International Journal of Architecture and Infrastructure Planning
Vol. 1: Issue 1
www.journalspub.com

Development of Piped Gas Service in São Paulo, Brazil (1900–2000) and its' Growth in 21st Century through the Hierarchical Analysis of Urban Indicators

Vanessa Meloni Massara
Civil and Urban Engineering, University of São Paulo, São Paulo, Brazil

Abstract

This paper presents an overview of piped gas in the city of São Paulo (Brazil) since its implementation in 1900 until its expansion in 2000. After this, are worked 27 urban indicators represented by four groups of study: quality of life, urban planning, consumption projection and costs of civil construction. These indicators are applied in a group of 24 districts using the analytic hierarchy process. This methodology intends to show urban parameters that determine the decision making to choose the most attractive neighborhoods to receive the service. By comparing "pair to pair" basis of this method, is possible to define the attractiveness ranking of the gas service deployment in these 24 districts, thus indicating those which, by their urban characteristics, are the most propitious to the use of channeled gas. The conclusion is that parameters that are not usually evaluated as quality of life and urban planning are crucial in market analysis of the implantation of the natural gas network. Among them are: land uses and family income can influence the network expansion more than common factors as consumption issues such as population density and density built.

Keywords: *urban development, natural gas, infrastructure, city of São Paulo (Brazil), energy, analytical hierarchy process*
Author for Correspondence*: Email ID: vmmassara@usp.br*

INTRODUCTION

Urban Indicators and Analytical Hierarchy Process

This work emphasizes the importance of the urban profile of each district as the basis for verification of market estimates supported on the relationship among social issues, demand for energy, the dynamics of cities[1] and the deployment cost of the channeled distribution of natural gas (NG). The objective is to propose a research methodology that integrates the dynamics of cities to the development of other energy sources, with a specific application for the issue of natural gas breakthrough in Brazil and especially in São Paulo market in order to develop procedures for analyzing and guiding the expansion and densification of the physical network of piped natural gas within a municipality.

The systemic modeling of the factors involved was prepared through the following steps:

1. Identification, characterization and systematization of the main involved parameters[2];
2. Hierarchisation of quantitative and qualitative factors by assigning a priority scale in order to unify the dimension associated to all indicators evaluated in the analysis unit so they can be treated statistically;
3. Evaluation system in order to guide the choice, using the theoretical guidelines as well as the application of the Analytic Hierarchy Process to support the modeling[3–5].

In this way is intended to identify opportunities in the medium and long term, to expand the use of natural gas piped in surrounding neighborhoods to the center and other peripherals, which have demand outlook for energy and in particular, they can use natural gas .

BRIEF HISTORY OF PIPED GAS IN SÃO PAULO, BRAZIL

The use of electricity and gas, besides improving aspects of convenience and safety, is the base for production, feeding industries and commerce, as Mascaró[6] emphasizes: "the gas and electricity networks allow that cities change their function and pass the administrative centers or exchange the centers of production".

In Brazil, there is a controversy about which was the first city with gas lighting: São Paulo or Rio de Janeiro, the first is considered by several authors, the precursor, the first experiments dating between 1860 and 1870, although Telles[7], mention which in 1834, had been illuminated the "Praça XV de Novembro" that other city. Other cities such as Porto Alegre became lighted by canalized gas still in the penultimate decade of the nineteenth century. At the end of this period, also had the service the cities of Belém, São Luis, Fortaleza and Salvador.
In the 70th, through the construction of pipelines connecting countries and continents were a large network expansion of global routes for natural gas[8].

The Natural Gas Network in the City of São Paulo

The history of gas supply in São Paulo is intertwined with the Public Lighting. In the early nineteenth century are made the first trials using olive oil for lighting. In 1847, begins the hydrogen gas lighting in the city, through a contract between the City Council and Afonso Milliet (owner of a gas plant).

A little later, around 1862, Camilo Bourroul proposed illuminate the city by lamps with oil photogenic resin without acceptance; in 1863, Francisco Alvim Taques is contracted by the government to run the residential and public lighting by coal gas which was carried forward by the San Paulo gas Company Ltd, formed in 1869 by the capital of British businessmen; in 1870, there were already destined to drive gas pipelines and in the same year is constructed gas Plant "Várzea do Carmo".

In 1872, appeared the first street lamps, fueled by "Casa das Retortas" with imported charcoal gas are illuminated the old cathedral and the Government Palace and nine years later, the "Jardim da Luz".
In 1880 had begun the gas home distribution, only for lighting. In the decade following the gasholder is built in "Rua da Figueira" in Bras (which had its capacity increased in 1908).

The contract between the company and the State Government for thirty years was renovated in 1897. But in 1905, a few electric lights were installed by "São Paulo Tramway, Light and Power Company" (from Canada), Rua Barão de Itapetininga and then on the streets of the "Triângulo".
In 1911, occurs the first contract with the Light government, using the argument that the contract with the gas company gave it the privilege to operate the gas lighting service but did not prevent another system implementation. During the 1910s, electric lights and gas lamps co-existed, in a proportion of 864 lights for 8605 lamps[9].
The opposition of the Gas Company occurred by request approved to the work with electricity lighting. Thus the "incandescent gas" came into competition with the incandescent carbon filament until that it became impossible for the company to sustain the gas dispute, by the appearance of lamps with "tungsten filament stretched".

In 1912, Light Company assumes a controlling stake in San Paulo Gas

Company. In 1918, the Government authorizes the use of mixed gas (water and another substance, such as coal, for example). The commercial struggle between Light and the Gas Company was long. In 1929, an agreement was made instructing for “Light” illumination services, getting the gas, only with heating[10]. The latest street lamps were disabled in 1936.

In summary, the timing of granting piped gas services is as follows (assuming the gas lighting and the subsequent period for residential, commercial and industrial):
1872: The San Paulo Gas Company Ltd
1912: control by the São Paulo Tramway, Light and Power Company Ltd.
1929: lighting electricity hiring third parties and distribute gas for private company takes over the group of Brazilian Traction Light
1959: is nationalized and becomes: Companhia Paulista Gas Services
1968: moves to control the city and is named Municipal Gas Company, authorized the establishment of a corporation
1974: name change: Company Municipal Gas Company of São Paulo - Comgas
1983: control by the state government
1984: control passes to the state CESP - Companhia Energetica de São Paulo
1999: stock control passes to British Gas and Shell.

Network Distribution: Residential, Commercial and Industrial Uses

In 1900, the network for this purpose was undeveloped; appears in 1901 the first gas stove, at the Government Palace.

In the late '20s, when the electric lights began to dominate the lighting market, the gas network began its expansion into distribution service in homes for the purpose of heating. With the end of that decade began the construction of pipelines for high pressure and the Gasometer “Mooca”. In 1929, it signed a contract by San Paulo Gas Company for gas supply network[11].

In the '50s, a survey[12] shows that the gas network had a little increase; this situation had confirmed in 1968 by the Basic Urban Plan, showing the concentration of the service in central city area, walking to the “Jardins” and Vila Mariana.

In 1967, the granting of permits is subject to the builders of gas facilities. In 1971, it was enlarged in “Mooca” followed by the execution of the Plant “Massinet Sorcinelli” (naphtha gas) and the high pressure system including neighboring municipalities of São Paulo[13].

In the mid-70s, city ordinance requires that all buildings must have facilities for canalized gas[14]. During this period, the network goes a little increase in the directions already commented in the period 1950/60, and also to the Lapa and Santana, but without significant data.

Until 1976, there is only network for gas naphtha made still in cast iron, entitled "subsystem I" serving residences and small commercial and industrial. In 1976, it created the so-called "subsystem II", first serving medium and large industries.

In the '80s, capacity expansion occurs, arising from the operation of the Campos Basin (State of Rio de Janeiro, Brasil). The Municipal Planning Secretary in 1983[15], describes the condition of the system at that time:

“Piped gas is one of the services offered to the citizens most affected by the city. Currently the number of connections is approximately 170,000, of which 160,000 houses are located mainly in the region of urbanization, consolidated around the center, representing about 10% of the potential demand. The rest of the city uses liquefied petroleum gas, received in cylinders, which, although carried by trucks, it is still cheaper for the consumer than the network."[16].In 1989, the network had been performed the conversion to natural gas of the first homes in the west of the City.

In the 90s, the population served is only 8%, covering of the expanded center, 70% of the volume produced for industrial use, 10% for commercial and 20% for residential[16]. In 1993, the Plant "Massinet Sorcinelli" starts producing natural gas and starts the conversion program on trade and residential large-scale (began in 1989).

After privatization in 1999, the company expands its plans to supply throughout the State of São Paulo, aiming to increase the supply to power plants and expand the use in industrial areas.

In the city of São Paulo, the other point of the network expansion is the replacement of cast iron pipe of polyethylene, supporting the highest pressures arising from the use of natural gas that began in the downtown area (the older network).

Also the use of gas heaters for residential use, hot water production and fireplaces, are increasing the use of piped gas in the central city.

Already, commercial businesses should respect gas connections in case of existing network, using natural gas. In the case of industries, mainly from petrochemicals, steel, glass, paper, ceramics, and aluminum beverage consumption has been increasing, with prior verification by dealership existing external network and its distance to the entrance of the industry.

Figure 1 shows three stages of deploying the infrastructure of underground gas in the city of São Paulo.

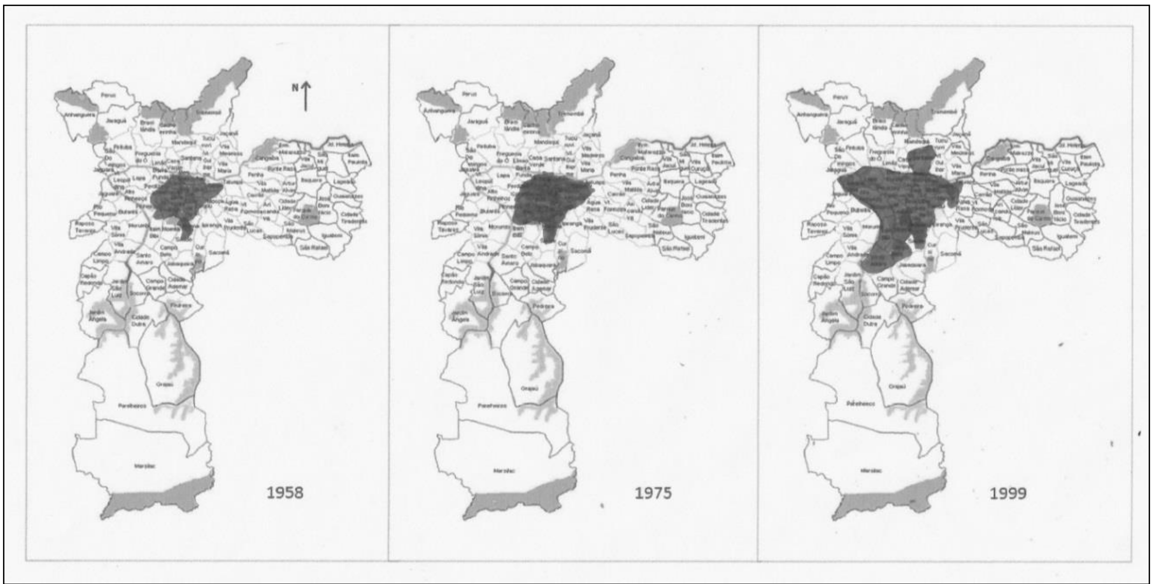

Fig.1: *Expansion of Piped Gas Network in São Paulo - 1958–1999. (Source: Author[13,17] No scale).*

Network Advance in 2000'

The city of Sao Paulo has 96 districts as shown in Figure 2of which 28 of them located in its geographical center were not used for this study because they already have piped gas network.

The other 68 districts were also subdivided according to the situation of the network and generating three distinct groupings[17,18]. Of these, two one group will be analyzed in this article (30–50% of natural gas service).

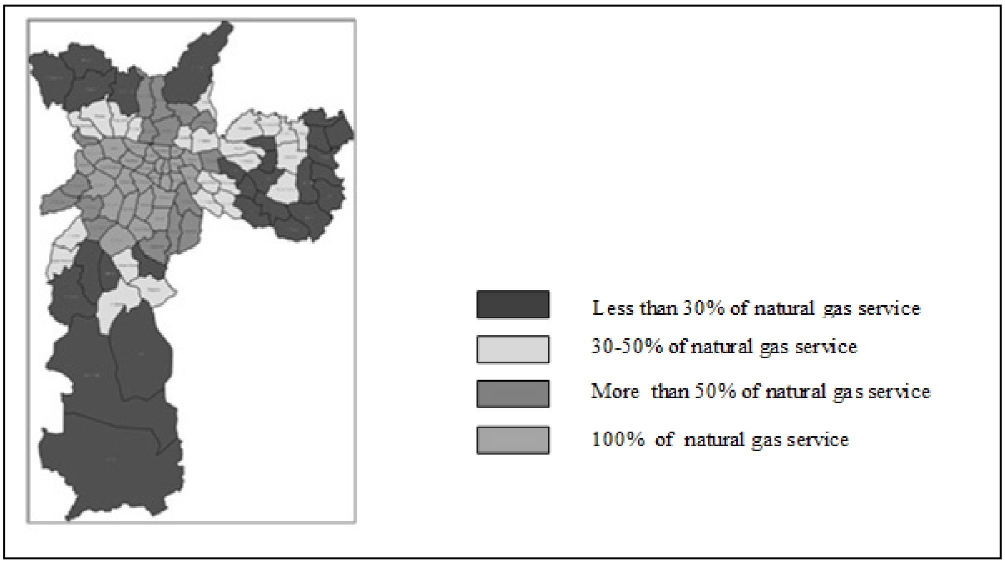

***Fig. 2:** Location of the Districts Separated in Groups of Different Stages. (Source: Massara[19,20] No scale.)*

The group focused has 24 districts that have 3–50% of natural gas service of its territory and which are represented by lower concentration residential buildings, commercial and industries more dispersed.

METHODS

Determination of the Factors That Encourage the Deployment of Piped Gas Network

According to studies conducted by Massara[19,20] factors that can affect the attraction of infrastructure networks such as underground gas, can be divided into four groups. In each of these groups are allocated factors that relate to quality of life, urban planning, projections of consumption and the cost of pipeline insertion.

In this work, the method entitled "Urban Information Systems" 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 and its reflection on the population welfare.

Social Exclusion Index; Index of Human Development; Water Supply; Sewer System; Streets Illumination

System 2-Urban Planning Indicators parameters related to guide 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 and industrial growth, areas already supplied by natural gas network, but always with capability of increase of use.

Residential Land Use; Commercial Land Use; Services Land Use; Industrial Land Use; Zoning; Urban Development; Urbanization Tax; Residential Real Estate; Services Real Estate

System 3- Indicators for natural gas consumption forecast (consumption projection) parameters directly related to the population concentration, domestic income (or purchasing power) and to the stratification in households and economic activities. With these parameters it is possible to forecast gas consumption only from the number of units without considering size or sector, this including sampling survey for determining the conversion volumes to natural gas from other energy like electricity, oil derivatives and LPG.

Demographic Density; Family Income; Residential Stratification; Commercial Stratification; Service Stratification; Industrial Stratification

System 4-Civil construction indicators (cost of civil construction) parameters not directly related to construction costs and to the problems derived from roads closure for installation of underground pipes, like the distance between the served area and areas to serve, road extensions, traffic incidence and densities constructed by type of soil use that indicate major or minor pipe branching.

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 Importance Traffic

The idea to determine the influence of each of these groups in different regions of São Paulo, used the concept of analytic hierarchy process (AHP)[4,21]. Numerical values that are assigned to the priority scale, as shown in Table 1.

Table 1: *Adaptation of AHP Scale to Natural Gas Study. (Source: Author[4]).*

Group	Semantic scale for natural gas	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

After this assignment of weights of 1–9, had been used the program Decision Lens (2006)[21] that permits to compare the influence of all factors on the deployment of the network thought a pairwise comparison, enabling the verification of which of the four groups of parameters is one that influence over the choice of districts appealing to the gas network.

DEVELOPMENT OF THE METHODOLOGY: A CASE STUDY

The districts of the case study have predominant characteristics as horizontal occupation for the population with middle and low vertical predominantly represented by numerous small housing incomes. The situation of gas service is 30–50% of implanted service.

The location of trade and services is on the main streets. In the medium term is expected to intensify the process of replacing homes and townhouses for residential buildings from the middle segment as shown in Figure 3.

In the past were characterized by the establishment of major industries in the chemical, ceramic and cement areas, but this profile is now represented by specific industries which do not constitute strong demand for energy use.

This group offers the possibility of increasing its land use and thus, attracts the service underground gas service underground gas.

Fig. 3: *Examples of Districts of Analysis: Freguesia do Ó, Pirituba and Ermelino Matarazzo. Source[3].*

The application of weights 1–9 follows the idea of dividing the numeric values that represent each indicator on 5 intervals. Being assigned the value 1 for the first interval and so on until the fifth range, with the highest values to which is assigned the weight 9.

Only for three numerical indicators, the attribution of weights is the opposite: the lowest values are given the most weight. They are: natural gas distribution ramification; natural gas infrastructure extension; and avenues and streets of great importance traffic.

This is justified by the fact that the cost of civil implementation of pipelines is cheaper while smaller are the distances, as well as the lower number of large avenues to interdict for the construction, the lower the disorder around. The exceptions in "qualitative" indicators are: "land use"; zoning and urban development, that follow a different scale as is presented on table 2:

Table 2(a): *Assigning Weights to the Qualitative Indicators.*

weight	zoning	land use
1	residential zone of low density / zone of environmental protection;	horizontal residential occupation;
3	residential zone of medium density / mixed zone of low density;	mixed use (commercial and residential horizontal);
5	residential zone of high density / mixed zone of medium density / special uses;	vertical residential occupation;
7	mixed zone of high density;	mixed use (commercial, services and residential vertical);
9	great industrial zone occupation.	mixed use (residential and industrial).

Table 2(b): *Assigning Weights to the Qualitative Indicators.*

weight	urban development
1	environmental protection – limits of public areas and preservation areas;
3	urbanization and urban qualification – areas predominantly occupied by low income families with high concentration of irregular constructions;irregular constructions;
5	3rd. Group: requalification – areas with good infrastructure although presenting many empty properties;
7	4th. Group: urbanization in consolidation – areas in condition to attract real estate investments in residences, services and commercial establishments;
9	5th. Group: consolidated urbanization – areas formed by consolidated neighborhoods inhabited by population of medium and high income and good urbanization conditions.

The next table shows the allocation of weights in the 24 case study districts for the 27 urban indicators.

These weights are introduced in Decision Lens (2006)[21], which make them a percentage.

This percentage indicates the "ranking" of importance of these indicators for each district, i.e., the attractiveness of each of the gas pipeline network as depicted in Table 4.

Table 3: *Assigning Weights to 27 Urban Indicators in 24 Districts of the Case Study.*

Districts	Life Quality Indicators					Urban Plan Indicators									Potential of Natural Gas Comsumption						Civil Construction Indicators						
	Social Exclusion Index	Index of Human Development	Water Supply	Sewer System	Streets 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 Importance Traffic
Água Rasa	9	7	9	9	7	5	3	3	5	7	9	9	1	5	5	5	3	1	3	3	1	3	9	9	9	7	3
Campo Grande	9	9	9	9	5	1	7	7	9	5	9	9	1	1	1	9	3	1	5	1	1	7	5	3	3	9	3
Campo Limpo	3	3	7	7	5	9	1	1	1	5	9	9	1	1	7	1	7	3	5	1	3	7	5	3	3	1	5
Cangaíba	5	3	7	9	7	9	3	1	1	5	9	9	1	1	3	1	5	1	3	1	5	9	3	1	1	1	5
Capão Redondo	1	3	7	5	5	9	3	1	3	5	9	9	1	1	9	1	9	1	3	1	3	9	3	3	3	1	7
Cidade Dutra	3	3	7	7	5	3	3	1	9	1	9	7	1	1	1	1	7	1	5	1	5	7	1	1	1	1	7
E.Matarazzo	5	3	7	7	5	5	3	5	7	7	9	9	1	1	5	1	3	3	3	1	5	5	3	3	3	3	3
Freguesia do Ó	7	5	9	9	7	9	1	3	1	7	5	9	3	1	5	1	5	7	7	1	1	5	7	5	5	3	1
Itaquera	3	3	7	7	7	7	1	1	5	7	9	9	7	5	7	1	7	9	5	3	3	7	3	3	3	1	5
Jaçanã	5	3	7	9	7	9	1	1	1	5	9	1	1	1	5	1	1	3	1	1	3	1	5	3	3	3	3
Limão	5	5	9	9	7	3	1	3	9	7	9	9	1	1	5	1	1	3	3	3	3	3	7	7	7	7	3
Pq. do Carmo	5	3	9	9	5	7	1	1	5	5	3	9	1	1	1	1	1	1	1	1	5	9	1	1	1	1	7
Pedreira	1	1	7	5	3	9	1	1	3	3	3	9	1	1	3	1	3	1	1	1	5	7	1	1	1	1	7
Penha	7	5	7	9	9	5	7	9	1	7	5	9	5	9	5	1	5	9	9	5	3	1	7	7	7	3	1
Pirituba	7	5	9	7	3	9	1	1	1	5	1	5	1	1	3	1	7	5	5	3	7	7	3	3	3	1	7
São Domingos	7	5	9	7	5	7	5	1	3	5	9	5	1	1	3	1	1	1	3	1	3	3	3	3	3	3	5
São Lucas	7	5	9	9	5	7	3	1	5	7	9	9	1	1	5	1	5	1	3	1	5	7	7	5	5	3	5
São Miguel	3	3	9	9	5	9	1	1	1	7	9	9	1	1	5	1	3	9	3	1	7	5	5	7	7	1	3
Vila Formosa	9	7	9	9	7	9	3	1	1	7	9	9	3	1	5	3	3	5	5	3	3	5	9	9	9	1	3
Vila Guilherme	9	7	9	9	7	3	9	9	3	7	9	9	3	1	1	1	1	5	3	3	1	3	5	9	9	7	1
Vila Jacuí	3	1	9	7	5	9	5	1	1	7	3	9	1	1	9	1	5	1	1	1	9	5	3	3	3	1	9
Vila Maria	5	3	9	9	7	1	9	7	5	9	9	9	5	5	3	1	3	5	7	9	1	7	3	9	9	7	1
Vila Matilde	7	5	9	9	5	7	5	5	1	5	5	9	1	1	5	1	3	3	5	1	5	5	7	5	5	1	3
Vila Prudente	7	5	9	9	9	5	3	3	5	7	9	9	9	5	3	1	3	9	7	5	5	7	7	5	5	5	1

RESULTS

In this group are listed districts with urban intermediate characteristics, which have a larger portion of the territory already served (without being fully served) and others where the network doesn't exist. There is a first group formed by Penha, Vila Maria, Vila Formosa, Vila Prudente, Água Rasa and less emphasis, Freguesia do Ó and Vila Guilherme that can come in the medium term is a market for the use of piped gas. Currently, the indication is to seek the vertically integrated areas that are expanding in Penha and Vila Prudente with some industrial concentration.

The second group is formed by the districts: Limão, São Lucas, Campo Grande, Ermelino Matarazzo, Itaquera, Vila Matilde, Cangaiba, Cidade Dutra, São Miguel Paulista, São Domingos and less emphasis Capão Redondo and Campo Limpo, presenting similar profile to the previous group, but with lower income, greater distance of the areas already served by NG and when vertically areas, these are housing projects of social interest (only from 2005 with facilities for gas).The dense population located in most of these districts is not enough to make them attractive as the population concentration has small portion of importance in the decrease in investments and only becomes relevant in places with higher purchasing power and sophistication of land uses.

Table 4: *Attraction Ranking of the Gas Network. Source*[4].

Indication on figure3	Districts	Ranking	% by Decision Lens
1	Água Rasa	**3°**	**5,8**
2	Campo Grande	**4°**	**5,2**
3	Campo Limpo	**12°**	**3,3**
4	Cangaíba	**13°**	**3,3**
5	Capão Redondo	**14°**	**3,3**
6	Cidade Dutra	**17°**	**2,5**
7	E.Matarazzo	**11°**	**3,3**
8	Freguesia do Ó	**6°**	**4,8**
9	Itaquera	**8°**	**4,8**
10	Jaçanã	**16°**	**2,3**
11	Limão	**7°**	**4,5**
12	Pq. do Carmo	**18°**	**2,3**
13	Pedreira	**19°**	**1,7**
14	Penha	**1°**	**6,5**
15	Pirituba	**12°**	**3,7**
16	São Domingos	**15°**	**2,7**
17	São Lucas	**9°**	**4,5**
18	São Miguel	**9°**	**4,1**
19	Vila Formosa	**3°**	**5,8**
20	Vila Guilherme	**5°**	**5,2**
21	Vila Jacuí	**15°**	**3,3**
22	Vila Maria	**2°**	**6,2**
23	Vila Matilde	**10°**	**4,1**
24	Vila Prudente	**1°**	**6,8**

A third group, consisting of Vila Jacuí, Jaçanã, Pedreira, Pirituba and Parque do Carmo, which doesn't indicate great potential in the medium and long term not for specific industrial uses.

Overall, these 24 districts do not represent a substantial market for network piped natural gas, unless go through an intensification of the urban development process in two ways: vertical living and /or the establishment of industrial centers (e.g. along the Jacu-Pêssego Road), which must be combined with culture of natural gas use and rates that strengthen the electric and liquefied petroleum gas energy replacement.

Figure 3 shows the case study districts in the city of São Paulo, combined with Table 4 presents the ranking of attraction to the gas service based on characteristics of urban districts.

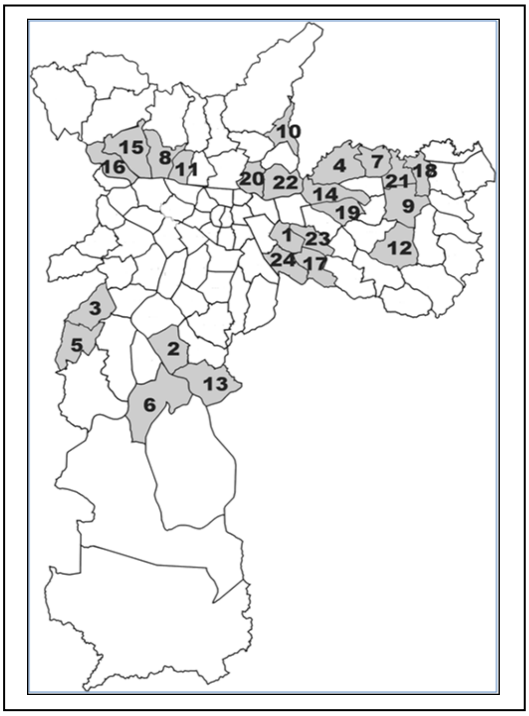

Fig.3: *Districts that are in the second group: 30–50% of natural gas service. Source[3,4].*

DISCUSSION AND CONCLUSION

The analysis of the degree of contribution of each system and indirectly, of the parameters that shows in general, the following prioritization of relevance:

1. Urban Development;
2. Zoning;
3. Distance from the area already served and extension of roads;
4. Uses of residential land, commercial and services and in the case of Araçatuba region, the agricultural use;
5. Densities built residential, commercial and services;
6. Demographic Density, family income and highways with heavy traffic;
7. Number of housing units, shops and services;
8. Industrial land use and built density;
9. Index of Human Development and Social Exclusion Index;
10. Real estate services.
11. The condition of network infrastructure and rate of urbanization (though they have the best contribution, but little interest from the

point of view of consumption projection and the cost of civil works).

12. The result of Figure 5 appears as the most influential, followed by the quality of life indicators system, followed for urban plan indicators, consumption projection and finally costs of civil construction indicators.

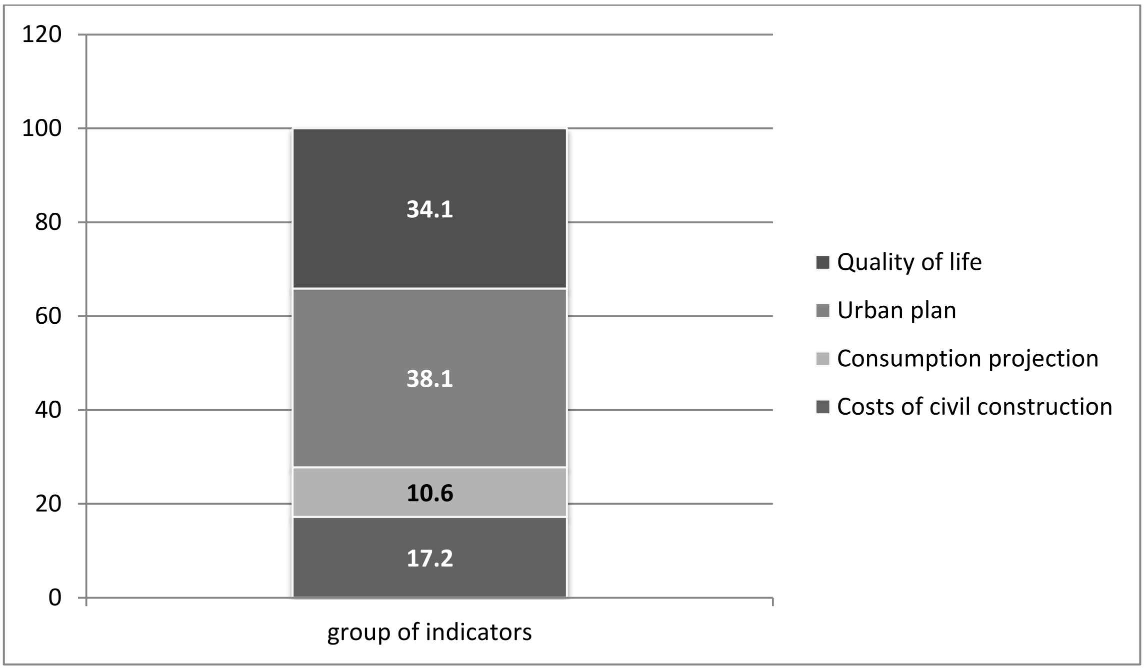

Fig. 5: *Influence of the Three Groups of Districts Based in the Urban Characteristics (Quality of Life, Urban Plan, Consumption Projection and Costs of Civil Construction). (Source: Author).*

In the analysis of the City of São Paulo, the result induces the hypothesis that the locations with better urban characteristics are those who receive the service first. This conclusion can be done by imagining the city as a series of layers with different scales, the scales being the center associated with the expanded center, which comprises the first city districts to use the gas network.

Through this brief analysis, it is clear that the process of deploying of the infrastructure for natural gas depends on a number of urban characteristics. It is a dynamic process that tends to spread throughout the city of São Paulo, making the use of piped gas as much as the diffused use of electricity.

REFERENCES

1. Forrester J. W. *Urban Dynamics*. Cambridge: M.I.T. Press; 1969.
2. Saaty T.; Vargas, L.G. *The Logic of Priorities, Applications in Business, Energy, Healthy, Transportation*. Boston: Kluwer-Nijhoff; 1982.
3. Saaty T. *Mathematical Methods of operations research.* Ontario: McGraw-Hill Book Company; 1959.
4. Saaty T. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. London: McGraw-Hill; 1980.
5. Saaty T. *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process*. Pittsburg; RWS; 1994.
6. Mascaró J.L. *Desenho Urbano e custos de urbanização*, Ministério da

Habitação, Urbanismo e Meio Ambiente, Brasília (in Portuguese); 1987.
7. Telles P.C.S. *História da Engenharia no Brasil-século XX,* Clube de Engenharia, Rio de Janeiro (in Portuguese); 1984.
8. Udaeta M.E.M., Grimoni J.A.B., Burani G.F., *et al*. Fundamentos e Introdução à Cadeia Produtiva do Gás Natural. *EDUSP/FAPESP*. São Paulo (in Portuguese); 2010.
9. Eletropaulo Metropolitana Eletricidade e Serviços (1990). *A Cidade da Light 1899-1930,* Eletropaulo, São Paulo (in Portuguese).
10. Zmitrowicz W. Obras públicas de engenharia e sua função na estruturação da cidade de São Paulo. *Escola Politécnica da Universidade de São Paulo*, São Paulo (in Portuguese); 1984.
11. Morse R. *Formação Histórica de São Paulo. Da comunidade a metrópole,* s.ed., São Paulo (in Portuguese); 1954.
12. Prefeitura do Município de São Paulo. *Relatório da Gestão Ademar de Barros 1958 -1961 PMSP*, São Paulo (in Portuguese); 1961.
13. Instituto Brasileiro de Geografia e Estatística. Censo Predial. Região Sudeste. *IBGE*, Brasília (in Portuguese); 1970.
14. Prefeitura do Município de São Paulo. *Administrações Regionais,* PMSP; São Paulo (in Portuguese); 1975.
15. Secretaria Municipal de Planejamento. *Diagnóstico regionalizado do município de São Paulo,* SEMPLA, São Paulo (in Portuguese); 1983.
16. Empresa Metropolitana de Planejamento. *Sumário de Dados da Grande São Paulo*, Emplasa, São Paulo (in Portuguese); 1998.
17. Companhia de Gás de São Paulo. *Gás Natural*, Comgás, São Paulo (in Portuguese); 2010.
18. Secretaria Municipal de Planejamento. *Atlas Ambiental*, SEMPLA, São Paulo (in Portuguese); 2006.
19. Massara V.M. O perfil da infra-estrutura no Município de São Paulo e sua relação com as transformações de uso do solo: o centro expandido e a região de São Miguel Paulista. *Escola Politécnica da Universidade de São Paulo*, São Paulo (in Portuguese); 2002.
20. Massara V.M. *A Dinâmica Urbana na Otimização da Infra-Estrutura de Gás Natural.* Instituto de Eletrotécnica e Energia da Universidade de São Paulo, São Paulo (in Portuguese); 2007.
21. Decision Lens. *User's Guide.* New York: Decision Lens; 2006.