THE ADVANCE OF NATURAL GAS MARKET USING URBAN INFORMATION: CASE STUDY IN SÃO PAULO CITY

1V. M. Massara*, 1M. T. W. Fagá

1 PRH/04-ANP - Instituto de Eletrotécnica e Energia, Universidade de São Paulo

* To whom all correspondence should be addressed.

Address: R. Piauí, 1017 Ap. 32 - São Caetano do Sul - São Paulo - Brazil - CEP 09541-150
Telephone number: +55 11 9860-8116
E-mail: vmassara@iee.usp.br

Abstract. In the decision-making process for the construction and expansion of natural gas infrastructure, different factors must be considered to prioritize areas with high market potential for the given service. The aim of this paper is to propose a systemic model that integrates the understanding of the urban dynamics to the strategies of expansion in the distribution network, taking the advance of natural gas in the city of São Paulo (Brazil) as a specific case study.

Keywords: energy; natural gas; infrastructure; distribution network; urban development

1. INTRODUCTION

In this work, an analytical methodology that integrates the understanding of the urban dynamics to the strategies of expansion in the natural gas distribution network is considered, characterizing gas consumption possibilities and attractiveness for the districts composing a city. The methodology is developed by gathering information such as family income, demographic density and construction area, percentage of land use, number of households as well as commercial, service and industrial establishments, number of real estate as well as indicative information released by the Urban Plan of the city regarding the increments in the peripheral districts. By relating the gas consumption estimated by each type of land occupation and the cost for expanding the gas distribution network, the model will indicate, for each neighborhood, the viability of implementing a gas network as well as the places with potential for growing density in the existing gas distribution system. In this paper, examples of essential information that compose the methodology are presented for five districts of São Paulo city (Brazil): São Domingos, Barra Funda, Freguesia do Ó, Itaquera, Mooca, which have different socioeconomic and geographical profiles. Finally the model tested for São Paulo will be generalized in a computer model, that allows its uses in other Brazilian cities, pointing out the possibilities of natural gas as a final option of energy in the urban uses, besides presenting guidelines for the Urban Plans and the sustainable gas infrastructure incorporation in the cities.

2. METHODS

The methodology based on urban indicators (Massara et al., 2004) has the main objective of developing procedures that allow to analyze and to guide the expansion and the growing density of the natural gas network inside a municipal district through the study of the dynamics among several parameters and also to analyze the urban dynamics that determines the expansion of the metropolitan natural gas infrastructure. The systemic model was elaborated according to the following stages:

• Identification, characterization and organization of the main interventionary factors;
• Definition of the study cells (streets, districts, suburbs) according to the availability of information about the parameters;
• Hierarchization of quantitative and qualitative parameters through the attribution scale of priorities that unifies the parameters units, so that they can mathematically be treated;
• Evaluation of the system with the purpose of directing the choice based on theoretical guidelines and also in the application of the Analytic Hierarchy Process (AHP) supporting the computer model (Saaty and Vargas, 1987);

• Validation of the decision-making process for the planning of the expansion of natural gas distribution infrastructure through case study in the City of São Paulo and comparison with the results obtained through the model and the mapping of the existent, implanted net.

In this preliminary analysis, all the parameters have been used with influence distribution indices in intervals from 1 to 5 (Massara et al., 2005). The attribution of this scale is related to the use of the cardinal and semantic scales (Allen, 1987). At the end of the study, it will be possible to determine whether this linear scale is valid or not, via test and comparison with analysis of multiple-criteria models that also use the priority scale as a tool in the decision-making process (Saaty, 1980).

Similarly, the algorithm used in this paper for the determination of the attractiveness index must be revised and compared with the results obtained according to the AHP methods.

In this example, the priority scale for natural gas infrastructure implantation has been described as follows:

1st. Group - Low attractiveness (or growing density);

2nd. Group - Low to medium attractiveness (or growing density);

3rd. Group - Medium attractiveness (or growing density);

4th. Group – Medium to High attractiveness (or growing density);

5th. Group - High attractiveness (or growing density).

Figure 1 summarizes the methodology employed herein.

3. THE PROPOSED MODEL AND THE INFORMATION SYSTEMS

The sets of data are composed of four systems referring to the study area, according to the Brazilian official denomination “SEPLA” (2002). These systems establish an attractiveness index for natural gas infrastructure expansion with regards to the urban development of the cities.

3.1. 1st. System: Life Quality Indicators

This system is represented by three factors, all of which represent numerical values that are distributed in the five groups that have been initially described.

- Social Exclusion Index: has the objective of identifying the social development degree of the districts (PRODAM, 2005) considering the existence of social equipments (green areas, bus lines, number of schools and hospitals). The final index attributed to each one of the districts lies within the interval

![Figure 1. Methodology used in the study of natural gas infrastructure.](http://www.portalabpg.org.br/bjpg)
that ranges between -1.00 (reflecting the worst exclusion situation, i.e., the first group) and +1.00 (reflecting the best inclusion situation, i.e., the fifth group).

- **Human Development Index (HDI):** This is an adaptation of the index created by the United Nations Organization (UNO), with the objective of comparing the degree of human development according to the districts. It comprises factors such as education and basic conditions of health in each district (SEADE, 2005). These indicators are transformed in intervals that range between 0 (first group, the worst development condition) and 1 (fifth group, referring to the best conditions).

- **Priority Infrastructure:** water supply, sewer system and streets illumination are considered "priority infrastructures" (SEMLA, 2002). This parameter corresponds to the idea that a given district will not be attractive to natural gas network if it still does not possess such infrastructure. The index considers the mean percentage of the actual conditions of the three nets, expressed in five groups in intervals of 20%.

### 3.2. 2nd. System: Urban Plan Indicators

These indicators combine qualitative parameters (land use, urban development and zoning) and quantitative (urbanization rate and real estate). For the analysis of non-numerical values, the systems are based on the mapping and classification of the Urban Plan of São Paulo City and its adaptation for any city, in order to verify the types of land occupation (residential, commercial, industrial and services) and their expansion perspectives. This is carried out with the purpose of effecting the elaboration of a neighborhood profile with larger tendency to industrial developments (higher attractiveness for natural gas), and follows the natural gas consumption projection listed below.

- **Land Use:** considering the largest percentage of streets with certain use type, this concept is based in the occupation characteristic of the city districts represented in the urban plan map (PRODAM, 2005). Although the municipality considers several occupation categories in view of the natural gas attractiveness, groups have been classified according to five main uses:
  1. Group: horizontal residential occupation;
  2. Group: mixed use (commercial and residential horizontal);
  3. Group: vertical residential occupation;
  4. Group: mixed use (commercial, services and residential vertical);
  5. Group: mixed use (residential and industrial).

- **Urban Development:** the basis of this concept is the Urban Plan of São Paulo City (SEMLA, 2002), corresponding to five "macroareas" that comprehend the present specifications and the future urban developments, as represented in the following five groups:
  1. Group: environmental protection - limits of public areas and preservation areas;
  2. Group: urbanization and urban qualification - areas predominantly occupied by low income families with high concentration of irregular constructions;
  3. Group: requalification - areas with good infrastructure although presenting many empty properties;
  4. Group: urbanization in consolidation – areas in condition to attract real estate investments in residences, services and commercial establishments;
  5. Group: consolidated urbanization - areas formed by consolidated neighborhoods inhabited by population of medium and high income and good urbanization conditions.

- **Land Use Rule (Zoning):** This refers to the rule imposed by the Municipality (SEMLA, 2002) that limits land use and the destination of the several sections of the city for determined uses (trade, services, housing, industries). The natural gas attractiveness predominance is in this case represented by the following five groups:
  1. Group: residential zone of low density / zone of environmental protection;
  2. Group: residential zone of medium density / mixed zone of low density;
  3. Group: residential zone of high density / mixed zone of medium density / special uses;
  4. Group: mixed zone of high density;
  5. Group: great industrial zone occupation.
The definition of “mixed zone” corresponds to the combination of the residential use, services and commercial uses.

- **Urbanization Rate**: corresponds to the percentage of the total district area occupied by urban use (blended residences with commerce, services and industries) as compared to the total population (PRODAM, 2005), which is represented in intervals of 20%.

- **Real Estate**: this concept is related to the Construction Code about building facilities for natural gas in new constructions, which must increase the consumption of natural gas. In order to attribute the attractiveness index, five groups have been selected which were based on the largest and the smallest number of district releases as reported in a survey by EMBRAESP (2005).

3.3. 3rd. System: Potential of Natural Gas Consumption

In this data system, the characteristics of the neighborhoods in terms of street extensions are stored. All parameters are numerical values, thus simplifying the creation of the five groups using the numerical simple division of values that are obtained by the Brazilians institutions IBGE (2003) and PRODAM (2005), as follows.

- **Demographic Density**: corresponds to the ratio between the number of resident people and the total area of the district (SEADE, 2005), considering that "larger people concentrations generate larger energy demand".

- **Family Income**: corresponds to the minimum wages in the homes of the district (PRODAM, 2005; SEADE, 2005), considering the relationship between "income and energy consumption possibilities".

- **Stratification according to the type of land use, households and economic activities**: the basis of this method (MASSARA et al, 2006) effectively considers that both the demand for natural gas and the attractiveness of the district receiving the canalized gas system increase with the number of domiciles or establishments with economic activities in a specific district. The division in establishments is made through the Economic Activities Cadaster (IBGE, 2003) and for the households through the “Census” (PRODAM, 2005; SEADE, 2005). Those data enter in the file as "number of units" and the system automatically transforms them in influence indices from 1 to 5, according to the lowest and the highest numbers obtained for each district. Besides the internal scale, the program allows the insertion by the user of one external influence that is multiplied by the attributed value. This comes already as a function of the number of units that distinguish the activities that are more appropriate to the use of natural gas or, for other reasons, are more attractive to the natural gas concessionaire.

In the following example, the external influence has not been attributed. All parameters have only the internal scale from 1 to 5.

3.4. 4th. System: Civil Construction

The function of this system is to represent values associated with the cost of the underground infrastructure implementation. As for other numerical parameters, the five groups have been elaborated by simple division of the acquired values expressed by the four factors below.

- **Natural Gas Infrastructure Extension**: corresponds to the distance between areas that can be served and others that are effectively attended by natural gas. The rule for the influence attribution is "the smaller the distance, the larger the influence attributed for natural gas attractiveness".

- **Natural Gas Distribution Ramification**: corresponds to the total sum of the internal streets that may be attended by natural gas supply systems. The parameters are also considered in the rule: "the smaller the distance, the larger the influence attributed for natural gas attractiveness".

- **Built Density**: this factor is obtained by the ratio between the built area according to the type of land use (residential, commercial, services and industrial) and the total area of the district (PRODAM, 2005). In districts...
with high industrial density, lower investments with ramifications are considered (“capillarity” of the distribution network).

- Avenues and Streets of Great Importance Traffic: even with the constructive process evolution, the parameter indicates the importance of the district as a connection among neighborhoods and other municipal districts and the special attention that must be given to the interdiction plan. The number of avenues (or streets) is obtained by simple consultation of any streets guide and by counting avenues and streets of larger extension within any given district.

4. RESULTS AND DISCUSSION

Since the case study has been used in the city of São Paulo, it has been divided in 96 districts in conformity with the information reported by the local Urban Plan Department (SEMPLA, 2002; MASSARA, 2002).

Figure 2 introduces the positioning of the districts selected in this paper, emphasizing the different geographical and social characteristics of each one.

The selected districts represent areas of the city with great urban transformations. Some of them face a process of intensification of the residential real estate market (Barra Funda and Mooca), attracting investments in several economic activities in order to respond to that new occupation style. Others have low family income but possess industrial areas that must consume natural gas (São Domingos and Freguesia do Ó).

Others present great urban complexity, functioning as a “bedroom cities”, with land use predominantly composed by habitational groups (Itaquera). However, there are reports (Urban Plan of the City of São Paulo) on the forecast of increments of the roads system, Jacu-Pêssego Avenue is an example (SEMPLA, 2002), which must, as a result, attract new investments for the area and its neighbourhood, thus reverting the economic stagnation of the area. The new industrial region can change the profile of natural gas attractiveness.

![Figure 2](http://www.portalabpg.org.br/bjpg)

Caption: Freguesia de Ó (north), Mooca (east), São Domingos (west), Barra Funda (center), Itaquera (east), green areas, water-course

Figure 2. Localization of the districts selected (City of São Paulo). Source: SEMPLA, 2002; PRODAM, 2005.
Table 1 resumes the attractiveness ranking for five municipal districts for the natural gas expansion projection. From the results listed therein, one may conclude that the districts with better positions contemplate mixed land use (Mooca is the best example of which) and equality of consumption projection in all uses, associated to a larger demographic density and larger family income.

Thus the creation of a residential and commercial market is based on the current use of PLG (petroleum liquefied gas) and on the gradual introduction of natural gas in daily activities, thus inducing customers to the use of natural gas and enabling the development of natural gas canalization and distribution.

5. CONCLUSIONS

The model based on urban indicators has presented coherent results when tested in the city of São Paulo. It has been demonstrated that the model proved to be a good calculation tool with a reasonable precision degree, being easily understood and functioning as an auxiliary in the decision-making process for the natural gas expansion infrastructure in the Brazilian cities.

ACKNOWLEDGMENTS

This work received financial support from the Brazilian agencies Agência Nacional do Petróleo – ANP (PRH-04), Financiadora de Estudos e Projetos – FINEP and Ministério da Ciência e Tecnologia – MCT.

REFERENCES


