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LOCATION INTELLIGENCE: USE OF GEOGRAPHIC INFORMATION SYSTEMS TO INCREASE SUSTAINABILITY OF NEW PROJECTS

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Abstract

The Locational Intelligence study aims to analyze potential locations for the structures of the Oil & Gas sector, which should serve as the basis for the entrepreneur to proceed the selection of the alternative that is most appropriate given the environmental sensitivity of each proposed alternative and its technical and economic feasibility. The integrated approach in projects conception, although it is an expectation of the entrepreneur, is not verified in practice. In fact what is observed are separate reviews that tend to suit to each other depending on the hierarchy in the decision process. Thus, first there is a conception of an economical pre-feasibility, later a conceptual engineering design, consolidating the economic viability, and at the end, at most, an assessment of social and environmental feasibility. What has been observed in the context of oil & gas projects are significant and recurring delays in obtaining environmental permits, constant need for changes in engineering projects and, consequently, the review of feasibility studies. Bad reputation regarding social and environmental impacts is also possible consequences from these practices. New technologies, especially those associated with geotechnology, such as geographic information systems (GIS) and geostatistical tools, appear to allow the integrated and systemic vision to be put into practice, creating a win-win relation for economic matters, engineering, social and environment. Furthermore, they make it possible to capture opportunities and avoiding risks associated with conflicts between these basic matters of feasibility analysis. The methodology presented in this paper is characterized by allowing the balance of new projects through a diverse and multidisciplinary approach, by using GIS to increase the capacity to big data analysis and by allowing the assessment of multiple scenarios. The implications of the methodology were compared under the analysis of two gas pipelines conceptual projects. It was demonstrated to be suitable for both onshore and offshore locational studies, indicating the most relevant characteristics and variables for each context. The results showed significant potential to reduce risks and complexity of the overall engineering development, with direct response to clear view associated with the socioenvironmental permitting process. As a consequence, from the application of the methodology projects developers should expect a reduction on the environmental licensing overall time, a better estimation of costs with mitigations, expropriations and compensation measures, a relevant rework reduction, a better alignment between engineering and environmental disciplines and, ultimately, greater institutional integrity. According to the results achieved it is recommended to use this systemic and integrated approach for the planning of new businesses and their constant improvement, with ultimate goal to consolidate the sustainability of the oil and gas sector, commonly associated with major social and environmental impacts and a bad picture from society as a whole.

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1. Introduction

The use of strategic intelligence tools when planning new ventures is a key element to bring effective sustainability concept to the projects. It is a consensus nowadays that the exclusion of socioenvironmental indicators from the economic analysis it is not benchmarked and it brings a high level of risks to the decision making process. This exclusion may result, for instance, in relevant delays to obtain the necessary environment licenses and to the approval of regulatory agencies, and also in increase of expected costs related to compensation and mitigation activities. During investment stage, socioenvironmental costs may represent up to 4-5% of CAPEX. This value may easily increase if the socioenvironmental variables are not appropriate identified and managed. At extreme scenarios, planning and execution errors translate into projects unfeasibility.

The definition of the gas pipe route, or the site location for a new refinery or any other infrastructure at the Oil&Gas industry are not exceptions to this scenario. However, several project feasibility aspects are neglected while project development, especially at the strategic planning phase (project pre-feasibility). It is usually explained by difficulties to access socioenvironmental data, lack of information about socioenvironmental aspects which impacts project development and low adoption of computational tools which allow a multidisciplinary and systemic assessment of the project.

The use of geographic information systems (GIS) has brought consistency when integrating and analyzing several data bases (big data) in order to support decision making process (Batista, 2005; Duarte et. al 2005). In this context, this paper presents an approach in which GIS has been used to support an interdisciplinary assessment for gas pipe route definition. An onshore project and an offshore one, both in conception phase, were analyzed and compared under this view.

2. Cases identification

In order to illustrate the proposed methodology, two cases are compared. The cases refer to early stage development (pre-feasibility studies) of independent gas pipelines. In both cases, the methodology was equally applied. One of the cases is relate to an onshore project, while the other is primarily an offshore venture. To maintain the confidentiality of the projects, some geographical information were omitted or changed, without compromising the methodological illustration or the results comparison.

The onshore case seeks a gas flow path originating from Uruguay for delivery in Brazil, in in the state of Rio Grande do Sul. It is approximately 500km route across Uruguay, covering almost all its southern / northern extension.

The areas for potential route definition for this case present several varieties of uses and land occupations. Although there are no major consolidated economic centers, several small productive regions have the potential for gas consumption, giving potential flexibility to diversify fuels in these regions. This is a relevant point for both feasibility and risk reduction to this project. In addition, the Uruguayan legislation is very restrictive related to economic use of its several environmental protection areas, increasing environmental sensitive risks to infrastructure projects.

For this case, the most important locational evaluation variables included aspects of land use and occupation, pre-existing infrastructure sharing capabilities, historic and artistic heritage areas, vulnerable populations, such as poor or native communities, and ecological-economic zoning. The latter is especially relevant because it translates the basic legislation for infrastructure location within the country, including investments in the oil and gas sector.

The offshore case seeks a solution for flow of gas to be produced in the Santos Basin to Baixada Santista, where it will be treated and distributed. The case is an offshore pipeline about 200 km long, and an onshore route of approximately 900 m long. The study area already has several other similar consolidated infrastructure, in a way it was easier to benchmark with other ventures.

For the offshore case the most relevant locational variables considered vulnerable fisherman communities and their fishing areas, marine geology and biota, boats routes, restrictions displayed on nautical charts from Brazilian Marine, oceanographic issues (i.e. marine currents, coastal processes, and others) and special marine formations such as rocky reefs and corals.

3. Methodology

In parallel to the development of the economic feasibility model of a project, it is necessary to analyze and develop the technical model of environmental and social impacts. This is because the balance between these dimensions of business results in greater sustainable indexes for the project. In general, economic models are preliminarily developed in order to obtain an indication of investment possibility. The inclusion of constraints and environmental risks analyses to such models makes them more robust, less susceptible to changes in environmental investments demands by environmental agencies and more consistency in the investment schedules.

Thus, in order to obtain a robust decision-making tool, the methodology proposed in this paper brings to the lights of the preliminary economic assessment, the environmental restrictions and its potential impacts on the feasibility results. It is understood by environmental restrictions, the biotic, abiotic, sociocultural and socioeconomic issues which ultimately boil down to a greater or lesser sensitivity to the activities planned to the project throughout its life cycle, from preliminary studies to the operations and further eventual demobilization. Within this concept, the locations with higher environmental sensitivity are regarded as high restrictive areas, while those with lower environmental sensitivity sites as low restrictive areas.

The methodology developed and applied to the cases is central in this article. It aims to meet the multidisciplinary requirements present in complex projects, as observed on the site location projects of linear infrastructure investments. The use of geographic systems allows to integrate on the same database economic, social and environmental variables previously developed for the region / route study. Figure 1 shows the context of methodology introduced in this study.

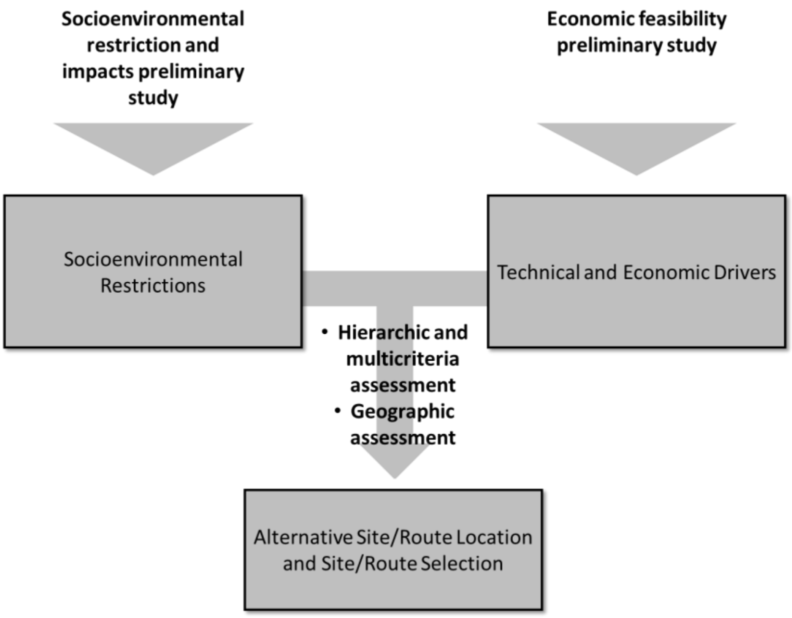

Figure 1. Methodological Context

In this context, the methodology presumes the use of solid and consistent databases, the technical discussion involving the different disciplines regarding the feasibility and the sustainability of the project, the use of computational geographic spatial analysis tools to support the analyzes, and the flexibility to analyze alternative options considering different analytical criteria and impact sensitivities. Thus, to meet such assumptions, figure 2 highlights the four steps defined by the methodology.

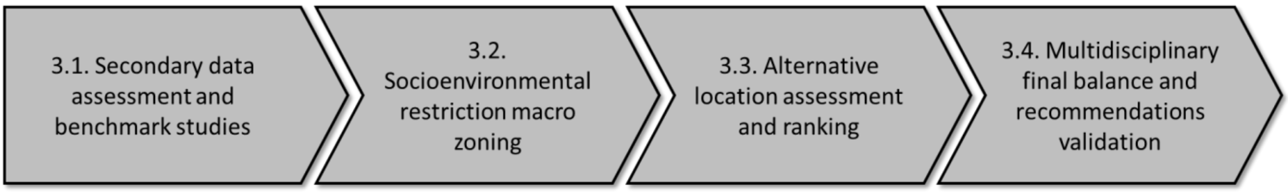

Figure 2. Methodology highlight

3.1. Secondary data assessment and benchmark studies

The first phase begins with the definition of the appropriate variables. The project team brainstorms over the project scope considering the different data and information required by the different disciplines. This team preliminarily identifies and select the data and indicators related to society, environment and economy.

Once the themes and issues are defined, secondary data from different sources are collected and stored on databases. Secondary data sources for the two case studied included private and public agencies, such as IBAMA; CETESB; Secretary of Energy of the State of São Paulo; universities; Ministry of Environment (MMA); Ministry of Mines and Energy (MME); Institute of Historical and Artistic Heritage (IPHAN) ; Brazil's navy; State and Environment

Agencies; National Agency of Petroleum, Natural Gas and Biofuels (ANP) ; Ministry of Housing, Spatial Planning and the Environment (MVOTMA - URUGUAY); Army Uruguay; Ministry of Industry, Energy and Mining (MIEM - URUGUAY); Ministry of Education and Culture (MEC - URUGUAY) . Such data are processed and checked in relation to its consistency and accuracy.

For both study cases, secondary collected data were sufficient for the analysis because of the project development stage. At this stage, maps and land classification considers mostly macro scales. That means high level choices are to be taken. At this stage, it is not possible to define very specific site/route location since the micro scale analysis was not taken into account.

In addition to the secondary data collected, other similar projects are evaluated. These information are also gathered from several sources, including previous projects developed by the team and cases reported in other studies conducted by the academia and the market.

3.2. Socioenvironmental restriction macro zoning

At this phase, the pre-defined indicators are refined from the perspective of environmental, social and economic impacts. The team's experience and previous surveys and studies are fundamental to develop a robust model.

The defined indicators should be evaluated in several ways or classes, according to its intrinsic nature. For instance, a hypothetical indicator "Land Conservation Units", could be divided into four classes, "Conservation Unit for Sustainable Use", "Protection Conservation Unit Integral", "Buffer Zone" and "Conservation Unit of Absence or influence in Buffer Zone". Or the “Presence of Infrastructure” indicator can be divided into “Roads”, “Highways”, “Railways”, “Power transmission lines”, among other. Both for social and environmental variables, as for the economic variables, technical and financial criteria are used. Table 1 shows an illustration of different indicators and their respective analytic classes.

The qualification of social and environmental indicators is then conducted. The methodology for this was based on *Expert Workshops*, adapted from Gomes & Malheiros (2012) proposal. At theses expert workshops, analysis of environmental indicators to support discussion of sustainability is therefore developed by a multidisciplinary team.

It is important the team to be formed by professionals from different areas of knowledge, including biologists, environmental engineers, forest engineers, lawyers, geographers, industrial chemists, metallurgical engineers, economists, sociologists, among others. This team decides from technical and economic studies previously developed, the final qualification of environmental indicators.

Once the indicators and their classes are defined, databases in Geographic Information System (GIS) are generated in preparation for the computational analysis. This tool enables the progress of different queries, crossing data analytics and managing spatial information. It also allows the quantification and qualification of areas, from the use of high-resolution satellite images. The bases that are not compatible with the software, or at not appropriate scale, are treated / corrected and georeferenced, so that accuracy is the best possible .

For both cases, software ArcGis version 10.1 and ArcGis Online, both developed by ESRI, were used. The online version of the software allows multiple users to work simultaneously on the platform using the internet, regardless their geographic location. This functionality is important because it allows best online interaction between distant teams.

Finally, the socioenvironmental macro zones are plotted in maps to ease visualization and analysis. Figure 3 shows an example of such macro zone maps. At this example, the darker areas represents maximum socioenvironmental restrictions. Typically, those are areas where human developed are forbidden by law, or areas where usually brings very high compensations costs related to the licensing stage; or even where it will bring a very high cost to relate to different stakeholders such as ONGs and environmental organizations. On the other side, the lighter areas represent low restriction zones, which are usually areas with high human activities indexes, or areas previously analyzed and licensed by environmental bodies.

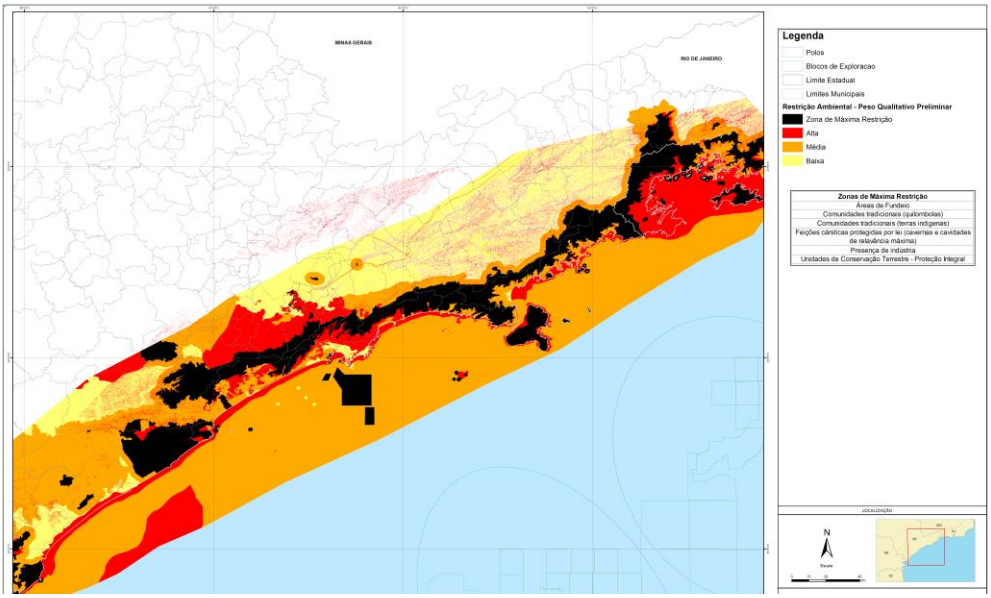

Figure 3. Example of georeferenced socioenvironmental restrictions macro zone: black areas are of maximum restriction, red areas are of high restriction, orange areas are of medium restriction and yellow ones of low restriction.

Table 1. Example of indicators and classes

Indicator	Socioenvironmental Restriction Classes
Conservation Units	Terrestrial Conservation Units – Sustainable Use
	Terrestrial Conservation Units – Full Protection Areas
	Conservation Units Dumping Zone (3km) – Full Protection Areas
Priority Areas for Conservation	Priority areas for Biodiversity Conservation - Extreme
	Priority areas for Biodiversity Conservation – Very High
	Priority areas for Biodiversity Conservation - High
Ecologic and Economic Zoning (ZEE)	ZEE – Z1
	ZEE – Z2
	ZEE – Z2
	ZEE – Z4
	ZEE – Z5
Traditional Communities	Quilombolas Influence Zone (5 km)
	Native Communities Influence Zone (10 km)
	Traditional Communities (Native Communities)
	Traditional Communities (Quilombolas)
Cultural Properties Sites by Law	Protected Cultural Sites (Properties 3924/61)
	Heritage Cultural Sites (Decree 25/37)
	Registered Cultural Sites (Decree 3551/2000)
Cumulative Impacts	Industrial Sites
	Industrial Sites Influence Zone (3km)
	Existing Infrastructures (Gas Pipelines)

At this phase, it is possible to identify preferable areas and, then, plot alternative routes to be further compared according to economic, social and environmental feasibility.

3.3. Alternative location assessment and ranking

Given the restrictions scenarios and economic studies, locational alternative scenarios are outlined. The cases studied considered between three and five alternative routes. These routes took into account engineering aspects and were developed qualitatively by the multidisciplinary project team. Figure 4 below shows an example of the pre-selection location alternatives based on macro zoning restrictions.

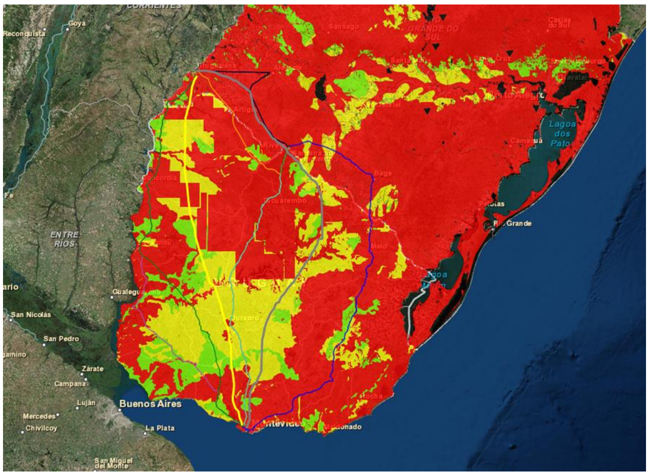

Figure 4. Example of pre-outlined routes considering the restriction macro zones

Once the preliminary alternative routes are defined, it is desired to rank and select each option. This activity takes into consideration the sustainability concept, where economic, social and environmental (biotic and abiotic) perspectives are equalizes and balanced. Figure 5 introduces the concept of sustainability used on the methodology applied to both cases.

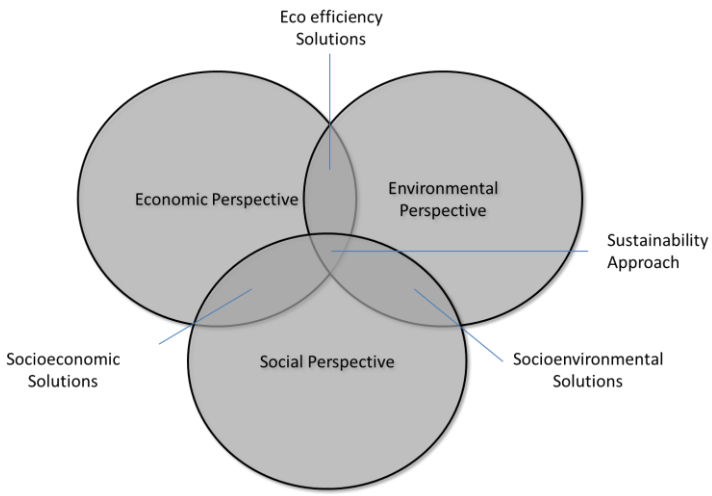

Figure 5. Sustainability concept visualization

This sustainability concept is translated into a ranking matrix. At this matrix, experts and the project team agree on the indicators, classes and on the weights. Based on the Expert Workshop methodology (Gomes & Malheiros, 2012), each of the classes are scored considering previous studies and specialists experience, in a way that each class receive a score according to its characteristics for each scenario. For instance, a class of higher restriction will receive a higher grade for that alternative. Figure 6 illustrates a matrix used to rank one of the cases. The actual used criteria were omitted and the scores were changed to preserve the confidentiality of the project.

Ranking Matrix						
Grupo Promon		Sensitivity analisys		Date: XX/XX/XXXX		
		%B	%A	Rev: X		
		Economic sensitivity tool	Social and Environmental sensitivity tool	Client: XXXXXXXXX		
Parameters	Basic weight balance	Sensitivity analisys: economic parameters weight	Sensitivity analisys: social and environmental parameters weight	Score		
				Alternative 1	Alternative 2	Alternative 3
A. Social and Environmental	66%		66%			
A1. Parameter 1	12%	-	12,00%	1	0,5	1
A2. Parameter 2	9%	-	9,00%	0,5	0	1
A3. Parameter 3	6%	-	6,00%	0	1	0
A4. Parameter 4	6%	-	6,00%	0	1	1
A5. Parameter 5	5%	-	5,00%	0	1	0,5
A6. Parameter 6	5%	-	5,00%	1	0,1	1
A7. Parameter 7	5%	-	5,00%	1	1	0
A8. Parameter 8	4%	-	4,00%	1	0,5	0
A9. Parameter 9	4%	-	4,00%	0,5	0,5	1
A10. Parameter 10	4%	-	4,00%	1	0	1
A11. Parameter 11	3%	-	3,00%	1	0,5	1
A.12. Parameter 12	3%	-	3,00%	1	0	1
PARTIAL SCORE - ENVIRONMENTAL PARAMETERS				43%	34%	49%
B. Economic	34%	34%				
B1. Parameter 1	15%	15,00%	-	0	0,5	1
B2. Parameter 2	6%	6,00%	-	0,5	0	1
B3. Parameter 3	3%	3,00%	-	0	1	1
B4. Parameter 4	2%	2,00%	-	0,5	1	0
B5. Parameter 5	2%	2,00%	-	0,5	0,5	0
B6. Parameter 6	2%	2,00%	-	1	0,5	0,5
B7. Parameter 7	1%	1,00%	-	1	1	1
B8. Parameter 8	1%	1,00%	-	0,5	1	0,5
B9. Parameter 9	1%	1,00%	-	1	1	1
B10. Parameter 10	1%	1,00%	-	0	0,1	0,5
PARTIAL SCORE - ECONOMIC PARAMETERS				10%	18%	28%
FINAL RESULT				52,0%	51,6%	76,5%

Figure 6. Example of alternative location raking matrix

The weights pointed to the classes are divided according to the concept of sustainability, in a way that social, environmental and economic issues receive balanced weights. In the cases, one third to each of the sustainability perspective were adopted. At the bottom line of the matrix, the lowest value among the alternatives results in less environmental restrictions, which ultimately represents a lower overall risk and licensing complexity, a lower environmental impact and lower costs for projects development, including mitigation measures and environmental compensation. The lowest value also represents an indication of best economically feasible alternative. The weights and grades are derived from both experts prior knowledge and previous studies. Therefore, the matrix combines investment and operations costs estimations in balanced with social, economic and environmental perspective of the project. Figure 6 shows example of the ranking array of locational alternative scenarios.

According to this matrix, the highest score represents the most restrictive alternative (worst qualified), and the smaller, consequently, the less restrictive (best qualified). It is noteworthy that the value should be between 0 (minimum restriction) and 100% (maximum restriction).

3.3. Multidisciplinary final balance and recommendations validation

Finally, the alternatives, their weights and routes results are plotted in the georeferenced database, to facilitate the locational adjustments and sensitivity analysis. This last analysis is conducted by varying the weights of the social, environmental and economic criteria to realize the weaknesses for each thematic basis.

Considering this study is conducted at the pre-feasibility stage, it is important to highlight most of the information are actually estimates. Therefore, recommendations for better understating of most sensible variables are easily identified using this methodology.

4. The Applicability of the Methodology to the Cases and Results

The application of the methodology to both cases allowed relevant comparisons in order to generate relevant lessons learned to future similar projects. Table 2 highlights key lessons obtained.

Table 2. Key lessons learned from the comparison between a onshore and offshore projects

Topic	Onshore Case	Offshore Case
Number of socioenvironmental indicators needed to be analyzed	High	Medium
Volume of data and databases to be created and analyzed	Very high	High
Priority disciplines	Logistics, socioeconomics and protected areas	Marine geology, marine biology, oceanography and socioeconomics
Criticality	Infrastructure synergies and gas distribution along the routes	Offshore-onshore connection (shore approach)
Socioenvironmental Criticality	High presence of protected areas and high demand for expropriation	Presence of reefs (rochy or corals), artisanal fishing zones and protected áreas
Flexibility to adjust core route further on the Project development	Litter possibilities	Higher possibility, with few exceptions

For the Onshore case it was identified that the volume of data needed for decision-making is much higher. This is because there are many regional variations over short distances. Furthermore, economic feasibility component along the track is essential to identify hot spots for regional gas distribution. Other important criteria in the economic evaluation are the presence of logistical support, the presence of pre-existing linear infrastructure (eg. Rail and road) as forms of synergies, and the expropriations potential volume and impacts. For the offshore project case, the most relevant criteria for evaluation are marine geology and marine biology, especially the presence of coral reefs. Also, the importance of artisanal fishing activities is higher in this type of venture, once additional cost to the project is mostly certain in these cases.

On the result side, the studies of onshore suggest less flexibility to future routes adjustment. It should be better defined because the sensitivity to chance to a different macro zone may be very high, while at the offshore case there are fewer changes on the type and amount these zones. It does not mean, however, that it should be neglected. On the offshore case, the advanced and geographic spatial analysis allowed assessing locational alternatives in complex environment by macro identification and by assessing micro zones as well. A small "gap" in highly occupied area of Atlantic Forest has been mapped, making it possible to obtain an alternative route that did not require expropriation or extraordinary compensation, significantly reducing the social, environmental and economic impact for the project and for local communities.

Regarding the onshore project, it was possible to identify that the shortest distance is not always the best solution, even from the economic perspective. Since logistics support and maintenance represent strong cost component and that the guidelines of the National Plan and the Protected Areas of Uruguay are very relevant to investment, advanced analysis and geographic spatial analysis has helped to identify alternatives that reduced the risk of investment and would ensure lower environmental expenditures.

5. Conclusions

What can be noticed is that locational intelligence effectively contributes to a better decision making process. It allowed a multidisciplinary and systemic approach to the project, through a friendly alignment between engineers and natural scientists. This alignment is very conflicting in most of the cases and is one of the reasons for a lack of systematic approach for infrastructure project development. The presented methodology promotes, therefore, the possibility to capture social, environmental and economic opportunities and weaknesses through an integrated and interdisciplinary analysis. This is only possible due to the use of powerful analytical tools, using geographic intelligence (GIS and WEBGIS platform) to analyze infrastructure, socio-economic assets, socio-cultural data, land use and land cover, protected areas, industrial poles, water uses, among others, in a single and friendly interface platform.

The goals of the methodology were fully accomplished for both cases. On the top, it stimulated the developed of a more balanced project, avoiding ungrateful surprises regarding investments in complex environments. From project concept, it allows engineers to better estimate environment schedule, costs and complexity. It positions the development team to an environmental friendly mindset, focusing on better view of negative impacts and on the better planning of the projects, thereby contributing to the effort to the oil and gas industry to become more sustainable. Without this methodology, infrastructure projects are compromised regarding its environmental licenses grants, its accordance to social and environmental organizations and its future operations and expansions

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