Preliminary Risk Assessment of the Rota 3 Gas Pipeline

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1. INTRODUCTION

The Rota 3 gas pipeline will link the fields of pre-salt Santos Basin to Rio de Janeiro coast and, thereby, will allow the transportation of rich gas to Comperj (Petrochemical Complex) in Itaboraí (RJ). In order to separate natural gas and other light fractions (such as ethane, LPG and naphtha) from this raw material, process units are expected to be constructed in the Petrochemical Complex mentioned above.

Among the several points which have to be considered when choosing the route of a pipeline, beyond the construction aspects, the variable "risk to the general public" represents one of the most important in the process of determining its viability and ensuring the Business Continuity. Besides being directly related to safety during the operation of the pipeline, it's also relevant because the Brazilian environmental agencies [1] [2] (both at the federal and in state spheres) define, during the permit process, risk criteria which must be attended in order to certify the feasibility of the project, as proposed.

Furthermore, it is important to inform that the procedures involved on choosing the pipeline route aims also to reduce costs, which are related, for example, to the pipeline extension, types of soil to be crossed, the value of the land that will be purchased for the permanent easement (RoW – Right of Way), and others. In this particular case, for example, the first route proposed by the designer area also aimed to share part of the route already designed for the Comperj emissary. However, there are also concerns about the proximity of the pipeline route to densely populated regions.

Therefore, taking into account the background explained above and the fact that the first route proposed passes, in some sections, next to densely populated areas, it became essential to perform this Preliminary Risk Assessment (PRA).

2. METHODOLOGY

In this PRA the Individual and Societal Risk calculations were performed considering the route initially developed by the pipeline designers, specifically for some sections of the route considered critical in terms of risk (so called High Consequence Areas - HCAs, i.e., regions along the pipeline that present significant population nearby). For the calculations, it was considered the assumptions established in the guidelines (Term of Reference) issued by IBAMA for gas pipelines [1].

The operating conditions which supported this study were based on the relevant project documentation available when the assessment was performed (2011). The data is presented below in Table 1.

Table 1. Operating conditions referred to the Rota 3 Gas Pipeline

Parameter	Value
Diameter (in)	24
Product	Natural Gas
MOP[1] (kgf/cm^2)	149
Temperature (°C)	23

In order to illustrate the solutions proposed in this work, it was selected a High Consequence Area identified along the route originally proposed which was considered the most critical in terms of risk. Data regarding this site are presented in the Table 2, whereas its aerial image is shown in the Figure 1.

[1] MOP stands for Maximum Operating Pressure.

Table 2. Location of the selected High Consequence Area

High Consequence Area	Location	Kilometer (km)
HCA 1	Reta Nova - Itaborai	42

Figure 1. Original Pipeline Route near to Reta Nova – Itaboraí.

Moreover, the calculations of the Individual Risk and Societal Risk were performed considering both the presence and the absence of mitigation measures, since the societal risk for the route originally proposed, without measures, has reached the ALARP region (see item 3). Thereby, it was possible to visualize the effect of such measures in the risk results obtained.

The mitigation measures considered were:

1. Greater depth of pipeline cover (> 1,0 m);
2. Concrete Slab.
3. A combination of them.

The implementation of these mitigation measures has a direct impact on reducing the pipeline failure rate, specifically in respect to external interference [3] [4] [5] [6].

The failure rates adopted for each case are presented in the Table 3 and were estimated taken as reference the data presented in the 7th Report of The European Gas Pipeline Incident Data Group (EGIG) [7], and the HSE[2] 372/2001 report [3]. The last one presents factors of reducing pipelines failure rate due to the adoption of the measures mentioned above.

[2] HSE stands for Health and Safety Executive (UK).

Table 3 – Failure rates used in the risk calculations.

Mitigation Measure	Failure rate ($km^{-1}.year^{-1}$)	External Interference (%)
Original failure rate (EGIG)	$1,40x10^{-4}$	49,6%
Concrete Slabs	$8,94x10^{-5}$	13.4%
Greater Depth of cover (> 1,0 m)	$1,17x10^{-4}$	32.7%
Concrete Slabs and Depth of cover	$8,31x10^{-5}$	8.8%

Besides these measures, another solution considered in this work, and which represents a better alternative in terms of costs, was the possibility of increasing the proximity distance from the gas pipeline route to the population next to it (as shown in Figure 4), in order to minimize the risk to the community surrounding the pipeline (reducing the societal risk). This distance proposed was based on the maximum effect distance (1% of lethality) obtained in the consequence calculations [8] [9] [10], which were performed following to the event trees shown in the Figures 2 and 3.

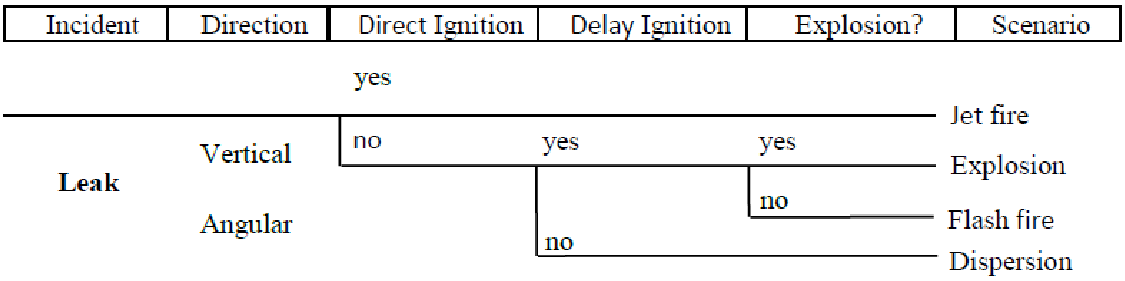

Figure 2. Event tree for leaks.

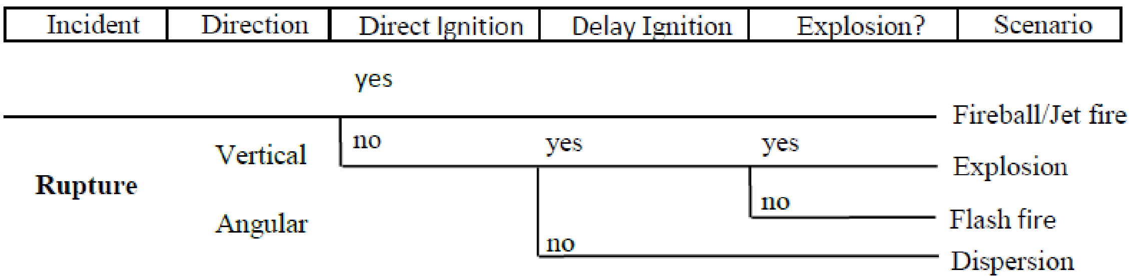

Figure 3. Event tree for ruptures.

For these accidental events considered, the maximum effect distance reached was about 440 meters, referred to rupture of the pipeline followed by immediate ignition and resulting in a Fireball. The resulting route, considering this solution, is presented in Figure 4 following.

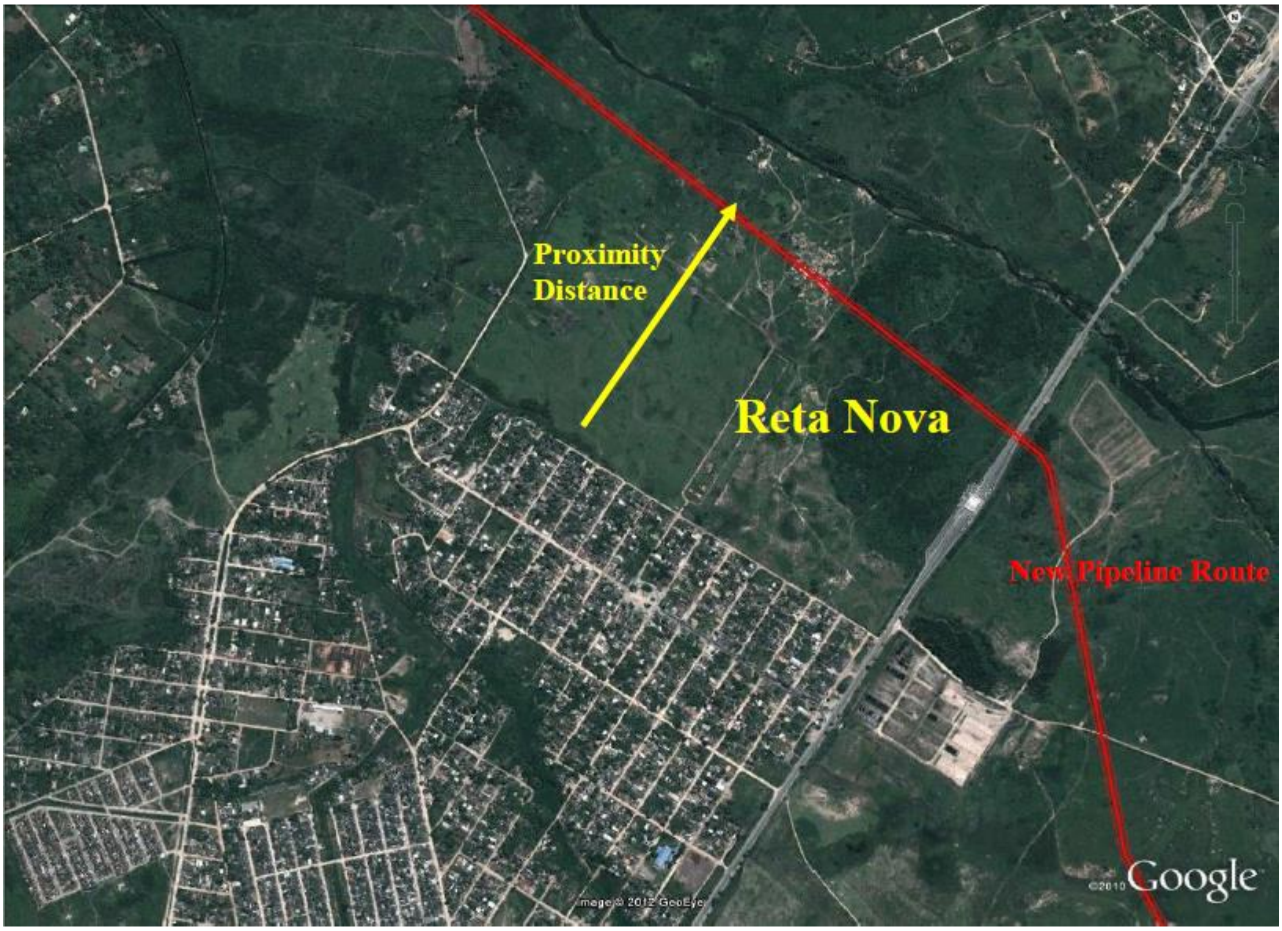

Figure 4. New Pipeline Route next to Reta Nova – Itaboraí.

The results of risk calculations for each case are presented in the next item.

3. RESULTS AND DISCUSSION

The individual risk curves are identical for both route alternatives and are presented in Figure 5. Please note that the risk profiles presented are related to each case, considering the presence or absence of mitigation measures. Thus, the curves obtained were compared with the criteria established by IBAMA [1].

Assessing the individual risk results, it was observed that the pipeline risk profiles for all situations considered were located in the region of tolerable risk, below the level of 1x10-6/year.

Therefore, it is concluded that the Individual Risk in the studied region is broadly acceptable considering the criteria established by the Terms of Reference (TOR).

Furthermore, the Figure 6 shows the FN curves (societal risk) for the original design (route presented in Figure 1), considering each analyzed case (with and without mitigation measures). They were compared with IBAMA's societal risk criteria [1].

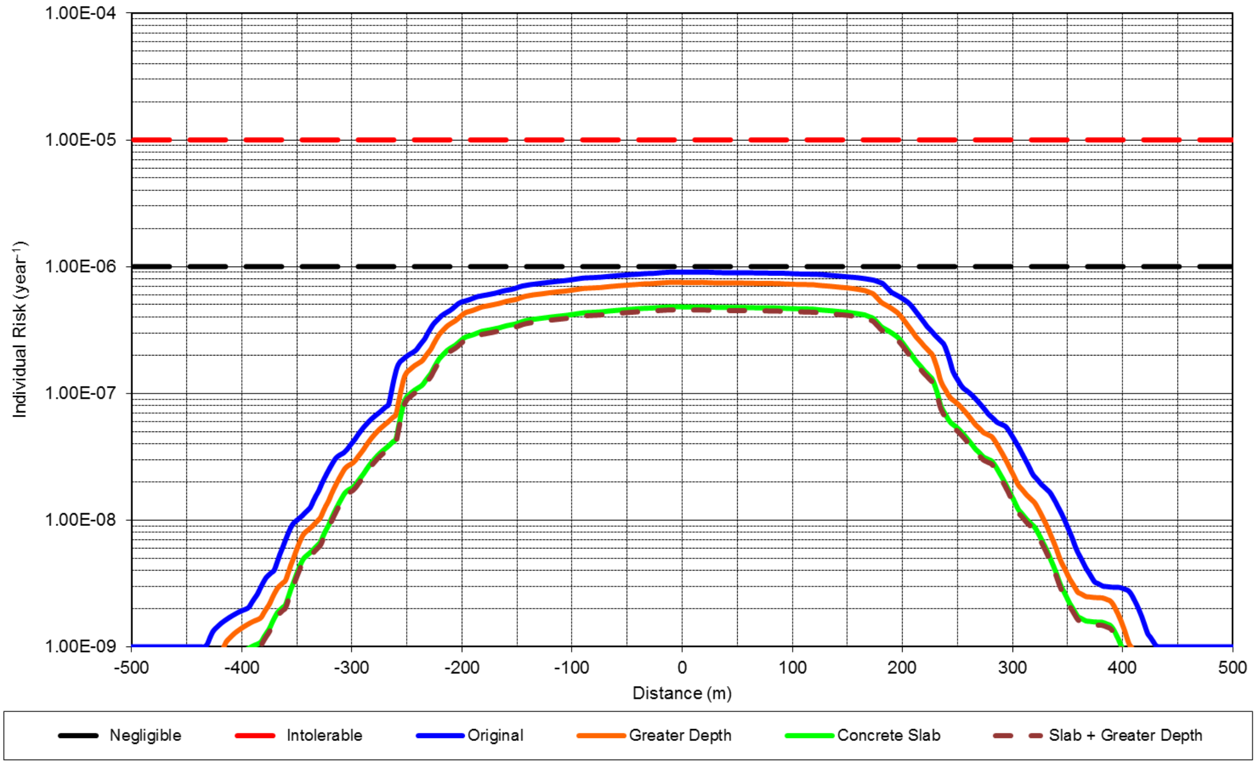

Figure 5. Individual Risk Results.

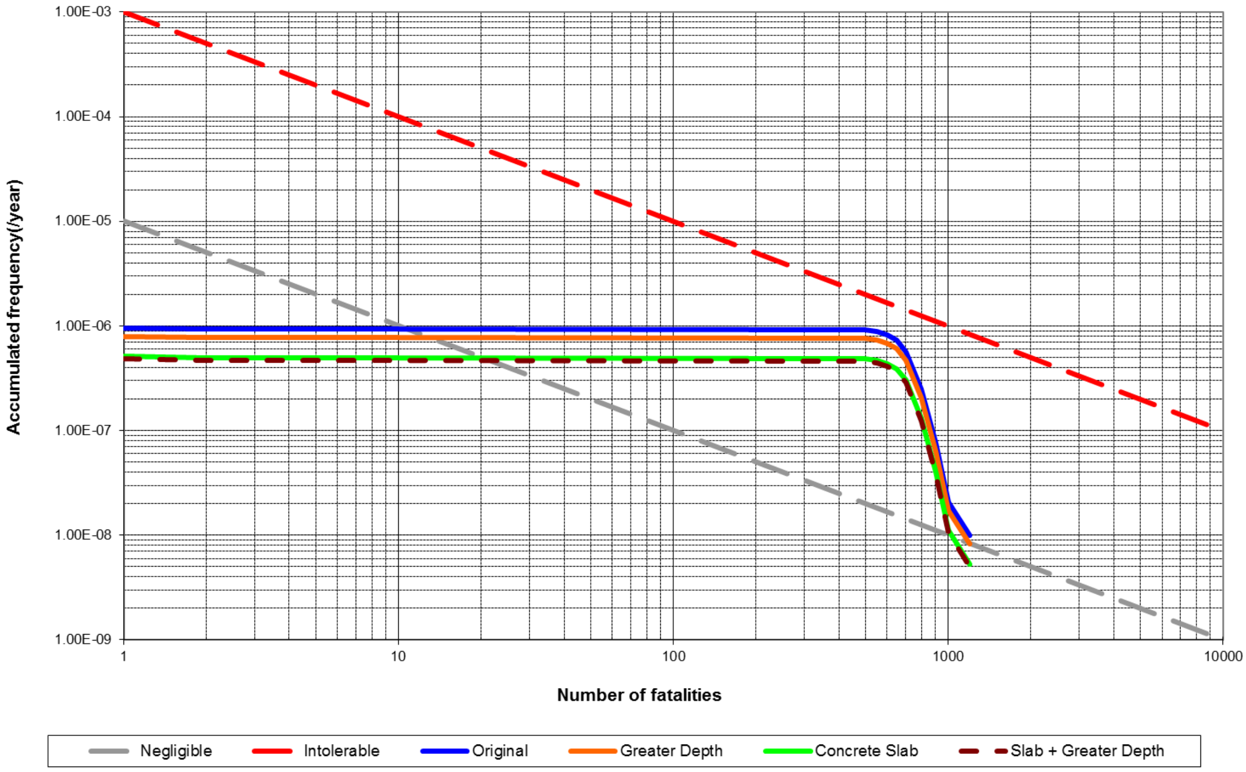

Figure 6. Societal Risk Results.

As noted in the previous figure, the FN curves related to all the analyzed situations are located in the intermediate region between the upper and lower lines that define the societal risk criteria.

In this intermediate region, so called ALARP [1] [2] [4] [5] (As Low As Reasonably Practicable), it's necessary to reduce the risks as far as practicable. This means that the project must be modified in order to adopt mitigation measures to reduce the risks, which must be presented and negotiated with the environmental agency (these measures, of course, contributes to increasing the project cost). In this process, the agency can also suggest additional measures to those presented by the entrepreneur.

In regard to the societal risk results for the new pipeline route proposed shown in the Figure 4, no FN curve was obtained to the new pipeline route proposed, which considers the proximity distance. This fact leads, therefore, to the broadly acceptance of societal risk for this alternative, without the need for implementation of additional risk mitigation measures. It means that the new pipeline route proposed represents the option that reduces not only the risks to the community located in the pipeline surroundings, but also the project costs and time for construction, compared to the previous situation (original route).

4. FINAL CONSIDERATIONS

Other places along the pipeline route were also analyzed with this focus and similar solutions were proposed by the application of Preliminary Risk Assessment (for example, it was also proposed placing the pipeline route away from the population located at Ponta Negra, in Marica, which is situated approximately at its km 4).

Therefore, it is important to emphasize the potential of this methodology, which allows identifying critical areas in terms of risk in the initial phase of the pipeline design and, then, propose solutions to make it more robust and less vulnerable during the permit process. Another relevant point is that this method aims to avoid the encroachment of the pipeline route, contributing to the pipeline integrity, the operational continuity and the safety of the surrounding communities (i.e. aiming the Business Continuity).

However, it is important to highlight that the proposed methodology is not able to ensure that new population developments will not grow towards the pipeline route in the future, which could result in the intolerability of risks along its operational life. In order to do so, an example of good practice is currently been applied in countries like Netherlands [11] and the United Kingdom [12] [13], which is known as Land Use Planning (a risk based approach). In the UK, for instance, when a new population development is planned in the vicinity of hazardous installations, Planning Authorities, Environmental Agencies and Companies are all involved in this process in order to mitigate the effects of major accidents on this population by following a consistent and systematic approach for planning permission around such sites.

Finally, it's also highlighted that, besides the Preliminary Risk Assessment, it's necessary to perform a comparative economic study in view of the costs and time for construction associated with the mitigation measures related to the original pipeline route and these parameters related to the new route proposed, in order to base the decision making process.

5. ACKNOWLEDGMENT

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6. REFERENCES

[1] Termo de Referência – Estudo de Análise de Riscos – EAR para o Empreendimento Gasoduto Rota 3 – IBAMA, Brasília, 2012.
[2] P4.261 Technical Standard - Risk of accident of technological origin. Method for decision-making and reference terms, 2nd Edition, CETESB, São Paulo, 2011.
[3] Mather, J., Blackmore, C., Petrie, A., Treves, C. Contract Research Report 372/2001 – An assessment of measures in use for gas pipelines to mitigate against damage caused by third party activity – Health and Safety Executive (HSE). United Kingdom, 2001.
[4] Code for Prictice for Pipelines – Part 3: Steel pipelines on land – Guide to the application of pipeline risk assessment to proposed developments in the vicinity of major accident hazard pipelines containing flammables – Supplement to PD 8010-1:2004, British Standards Institution, London, UK, 2009.
[5] Assessing the risks from high pressure Natural Gas pipelines, IGEM/TD/2 Edition 2, Institute of Gas Engineers & Managers, Communication 1764, 2013.
[6] Laheij, G., Vliet, A., "Measures for reducing the probability of ruptures of high pressure natural gas pipelines", Reliability, Risk and Safety: Theory and Applications, London, 2010.
Handleiding risicoberekeningen Bevb, versie 1.0, Rijksinstituut voor Volksgezondheid en Milieu (RVIM),

The Netherlands, 2010.
[7] EGIG – Gas Pipeline Incidents: 8th Report of the European Gas Pipeline Incident Data Group, version 2 (Doc. Number EGIG 11.R.0402), Groningen, 2011.
[8] CPR 14E – Methods for the calculation of physical effects - “Yellow Book”, TNO (The Netherlands Organization), The Netherlands, 2005.
[9] CPR 18E – Guideline for quantitative risk assessment - “Purple Book”, RIVM (National Institute of Public Health and the Environment), The Netherlands, 2005.
[10] Reference Manual Bevi Risk Assessment, RIVM (National Institute of Public Health and the Environment), version 3.2, The Netherlands, 2009.
[11] NEEDHAM, B; Dutch Land-use Planning – The principles and the practice, Radboud University, Nijmegen, The Netherlands, 2014.
[12] Health and Safety Executive, Reducing risk, protecting people: HSE’s decision-makings process, HSE Books; 2001, http://www.hse.gov.uk/risk/theory/r2p2.pdf.
[13] Health and Safety Executive, PADHI – HSE’s land use planning methodology, Published by HSE, Version March 2008, © Crown copyright, last updated May 2011, http://www.hse.gov.uk/landuseplanning/padhi.htm.