Theoretical and Empirical Researches in Urban Management
Volume 8 Issue 3 / August 2013

MANAGEMENT OF URBAN DISTRIBUTION GAS PIPELINE THROUGH THE ANALYTIC HIERARCHY PROCESS: CASE STUDY IN SÃO PAULO, BRAZIL

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Abstract
The article presents a methodology for market research based on urban indicators that aims to develop procedures to analyze and guide the expansion of the physical network of piped natural gas within a municipality through the study of different consuming sectors, based on the urban dynamics that determines the characteristics of occupation of the neighborhoods in big cities. The creation of a model is suggested as a way of basing the decision-making through the assessment of interactions between components of a system represented by four databases, called "information systems" and the degrees of influence of its parameters in the determination of attractive areas for underground natural gas infrastructure. The study based on Analytic Hierarchy Process (AHP), using the districts of São Paulo (Brazil) concluded that the influence of urban dynamics has greater relevance or equal to the estimated consumption and that their inclusion models of market research effectively translates the potential to attract the establishment of private infrastructure services, such as natural gas.
Keywords: Analytic Hierarchy Process, infrastructure logistics, urban dynamics, natural gas, São Paulo.

1. INTRODUCTION

In Brazil, the proven reserves of natural gas, had an increase of 15.23% when comparing 2009 and 2010 from 367,095 million cubic meters to 423,003 cubic meters more than just the rise of 32.9% in 2004 compared to 2003 (ANP, 2010; BP, 2010).

The natural gas consumption reflects structural and cyclical economic characteristics of different regions of the world, but is also strongly influenced by the distribution of reserves.

Thus it is expected that Brazil, computing the volume of recent discoveries, go to consume natural gas more intense, not only in automotive and industrial, but also in everyday uses in commerce, services and residences.

In particular the state of São Paulo, after the discoveries of oil and natural gas in the Santos Basin, there are great expectations of supply and demand for the next years. Figure 1 shows that in all State of

São Paulo there is a predominance of industrial consumption. The goals of expansion in general, also favor this sector, as well as electricity generation and cogeneration, there is little emphasis on other sectors: the residential market is attractive; sell large amounts to a few consumers seem to be the watchword of the market gas for the next year (Udaeta et al, 2010).

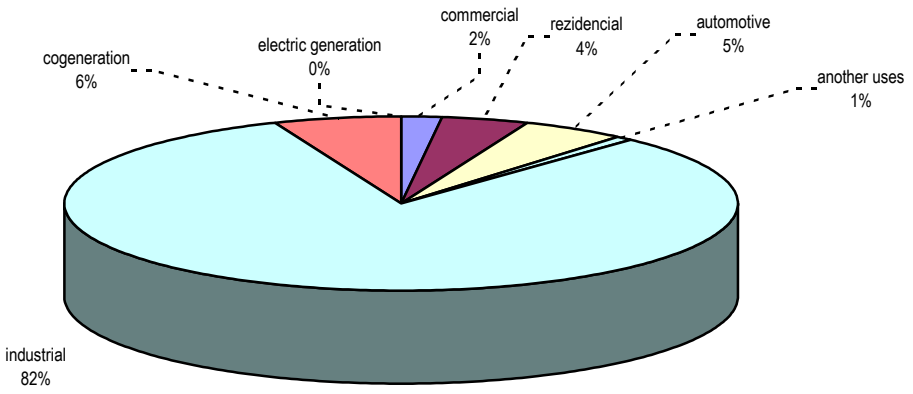

FIGURE 1 - DISTRIBUTION OF NATURAL GAS CONSUMPTION BY SECTOR - SÃO PAULO (BRAZIL).
Source: CESPEG (2011)

2 OBJECTIVES

The objective of this work is to analyze the expansion of the infrastructure of natural gas distribution, identifying priorities from large metropolis using the energy planning based on urban design tools like urban dynamics and techniques like AHP. The methodology proposed uses matrices considering the relations between the concept of urban dynamics, quality of life and the possibilities of natural gas displacing other energy forms. The matrices are made up of information about social and urban development, costs of establishing the infrastructure and projections of the consumption potential in various sectors. Relating the consumption to urban development parameters and the real estate future development of the areas in study, the methodology allows to indicate the viability of a gas network for each district. As conclusion, the model presents the integration between the cities profile and the natural gas use, by means of a growing natural gas use in districts of São Paulo City as a specific case study, with specific advances from the proposed methodology:

- Evaluation of the joint influence of social, technical and economic parameters, in the decision-making process of investments related to private enterprises infrastructure.
- The development of a modeling tool of natural gas market based on urban dynamic concept.

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- Use of the AHP as reference in research of natural gas distribution network expansion, involving usual aspects like costs, demand and others like, urban planning and life quality, considering private and public approaches in the development of the supply network.
- Consolidate a data base for the implementation of other urban essentials services.
- Observation about the director plans of the cities and the inclusion of sustainable procedures to install natural gas services. The process of civil construction has evolved with the use of non-destructive method (ISTT, 2011) a method that uses small cutting trenches of the pavement. It reduces the trouble caused by the interdiction of traffic ways to rebuild the pavement, thus making its execution cheaper, mainly in already consolidated urban areas.

3. THE PRIORITIZATION OF THE PARAMETERS UNDER THE ANALYTICAL HIERARCHY PROCESS

In this study the AHP (analytic hierarchy process) theory is used to obtain the levels of influence of the several parameters in the expansion of the natural gas distribution grid. The method makes possible that when different factors contributes to the decision making process, the relative contribution of each one can be determined, giving all the system characteristics, including all the elements so that an alteration in one of them will be reflected in all the others.

Analytic Hierarchy Process (AHP), favors the evaluations that consider a relatively large set of parameters to determine the relative importance of each in aid of decision making. In order to relate existing techniques to the evaluation based on the prioritization of parameters involving the profile of urban cities, the quality of life, consumption of energy and cost of deployment, we propose the method described below.

This method allows, where there are several factors that contribute to making a decision, is determined the relative contribution of each one, offering all the features of a system, encompassing the elements so that a change in one of them is reflected in all the other. To that end, Saaty created in the late 70's, a technique of choice based on the logic of comparison among all parameters.

TABLE 1 - ADAPTATION OF AHP SCALE TO NATURAL GAS STUDY

Group	Semantic scale for natural gás	AHP scale
1	Low attractivity to network installation	1
2	Low to medium attractivity to the installation of the network	3
3	Medium attractivity to the installation of the network	5
4	Medium to high attractivity to the installation of the network	7
5	High attractivity to the installation of the network	9

Source: Author, based on Saaty (1980)

In this procedure, the different factors that influence decision making are compared pair to pair. A criterion of relative importance is assigned to the relationship between these factors, as the scale pre-defined in the Table 1, adapted to the particular case of natural gas.

It is considered that in doing so there may be a direct response bias that wrongly, when the goal is just to point out the possibilities of expanding the network through different approaches.

For this calculation, the matrix is squared, dividing the sum of each line by the sum of the matrix elements (Decision Lens, 2006). As a result it is obtained a eigenvector of priorities for sorting of the attractiveness. The operation is repeated until the difference between the normalized result of the last operation is very close to the operation precedent. The operation is repeated until the difference between the standard result of the last operation is very close to the result of the preceding.

4. URBAN INDICATORS TO IDENTIFY ATTRACTIVE AREAS TO RECEIVE NATURAL GAS NETWORK

The four information systems that make up the model combining social, technical and economic factors for the deployment to the natural gas pipeline, based on the concept of urban dynamic of the cities, related to its characteristics as a consumer of energy (Alfed, 1995: Forrester, 1969; Rickles, 1973).

For each of the parameters that make up the systems is assigned a scale of priority , due to its numerical value divided into five classes, as shown previously in Table 1.

In this work, the method entitled “Urban Information Systems” (Massara, 2007), join up urban parameters that characterize the cities, determining 4 databases:

- System 1 - Indicators of life quality: parameters related to the existence of social facilities (schools, hospitals and leisure) and other infrastructure networks (water supply, sewer service and illumination) and its reflection on the population welfare.
- System 2 - Urban planning indicators: parameters related to plans for the cities and that collaborate with the analysis indicating concentrations by soil use, areas with capability of increasing end-use creating more demand for energy as industrial uses and areas with residencial development.
- System 3 – Indicators for natural gas consumption forecast: parameters directly related to the population concentration, domestic income (or purchasing power) and stratification in

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residences and economic activities. With these parameters it is possible to forecast gas consumption only through the number of units without considering size or sector.

- System 4 – Civil construction indicators: parameters like the distance between the served area and areas to serve, streets extensions, traffic incidence and densities constructed by type of soil use that indicate major or minor pipe branchings.

Figure 2 shows the four information systems and their parameters.

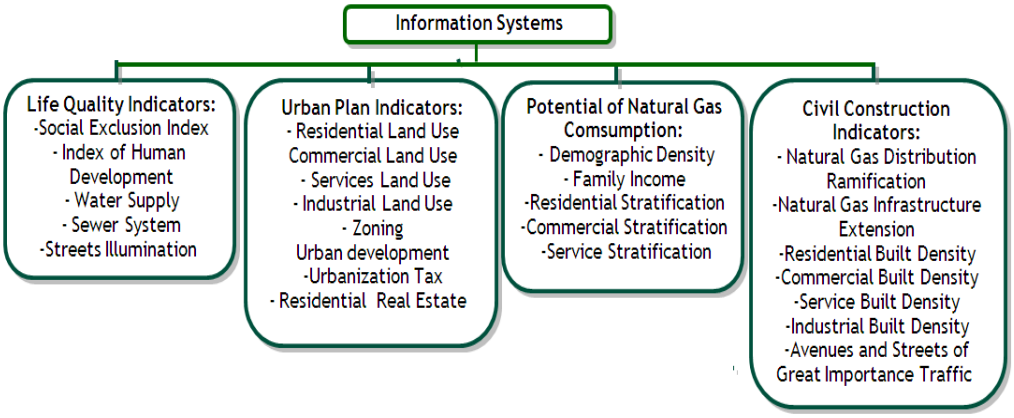


FIGURE 2 - THE INFORMATION SYSTEMS
Source: Massara (2007) based on IBGE (2006), EMPLASA (2006), Groenendaal (1998), SEADE (2009), PRODAM(2007)

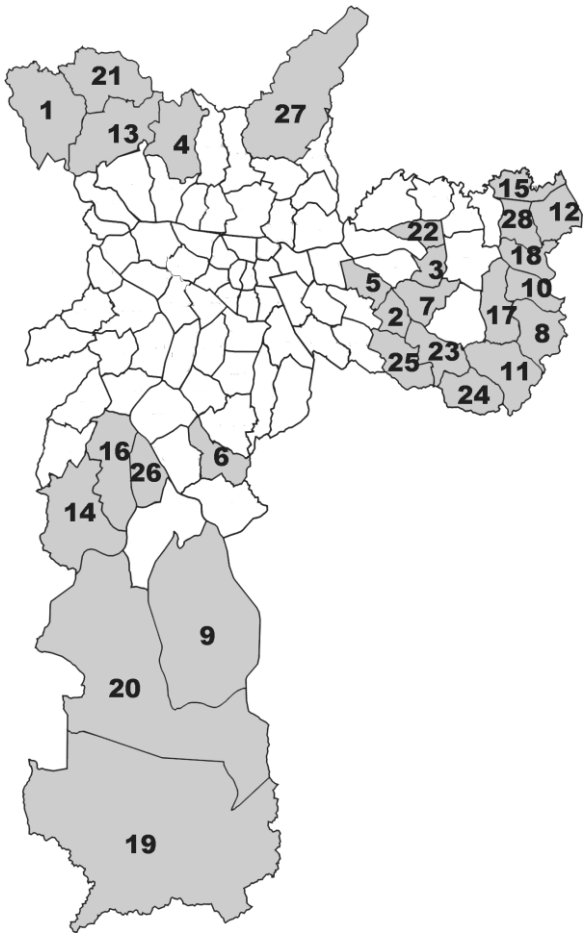
5. CASE STUDY: THE CITY OF SÃO PAULO

São Paulo is the principal city of trade in South America and is the city of the country with mthe major development in natural gas infrastructure. Figure 3 shows the state of São Paulo, with the City of São Paulo in gray. On the left corner of the same figure is the map of Brazil, showing the localization of the state of São Paulo.

FIGURE 3 - MAPS OF BRAZIL, STATE OF SÃO PAULO AND THE CITY OF SÃO PAULO
Source: SEADE (2009)

The city of Sao Paulo (figure 3) has 96 districts (SEADE, 2006). The group of study consists of 28 districts that do not have natural gas network. They are mostly residential districts primarily

characterized by very simple houses or housing projects. Figure 4 shows these districts at the map of the city of São Paulo.



Legend:

1. Anhanguera
2. Aricanduva
3. Artur Alvim
4. Brasilândia
5. Carrão
6. Cidade Ademar
7. Cidade Líder
8. Cid. Tiradentes
9. Grajaú
10. Guaianazes
11. Iguatemi
12. Itaim Paulista
13. Jaraguá
14. Jardim Ângela
15. Jardim Helena
16. Jardim São Luís
17. José Bonifácio
18. Lageado
19. Marsilac
20. Parelheiros
21. Perus
22. Ponte Rasa
23. São Mateus
24. São Rafael
25. Sapopemba
26. Socorro
27. Tremembé
28. Vila Curuçá

FIGURE 4 - LOCATION OF THE DISTRICTS USED FOR THE TEST OF THE MODEL - THE CITY OF SÃO PAULO.
Note: no scale figure. Adapted from Sempla (2006)

With the advent of the sets of "CDHU" (Urban Company of Habitational Development) and introduction the building facilities for gas, districts with low- income, low human development, high social exclusion index and problems with sewer systems and lighting, became atractive to expansion of natural gas (Figures 5a and 5b).

Table 2 presents the attractiveness ranking for the expansion of the natural gas grid obtained with de application of AHP methodology. For methodological basis validation, the result was compared to the current condition of the natural gas network as well as considering the expansion plan of the gas utility (COMGÁS, 2008), which that comparison has obtained a satisfactory outcome.

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FIGURE 5A - DISTRICT OF CIDADE TIRADENTES

FIGURE 5B - DISTRICT OF BRASILÂNDIA
Source: SEMPLA (2006)

To analyze the ranking obtained, we divided the 28 districts into three groups:

- A first group with the four districts better rated: Aricanduva, Carrão, Artur Alvim and Ponte Rasa. The first two with an increase of the residential uses for better income and the other two, with occasional possibilities for industrial use.
- A second group with districts ranging between rankings: Sapopemba, Socorro, Cidade Lider, Cidade Ademar and São Mateus, who have high population concentration living in horizontal residences. The use of natural gas must still go around the neighborhood these districts, for the medium term to make them more attractive.

- Already a last group, composed of 19 districts, that has how principal characteristics, the very low income (as districts of Sapopemba, Brasilândia, Sao Rafael, Perus and Vila Curuçá), problems in other network infrastructure (as in Jardim Sao Luis and Jardim Angela districts), old housing complexes (districts of: Lageado, Cidade Tiradentes, Iguatemi, Jose Bonifacio), low industrial concentration and great distance from areas already served by piped gas (as Grajaú, Jaragua, Jardim Itaim Paulista and Helena), great constraintsof zoning and hence of development and sophistication of land use, and some are located in the area of environmental protection, as Marsilac, Parelheiros, Tremembé and Anhanguera districts).

TABLE 2 - INFLUENCE (IN %) FOR THE ATTRACTIVENESS OF NATURAL GAS EXPANSION BY AHP

District	AHP index	AHP ranking
Anhanguera	2.0	17º
Aricanduva	10.0	1˚
Artur Alvim	5.0	3º
Brasilândia	3.4	10º
Carrão	9.4	2º
Cidade Ademar	4.4	5º
Cidade Líder	4.3	6º
Cid. Tiradentes	2.5	13º
Grajaú	2.0	16º
Guaianases	3.5	9˚
Iguatemi	2.2	15º
Itaim Paulista	3.5	9˚
Jaraguá	3.4	10º
Jardim Ângela	2.9	12º
Jardim Helena	2.9	12º
Jd. São Luís	4.2	7˚
José Bonifácio	2.4	14º
Lajeado	3.4	10º
Marsilac	1.6	19º
Parelheiros	1.7	18º
Perus	2.2	15º
Ponte Rasa	5.0	4˚
São Mateus	4.4	5º
São Rafael	2.7	13˚
Sapopemba	5.0	4˚
Socorro	5.0	4˚
Tremembé	3.3	11º
Vila Curuçá	4.1	8˚

Source: Author, based on Decision Lens (2006)

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Thus, the deployment of natural gas in this group must wait for the long term that districts receive around the service. Inverting the inputs of the weights assigned to each parameter (see Table 3) and applying AHP, we have the influence of each factor in the attractiveness (Figure 6).

TABLE 3 - SAATY'S SCALE ATTRIBUTION FOR THE CASE STUDY: 28 DISTRICTS OF THE CITY OF SÃO PAULO.

Districts	Life Quality Indicators					Urban Plan Indicators								Potential of Natural Gas Consumption						Civil Construction Indicators						
	Social Exclusion Index	Index of Human Development	Water Supply	Sewer System	Street Illumination	Residential Land Use	Commercial Land Use	Services Land Use	Industrial Land Use	Zoning	Urban Development	Urbanization Tax	Residential Real Estate	Services Real Estate	Demographic Density	Family Income	Residential Stratification	Commercial Stratification	Service Stratification	Industrial Stratification	Natural Gas Distribution Ramification	Natural Gas Infrastructure Extension	Residential Built Density	Commercial Built Density	Service Built Density	Industrial Built Density	Avenues and Streets of Great Importnce Traffic
Anhanguera	5	5	3	3	1	3	1	3	7	1	3	5	1	1	1	1	1	1	1	1	1	9	1	1	1	1	9
Aricanduva	9	9	9	9	9	9	1	3	1	7	9	9	9	9	7	7	3	5	5	3	7	9	9	7	7	7	3
Artur Alvim	3	7	9	9	9	7	9	3	1	5	9	9	1	1	7	7	3	3	7	1	3	9	9	5	5	1	7
Brasilândia	1	3	5	5	7	9	1	1	1	5	3	9	1	1	5	5	7	3	5	1	5	5	3	3	3	1	5
Carrão	7	5	9	9	9	5	3	5	3	7	9	9	3	1	5	9	3	7	9	5	7	9	9	9	9	9	3
Cidade Ademar	3	3	5	5	7	9	1	1	1	5	9	9	1	1	9	3	7	3	9	3	7	7	9	7	7	3	3
Cidade Líder	5	3	5	7	9	7	5	3	1	5	9	9	1	1	5	3	3	3	5	1	3	9	5	7	7	1	7
Cid. Tiradentes	1	3	5	5	3	9	1	1	1	5	9	1	1	1	7	1	5	1	5	1	1	9	1	1	1	1	9
Grajaú	1	3	1	1	3	5	5	3	3	1	3	9	1	1	1	3	9	3	7	1	3	1	1	1	1	1	7
Guaianases	1	3	5	7	9	9	5	1	1	5	9	9	1	1	5	1	3	5	5	1	1	9	3	3	3	1	9
Iguatemi	1	3	3	7	3	9	1	1	1	1	9	7	1	1	3	3	3	1	3	1	1	7	1	1	1	1	9
Itaim Paulista	1	3	5	7	7	7	9	1	1	5	9	9	1	1	9	1	7	5	7	1	1	7	1	1	1	1	9
Jaraguá	3	3	5	5	5	5	9	9	1	5	9	9	1	1	3	5	5	3	3	1	5	5	1	1	1	1	5
Jardim Ângela	1	3	5	1	5	7	7	3	1	5	9	9	1	1	3	1	7	3	5	1	3	5	5	1	1	1	7
Jardim Helena	1	3	3	3	7	7	1	1	1	5	9	9	1	1	7	1	5	1	3	1	1	7	3	3	3	3	9
Jd. São Luís	3	3	3	5	9	7	1	1	1	5	9	9	1	1	5	1	7	5	9	5	7	7	3	5	5	1	3
José Bonifácio	3	5	3	1	5	7	5	1	3	3	3	9	1	1	3	3	3	1	3	1	1	7	5	1	1	1	9
Lajeado	3	3	3	7	9	9	1	1	1	5	3	9	1	1	9	1	5	1	3	1	1	9	1	3	3	1	9
Marsilac	1	1	1	1	1	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5	1	1	1	1	9
Parelheiros	1	3	1	3	1	1	1	1	9	1	1	1	1	1	1	1	3	1	3	1	1	7	1	1	1	1	9
Perus	1	3	1	7	3	5	3	1	5	5	3	5	1	1	1	1	1	1	1	1	1	9	9	1	1	1	9
Ponte Rasa	5	5	9	9	9	9	1	1	1	7	9	9	3	3	7	5	3	1	5	1	5	9	5	7	7	1	5
São Mateus	5	5	5	7	9	5	9	3	3	7	9	5	3	1	5	3	5	3	7	1	3	9	3	5	5	3	7
São Rafael	1	3	1	3	9	9	1	1	1	3	9	5	1	1	5	3	3	1	3	1	1	9	3	1	1	1	9
Sapopemba	3	3	5	7	9	9	1	1	1	5	9	9	1	1	9	5	9	9	7	1	3	7	7	7	7	1	7
Socorro	9	7	9	1	9	3	3	1	7	5	9	9	1	5	1	3	1	9	5	9	9	9	3	3	3	9	1
Tremembé	3	5	3	7	7	9	3	3	1	1	9	5	1	1	1	7	5	3	5	1	7	5	1	1	1	1	3
Vila Curuçá	1	3	5	7	9	9	1	1	1	5	9	9	1	1	7	1	5	3	5	1	1	7	5	5	5	1	9

Source: Massara (2007), Saaty(1980), Decision Lens (2006), SEMPLA(2006), IBGE (2006), Prodam(2007), SEADE(2009), EMPLASA (2006), COMGÁS (2008)

The absence of the priority networks representing leading contributions. The parameters related to Urban Planning, emphasize residential land use and the characteristic of "dormitory town" of many of these districts. Also the trade and services uses have significant contributions. The industrial use has less influence than other uses, particularly in districts just Anhanguera, Parelheiros and Socorro.

As for the real estate developments, they have negligible contribution, less than 1%, what is explained by the characteristics of the housing market that is based in low-income residences.

For the projection factors of consumption, the importance of population density grows and also the family income. The number of households and trade have Significant impact on influence for deploying service gas (scale of 1 to 9).

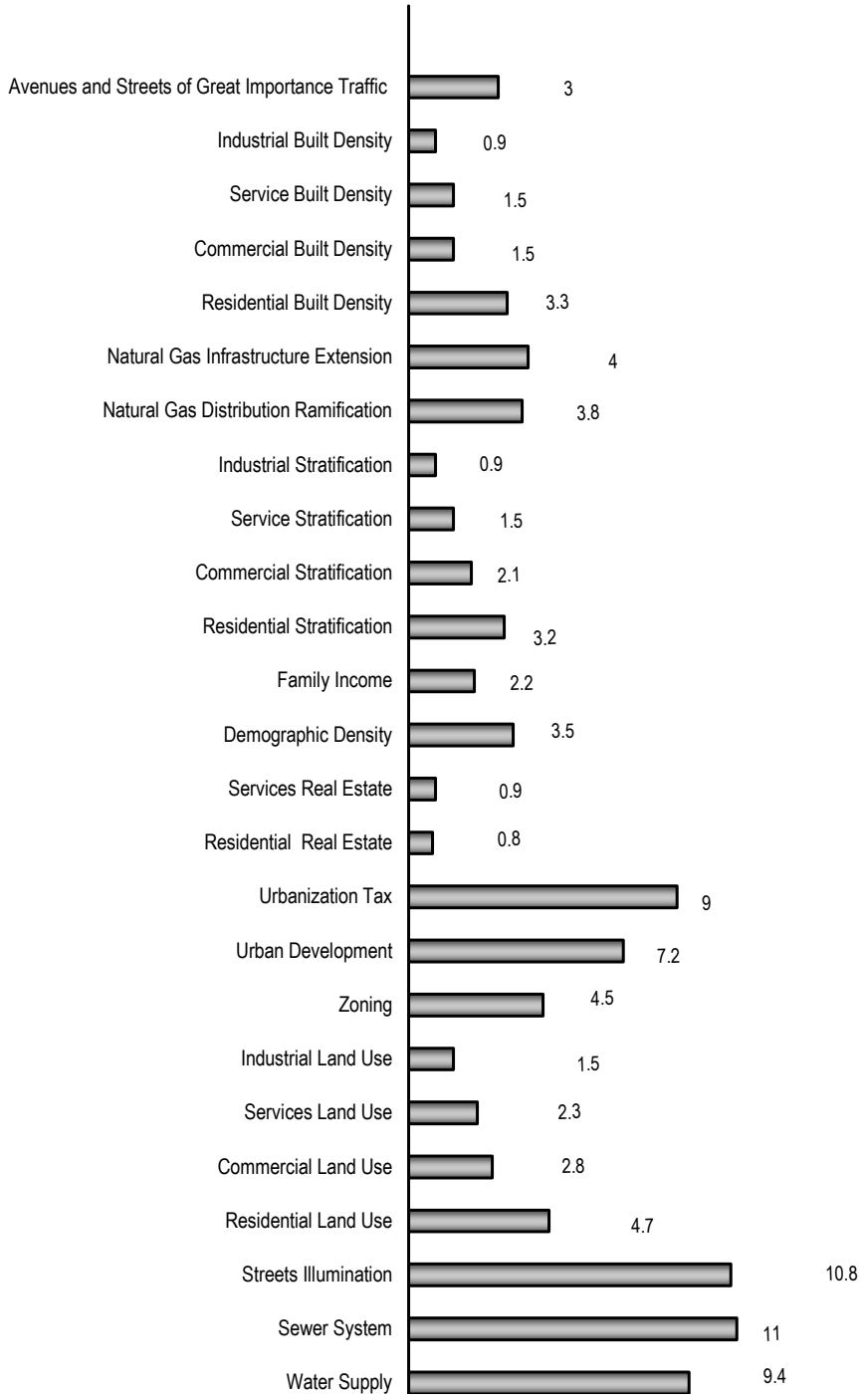

FIGURE 6 - INFLUENCE OF JOINT PARAMETERS - SÃO PAULO (in %)
Source: Author, based on Decision Lens (2006)

The last parameters que make up the group related to civil work, to the distance of the area served, the length of streets and the incidence of traffic contribute significantly que because these districts have large territorial extensions and are distant of the network already deployed. The residential density

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presents relevant weight attribution, but the others densities (trades, services and industrial densities) have influence median basically oscillating between 1 and 5.

The analysis of the degree of contribution of each parameters shows briefly the sequence of relevance:

- Water supply, sewer system and public illumination present great deficits and, therefore, have great influence on the decision for expansion of natural gas infrastructure;
- Urban Development;
- Zoning;
- Distance from the area already served and the great extension of the districts's streets;
- Uses of residential land, commercial and services;
- Densities of built residential, commercial and services;
- Demographic density, household income and streets and avenues with heavy traffic;
- Number of housing units, shops and services;
- Use of industrial land, built density and number of industrial sites;
- Index of human development and social exclusion index;
- Real state releases.

6.CONCLUSIONS

Through this case study it is concludes that the selection of parameters linked to the profile of cities can be adapted to study the market for natural gas translating the possibilities of consumption in consolidated urban areas.

To have the greatest potential for expansion of the service network, it is also necessary to intensify the relationship between dealers, govern and gas facilities companies, development of equipment that use the natural gas for various purposes, as well as aid of public agencies in the implementation of infrastructure and the widespread use of natural gas as an agent of urban development. The creation of a residential and commercial markets based on the gradual introduction of natural gas in everyday uses may ultimately lead to a clientele that makes possible the introduction of network distribution.

The proposal to study markets for natural gas through urban informations brings an interactive view of the dynamic development of cities to other energy sources, with the intention to introduce a concept of network distribution for natural gas , which may be relevant to balance and level of tariffs, providing the increase in quality of life and optimizing production processes.

ACKNOWLEDGEMENTS

To the ANP (National Agency of Oil, Natural Gas and Biofuels through the PRH-ANP/04 (Program of Human Resources of ANP number 04).

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