and 1.000 meaning a extremely high potential to negative impacts.

For the selection and valuation of spatial features the gas pipeline will be considered a line-theme, but the final result is a region where accumulated impact scores are minimum.

The table below presents the negative impacts previously listed, and a second column, that identifies which negative impacts can be directly minimized or even avoided (YES column) through a better corridor choice, considering environmental issues.

Table 2: Negative Impacts that Can be Minimized/Avoided by The Consideration of Environmental Issues at the Decision Making Process

Negative Impacts	YES
Interference on ways of life of communities	x
Increase of STD’s and other endemism	
Probability of increase on prostitution	
Increase of violence occurrences	
Pressure over infra-structure of essential services	
Disordered urban occupation	
Pressure over highway infrastructure	
Noise and dust emissions	

Accidents Risk	
Aggradation of water bodies	x
Changes on water quality	
Interferences on aquatic flora and fauna	
Changes on land use	x
Loss of agricultural areas	x
Intensification / beginning of erosive processes	x
Fragmentation of forests	x
Increasing mortality of fauna individuals	
Probability of selective extraction of vegetal species	
Loss of habitats	x
Water and soil pollution	

Using information of table 2, the table below presents the negative impacts marked above and the spatial features related to them, potentially affected by gas pipelines.

Table 2: Spatial Features

Negative Impacts	Spatial Features
Interference on ways of life of communities	Urban sites, settlements, Indian territories
Aggradation of water bodies	Wetlands, water ways, erosive areas
Changes on land use	Mining activities, urban areas, etc
Loss of agricultural areas	Agricultural areas, areas with agricultural potential, forestry
Intensification / beginning of erosive processes	Erosive areas, declivity
Fragmentation of forests	Protected areas, Primary Vegetation areas, etc
Loss of habitats	Protected areas, Primary Vegetation areas, etc

These are some of the spatial features considered relevant for impact assessment of Gas Pipelines projects. Also it must be determined the kind of spatial interactions that are to be valued: proximity and/or interference. Interference implies intersection of spatial feature by the gas pipeline feature. Proximity can be considered in different levels of distance, between the spatial feature and the gas pipeline feature. The table shows examples of spatial features considered relevant. It presents both social and environmental aspects and points out the type of interaction between the spatial feature and the gas pipeline feature.

Table 3: Spatial Interactions

Spatial Features	Type of Interaction
Roads, Railways	Interference
Urban Sites / Agglomerations	Interference / Proximity
Agriculture / forestry	Interference
Agricultural Potential	Interference
Vegetation	Interference
Protected Areas	Interference / Proximity
Wetlands / Water bodies	Interference / Proximity
Indian Territories	Interference / Proximity
Declivity	Interference

Specialists of a multidisplinary spectrum should work together to determine the impact scores of the spatial features, in such a way that it is respected their relative importance to environmental complexity and their susceptibility to being affected by the gas pipeline be mirrored on the Total Accumulated Surface.

The table below shows a set of impact scores. In this example it was considered of low potential to bring impacts if the gas pipeline feature is within a distance of 1km from existing roads, and the more distant roads are, higher impacts we have. It is because it was considered that regions far from existing roads would suffer impacts because of the need to open ways, which is an impact in itself.

Table 4: Definition of Impact Scores

Features	Interference	Proximity
Distance of 1 km from roads		0
Distance of 1-5 km from roads		10
Distance of 5-10 km from roads		50
Distance of 10-20 km from roads		75
Distance of > 20 km from roads		100
Urban Site	1000	
Agriculture	20	
Forest	200	
Savanna	250	
River – Water body	1000	
Wetland	500	
Protected Area	500	300
Indian Territory	1000	300

Three features appear with maximum scores: urban areas, rivers and Indian territories, for the difficulties of crossing, difficulties on legislation and high potential impacts involved.

C. Building the Total Accumulated Surface

The Total Accumulated Surface is the result of the sum of the overlaid themes considered the operation as follows:

- For each pixel in the study area there are n impact scores, as many as there are overlaid themes;

- The resulting score for each pixel is the sum of the n scores: Acc Score = T1+T2+…+Tn;

- The set of pixels with accumulated scores is a surface that shows avoidance / attraction areas from the social and environmental impact minimization point of view;

In the Total Accumulated Surface (as can be seen in the example below), some areas concentrate bigger accumulated scores (in red), others have low accumulated scores (in blue). In this case the existing roads were the main vectors to determine the lower accumulated scores areas.

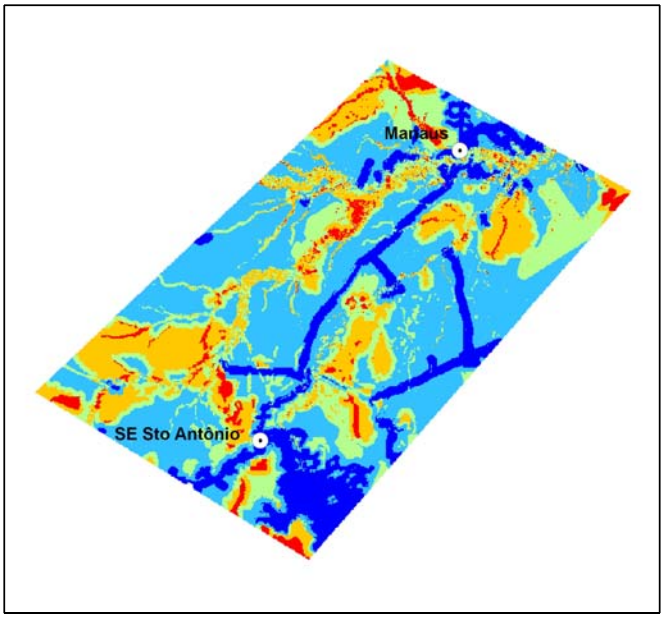
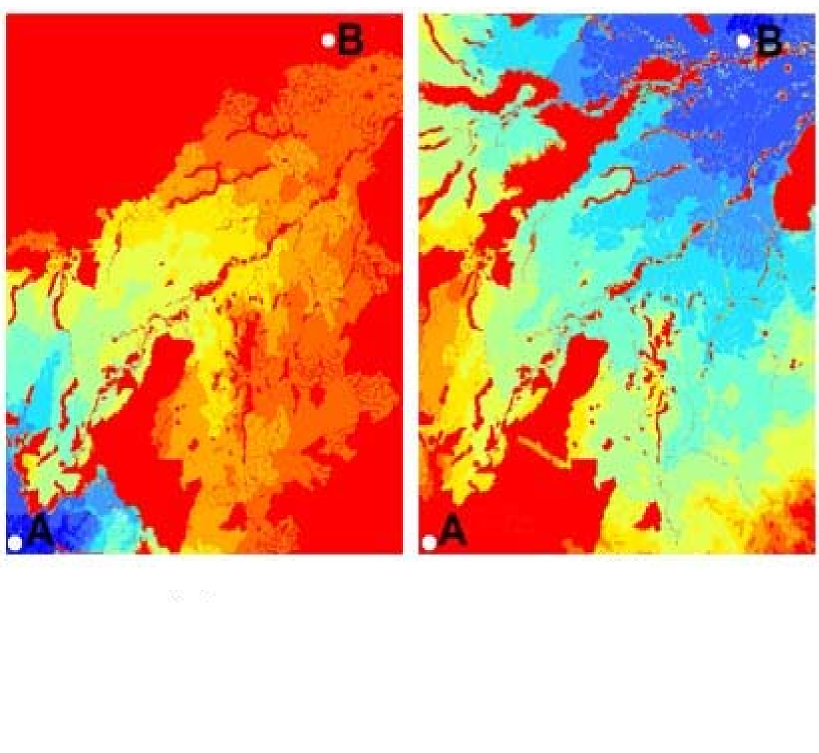


Figure: Total Accumulate surface

D. Proceed Directional Analysis

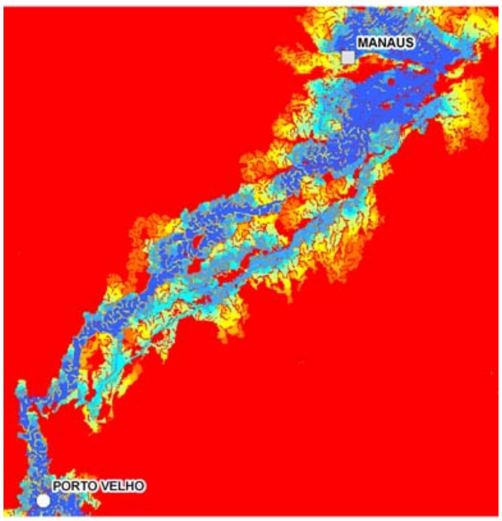
After achieving the Total Accumulated Surface, two directional analysis are made, from point A to all points and from point B to all points of the surface. Using the ArcGis 9.0 CostDistance function, two surfaces are produced, in which each pixel is the sum of scores until that point from one extreme of the Gas Pipeline feature. On the pictures below the sum of scores vary from blue (smaller) to red (bigger). On the picture on the right the starting point is A, the other one has its starting point on B.

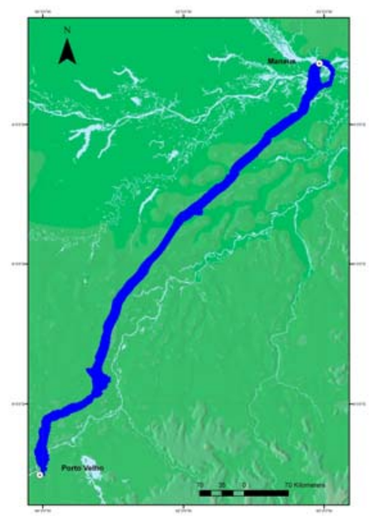


E. Corridor Selection

After obtaining the two directional analysis surfaces, it is produced a third surface, named “Corridor”. In this surface the smaller values correspond to smaller accumulated scores in the smallest distance from both extremes considered. The corridor selection is made by selecting the region between the two extremes with smaller accumulated scores. It is useful to establish a percentage and sum it to the minimum accumulated score found, than draw the corridor using these limits.

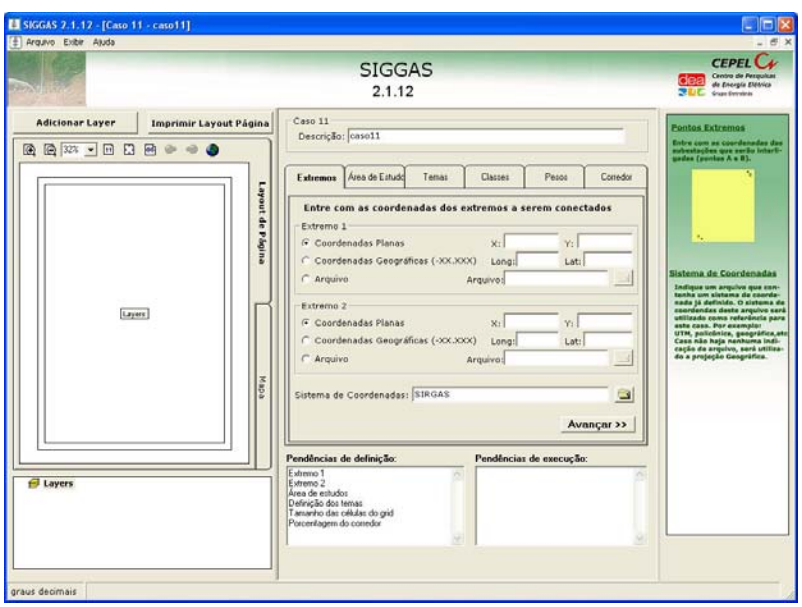
The picture at the right shows the areas at the Corridor Surface, colored according to different ranges, and the picture on the right shows the result of selecting areas on the corridor surface with accumulated impact score equal to minimum score found, plus five percent of its value.





3. The Automate Tool

It has been developed a tool that automate these steps, substituting the use of ArcGis 9.0 tools and functions. It makes possible to perform the corridor selection without having ArcGis installed. In the figure you can see the first window of this automatic tool.



Also it is already possible to give weights to the different themes. In the tool there sets of weights to the themes:

- All themes with equal weight, or 1;
- “arbitrary” weights –simply complete the blanks with weights to the themes, in a way that their sum is equal to 1;
- “AHP” weights – using a portion of the analytical hierarchy process (AHP). The procedure involves mathematically summarizing paired comparisons of the relative importance of the map layers.

4. Future Improvements and Final Remarks

Future developments include:

- Locate obligatory stops in the way;
- Further studies regarding spatial features and their respective impact scores;
- Creation of prohibited places, called NO DATA.

The location of obligatory stops may be useful to insert information like placing city gates along the pipeline way.

Another new improvement is the creation of areas of no data, meaning that there will be regions prohibited for the corridor in the Total Accumulated Surface. This choice is to be taken to the specialists.

This tool does not replace the knowledge of the region and the importance of fieldwork. It also requires cartographic information of high quality, up to date and in appropriate detail. But it was considered that the results achieved are a good starting point to the environmental studies.

Also it provides a possibility of doing sensitive analysis, trying different scales of scores, what can be used in multidisciplinary works, in order to help specialists picture the results of different scales of importance to the spatial features in building the gas pipeline corridors.

Finally it can be added layers with engineering requirements, which would allow environmental and engineering issues be considered together, giving them a higher level of interdependence and balance.

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