

QUALITY EVALUATION CRITERIUM OF HISTORICAL MAPS

LEAL DE MENEZES P.M., MICELI B.S., GODOY V.F.

Federal University of Rio de Janeiro, RIO DE JANEIRO RJ, BRAZIL

ABSTRACT

This work is part of a research undertaken on Historical Cartography and History of Cartography, performed by the Cartography Laboratory, Department of Geography, Federal University of Rio de Janeiro. The main purpose of this paper is to present the methodology developed and applied in assessing the quality of historical maps of the city of Rio de Janeiro, Brazil, in cartographic documents from the mid eighteenth century, when city maps were projected on orthogonal projections and prepared with the help of topography and position astronomy. The methodology is based on the deployment of a network of fifteen control points, determined with differential GPS and a mean error of 2 cm, defining points, distance and angles in a mesh sufficiently rigid in geometric terms. In each historical map we sought to identify the maximum points possible among determined control points. Thus each point mesh allows the development of a network of distances and angles, which, compared among themselves, enable the characterization of two assessment structures.

Initially, we evaluate the internal behavior of the network in relation to the scale of the historical survey. The values of observations concerning the measures established by the graphical scale of the map are worked. It is thus possible to verify the accuracy of the measurements at the time, and conclusions can be inferred about the accuracy of the equipment used at the time.

The second evaluation criterion is established by comparing the linear and angular values between among the different homologous points of the present and historical network, revealing the structural differences between the observations at both times.

The analysis of these criteria enables the evaluation of the internal quality, i.e., the precision of the methods at the time and the results achieved, in relation to the first sets of data, as well as the external precision, i.e. the behavior of the survey performed at the time, in view of the values observed. All values were matched to a coordinate system of UTM Projection and with SAD 69 geodesic system; no dislocations were deemed possible due to time constraints.

For this work four maps were chosen covering the historical city center: Roscio in 1769, D. João in 1812, Neutral Municipality in 1875 and Pereira Passos in 1906.

1 - INTRODUCTION

The arrival of Jesuit priests Domingos Capacci and Diogo Soares in Brazil, appointed by the Portuguese crown in 1730 to carry out surveys and studies to determine precise geographic coordinates, initiated the work of mapping, based on scientific methods with the use of positioning astronomy, as well as tools related to the topography of that period.

One of the first cities mapped in accordance with this methodology was the city of São Sebastião do Rio de Janeiro. All maps previously elaborated during the sixteenth and seventeenth centuries, presented the city according to perspective drawings, which enabled only a qualitative view; though some presented a graphic reference scale, their measures were not reliable.

From 1750 onwards, using new methods and equipment, maps, charts and plans emerged, using the horizontal topographical plan as the projection plan. These maps are diverse and present a chronologic source of information, enabling historical and geographical studies and research, in relation to urban sprawl, changes in urban landscape, works performed, among others.

However, the maps and plans developed until the early twentieth century may be questioned regarding some of the methodologies used for their preparation, which do not directly imply a good quality of the information represented, both as for the accuracy of the maps, and with regard to the representation scale.

Thus, this work aims at presenting a methodology to analyze and obtain information about the quality of the cartographic representation at the time. With this methodology, developed by the Laboratory of Cartography, Department of Geography, Federal University of Rio de Janeiro, applied to historical maps of the city of Rio de Janeiro, Brazil, between mid-eighteenth century until early twentieth century, it was possible to obtain information, which enables the precise internal and external evaluation of these maps.

2 - SOME CONSIDERATIONS ON MEASUREMENT UNITS AND INTERNAL AND EXTERNAL PRECISION.

In the case of Luso-Brazilian ancient cartography, especially in the eighteenth and early nineteenth century, all the measures used were the same from Portugal.

In this research work, considering the period of analyses and comparisons, certainly there are more than two centuries, in which different measurement units were used; these must be made compatible, so we could have the information and results related to the work's precision.

It should also be considered that the work has been conducted at each time by following the availability of methods, methodologies and equipment typical of the time, with their respective accuracies and inaccuracies. Of course, it can be ascertained that instrumental precision is inversely proportional to the instrument's age; that is to say, in principle, the older, the less precise it is, mainly due to deficiencies in construction of equipment then used.

The orientation of the maps, though not having a direct influence on the accuracy of the maps, confounds the user. Maps of the same area, represented by different orientations, in principle have no reason for differences in accuracy.

Regarding the use of a cartographic projection system, it applies only to the 1996 comparative topographic map. On all others, only the existence of adoption of a topographic plan has been verified. However, for the area under consideration, approximately 10 km², there is no need to adopt any projection system.

The greatest difficulties, however, for some of the older maps, namely those that relate to Portuguese units, are in determining the correct scale and in identifying the control points. The decimal metric system was only introduced in Portugal in 1852 (Decree of 12/13/1852). In Brazil, it happened in 1872, when it was regulated by the Imperial Act of 1862. Until this time, the measuring units were many, varying and often confusing.

According to Fortes (1728), the main terrestrial linear measuring units, used by Portuguese engineers in their work, including here surveys and mappings, were the fathoms and rods, which were in turn divided into palms and inches. One could further rely on the league and the nautical mile. The value identified for the Portuguese inch was 2.75 cm.

The values of these measures was as follows:

1 palm = 8 inches

1 foot = 12 inches (1 palm and a half)

1 rod = 40 inches

1 fathom = 80 inches

The league was defined as a part of first-degree meridian arc yielding values of dividers 17, 17.5, 18, 18.75, 19 and 20, establishing its denomination as an 18-league to degree, 20-league to degree. There were also found quotes like old league (that of 18 to degree), legal league (that of 19 to degree) and the common league. Related to the fathoms, there was the 2540 fathom league.

The metric relationship between these measuring units can be observed, according to table I.

Table I - Portuguese linear units of measurement

Measures	Equivalences	Measures in arc	Metric relation
Palm	8 inches		22 cm
Foot	12 inches		33 cm
Rod	40 inches		110,00
Fathom	80 inches		220,00
League		1°/17	6535,94
		1°/17,50	6349,20
		1°/18	6172,83
		1°/18,75	5925,92
		1°/19	5847,95
		1°/20	5555,55

In Brazil, some of these units have undergone variations, and one might quote the fathom, with a value of 10 palms, but regarding the metric system of 2,174 m and the league, defined as 3000 fathoms and corresponding to 6,522.00 m.

Thus, we can establish a view of the units used in the period under consideration. In relation to the representation scales, Manoel de Azevedo Fortes (1792) establishes a series of recommendations for works, fortifications of factories and geographical maps, related to the units of measure at the time.

3 - A SHORT HISTORY OF THE CITY OF RIO DE JANEIRO

The Guanabara Bay, discovered on January 1, 1502, by the expedition of Gonçalo Coelho and Américo Vespúcio of 1501, had practically no colonialist activity during the first half of the sixteenth century. The second half of the sixteenth century was marked by attempts of invasion and colonization by the French, with the expedition of Nicolau Durand de Villegaignon in 1555, founding the Antarctic France with his expedition. Only in 1564, with the expedition of Estácio de Sá, nephew of the Governor General Mem de Sá, under orders of the Portuguese crown to fortify and establish settlements in the area, combats against the French were started, driving them away into the Bay of Rio de Janeiro.

The city of São Sebastião do Rio de Janeiro was founded on March 1, 1565, between the hills of Cara de Cão and Pão de Açúcar, called Cidade Nova (New Town). Only in 1567 the battles came to a close, assuring the Portuguese domain over the entire area of the Guanabara Bay.

At this time there is a transfer of the then New Town, located where Estácio de Sá founded it, to the old town area, located between the four hills surrounding it, as can be seen in Figure 1.



Figure 1 - 1750 Map of the City of Rio de Janeiro, by André Vaz Figueira.

From this core the city starts to expand demographically and economically as of the middle of the first half of the eighteenth century. At that time Rio de Janeiro was already an important regional center, featuring a remarkable economic growth, due to the expansion of mining activities in the Colony, mainly in the Minas Gerais region.

In the nineteenth century, one of the major factors that led to a series of changes to the city occurred just at the beginning of the century, with the transfer of the Portuguese Court to Rio de Janeiro in 1808, with the consequent opening of the ports and trade to friendly nations. The city expands mostly to the north, towards Gamboa and São Cristóvão, where the Royal Family settles down at Quinta da Boa Vista.

Due to the tremendous growth of the movement by sea, the coastline begins to change with the improvement and construction of wharves along the Vallonguinho area with ramps and stairs for access and unloading of vessels, thus virtually the entire port area is changed.

Many projects are developed and the main changes consist of the embankment between the hills of São Bento and the tip of Calabouço.

In the second half of the century there is the construction of the quay along the Vallonguinho as well as in the vicinity of Morro de São Bento. The city also expands westward, toward the current neighborhoods of Flamengo and Botafogo, and the current historical center of Rio de Janeiro is outlined.

In the twentieth century, there are of course the greatest transformations, especially during the administration of Pereira Passos (1903/1906), of which one can mention the earthwork throughout the entire area of the Vallonguinho, the opening of Central Avenue (Rio Branco), the urbanization of the south coastline, the construction of the Beira Mar Avenue, and the earthwork of the fringe of Morro da Glória, and the dismantling of Morro José Dias, embanking the marsh nearby.

The subsequent governments, especially Carlos Sampaio, Henrique Dodsworth and Carlos Lacerda, conclude the urban reform, resulting in the razing of Morro do Castelo, the opening and urbanization of avenues, and the Flamengo and Calabouço earthwork.

Figure 2 shows the development from the eighteenth century to the end of the twentieth century.



Figure 2 - Superposition of maps from the 18th century until the 20th century.

4 - METHODOLOGY

The research herein was based entirely on the comparative study of distances and angles defined by a network of control points, chosen in locations that could be identified in the universe of maps, charts and topographical plans of the city of Rio de Janeiro, elaborated from the 18th century onwards.

Initially, fifteen points for easy identification, named control points, were selected on sheets 287A, B and C, which are part of the 1996 chart in 1:10000 scale of the municipality of Rio de Janeiro, by Instituto Pereira Passos, Rio de Janeiro City Hall. The following criteria were used to define the points:

- easy identification on the current topographical map;
- easy identification in the field and occupation to determine the coordinates;
- easy identification on the historical maps to be analyzed.

The fifteen points do not necessarily appear on all maps analyzed, but a minimum set of eight mandatory points has been established on all maps, encompassing the core of the center of Rio de Janeiro.

Identified on the topographic map, these points have their coordinates obtained through a campaign for DGPS determination, making use of an ASTECH crawler of a frequency.

The occupied base station is situated in a location roughly in the center of the study area, with a maximum distance of approximately 2500 m between the farthest points. Thus, a precision approximately equal to ± 3 cm was secured at each given point.

The points were determined in the coordinate system in the UTM projection and in the geodesic WGS84 system, being transformed to the SAD69 geodesic system of the 1996 topographic map for compatibility purposes.

The need to apply the scale factor of the UTM projection at the distances obtained was verified. The scale factor for the area, 1.000023, was calculated and we found that there would not be a significant influence on its application. Thus we worked with the distances and angles calculated directly with the UTM projection coordinates.

Table II shows the list of control points, as well as their coordinates, already on UTM projection.

Table II – List of control point coordinates

Ponto	Coord E SAD	Coord N SAD
1 Mosteiro de São Bento	686981,2990	7466767,4390
2 Igr N S Bonsucesso	687710,3300	7465721,8800
3 Palácio Episcopal	686452,0030	7466498,4860
4 Igr N S da Glória	687172,7860	7464062,9920
5 Igr Santa cruz dos Militares	687147,6510	7466178,9040
6 Cap S. Francisco da Prainha	686352,9060	7466669,2920
7 Pta Esq Emida Igr Sta Luzia	687477,8440	7465371,4990
8 Cap N S Livramento	685581,7330	7466649,5030
9 Ponta Esq Aqueduto	686651,6710	7464857,1856
10 Capela Sta Efigênia	686427,5070	7465816,1020
11 Conv Sto Antônio	686605,7500	7465651,5100
12 Pta Esq Min Ex	685810,1793	7466104,1612
13 Chafariz M Valentim	687345,8161	7466138,0221
14 Pta Dir Igr S. José	687304,3635	7465938,1039
15 Pt Dir Igr NS Carmo Ant Sé	687194,5080	7466069,9761

Figure 3 shows the layout of control points and network.



Figure 3 - arrangement of points and network control.

The distances were calculated between each two points, setting up a matrix of actual distances. A spreadsheet was also assembled, providing the angle between any two directions, given the large number of angles that the network presents.

4.1 - Maps Analyzed

The choice of maps for the completion of the work was determined by the establishment of the following criteria:

- Maps that covered the period between the eighteenth century and early twentieth century, all in orthogonal projection;
- If there was the possibility of identifying the highest possible number of control points, with low uncertainty;
- Presence of a graphic scale or the possibility of determining the scale;
- Scanning in a resolution compatible with the research, higher than 300 dpi.

Thus the following maps were chosen for the job:

- Plan of the city of Rio de Janeiro, capital of studies in Brazil - Surveyed for the Sergeant Major of Engineers, 1769;
- Plan of the city of Rio de Janeiro in 1812 - National Library of Rio de Janeiro;
- Sheet F2-MAP 347-F4 of the 1875 chart of Rio de Janeiro 1:10000 – National Archive;
- 1906 Plant in 1:10000 scale of the Rio de Janeiro City Hall, Pereira Passos Administration.

The 1769 plant has a petipé (graphic scale) of 400 fathoms, divided into 4 parts of 100 fathoms, being one of the divisions subdivided in two of 50 fathoms each.

According to the time of preparation, one can assume that the value of the fathom is 2.2 m, this being the value adopted in the work.

The 1812 map presents a graphic scale at 300 fathoms, divided into 10 fathoms and also in meters, corresponding to 660 meters.

The sheet of the 1875 chart does not contain scale indications and the 1906 sheet only shows the numerical scale. In this case the analysis performed was developed only on external accuracy by comparing the linear measures between each point, angle values, checking the difference between the values of the base map and history.

4.2 - Reconstruction of control network on the maps analyzed.

The reconstruction of the network was accomplished through the following steps:

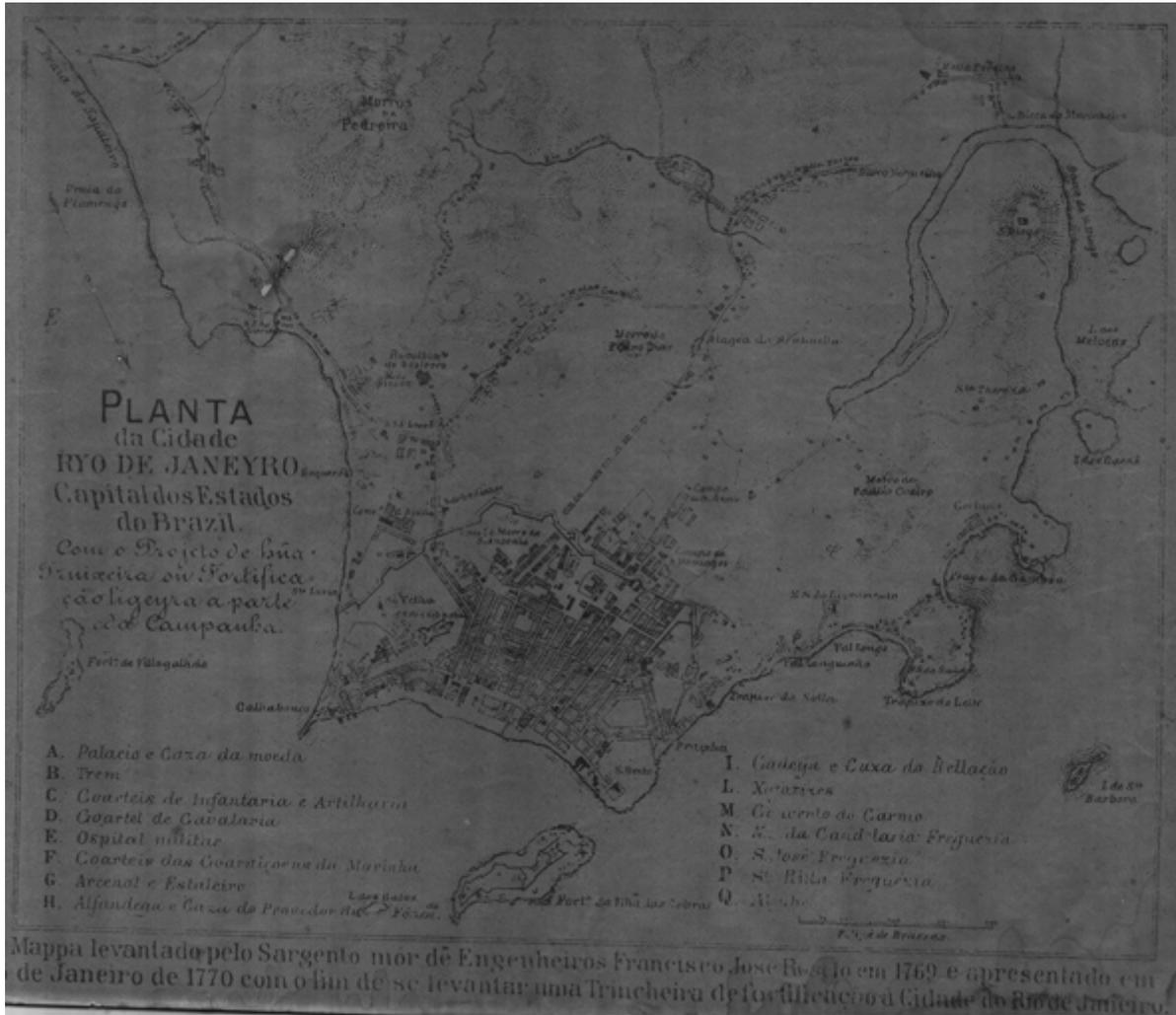
- Identification of control points and certification of their positioning on the maps.
- Materialization of points and lines of the networks with the calculation of distances, transformed to the comparison units (meters).

Equipped with the mounted networks, table III presents the number of points and lines of each one of them:

Table III - Number of Control Points by map

Map	Number of Points	Number of Lines	Number of coincident points
1769	10	45	9
1812	9	36	9
1875	11	55	9
1906	10	45	9

Figures 4, 5, 6 and 7 show the network and the control points that were used for the accuracy analysis.



Mappa levantado pelo Sargento mor de Engenheiros Francisco José de Barros em 1769 e apresentado em Rio de Janeiro de 1770 com o fim de se levantar uma Trincheira de fortificação a Cidade do Rio de Janeiro.

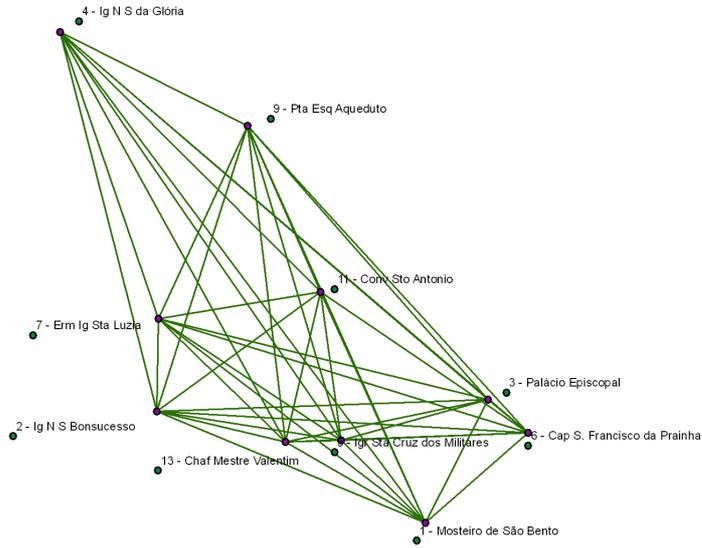
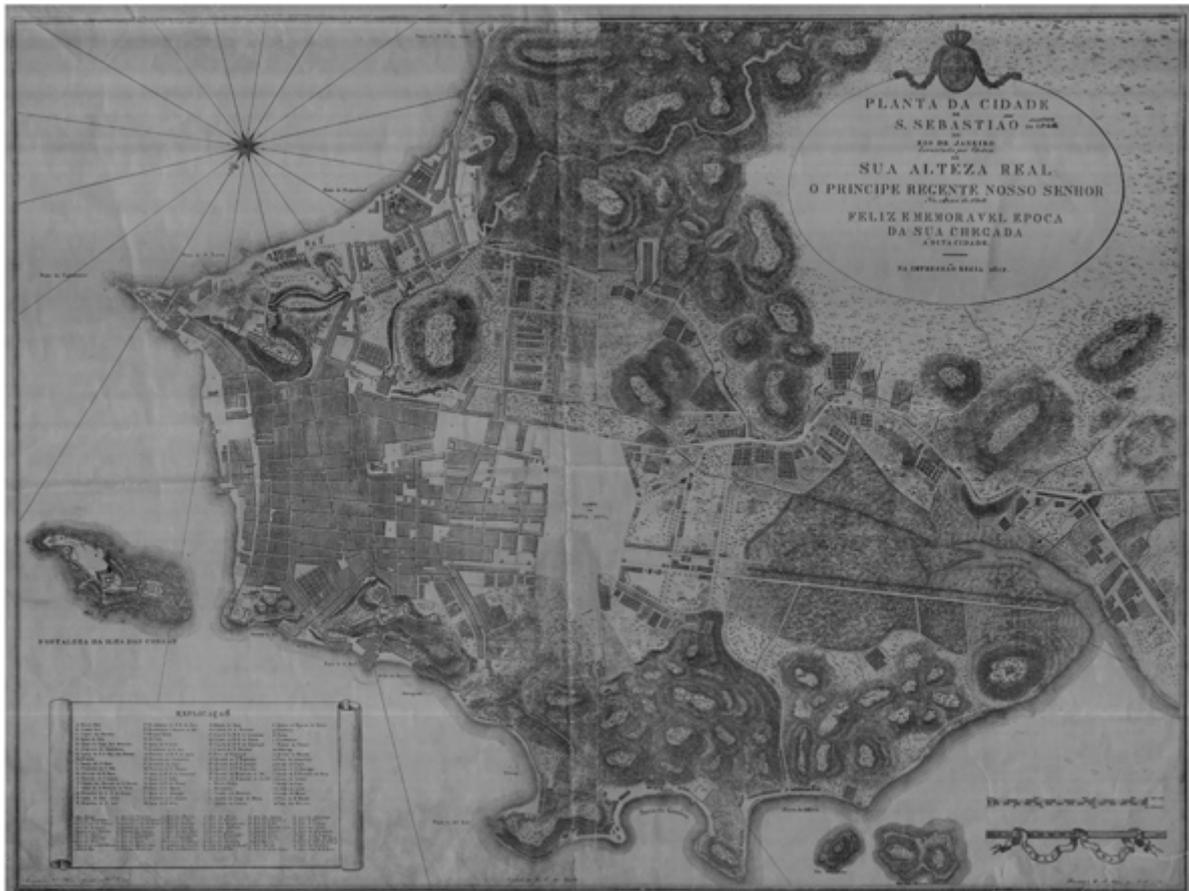


Figure 4 – 1769 map and Network and control points



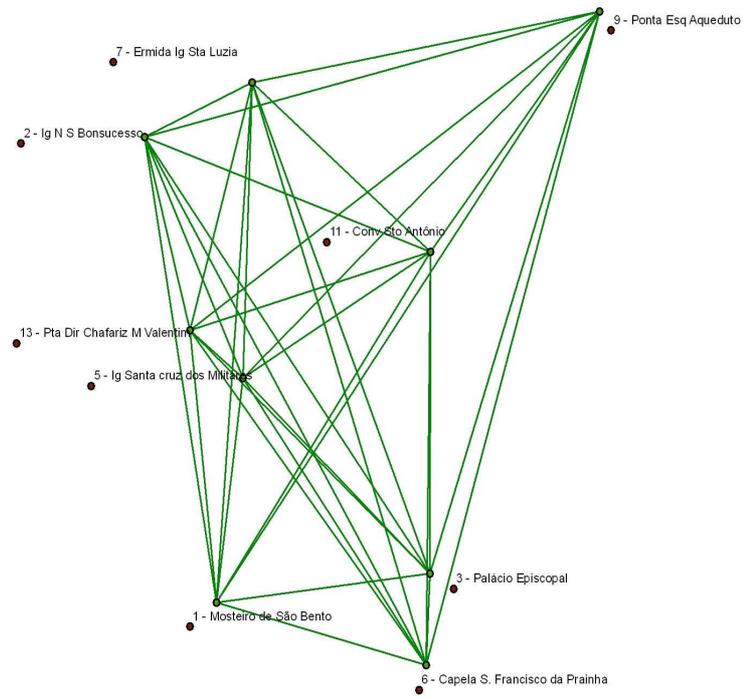


Figure 5 – Network and control points of 1812 map



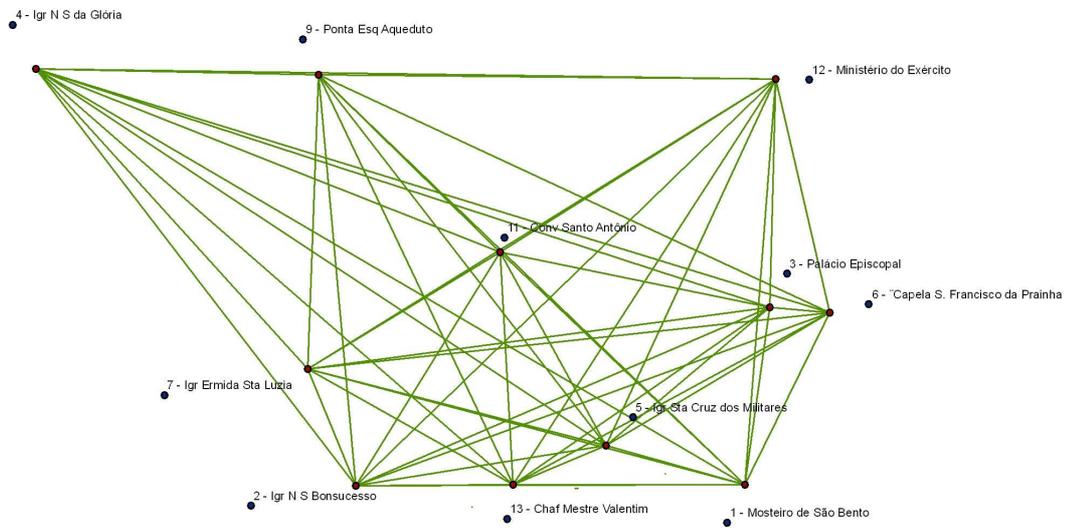


Figure 7 – Network and control points of 1906 map

The internal accuracy of the maps was verified by comparison with the graphic scales presented on the map. The comparison values were determined and the mean and standard deviation calculated for differences between the several linear and angular measures submitted to the comparative process.

The external precision was defined by comparing the differences between the values measured with the 1996 chart, laying down the same calculations of measures and standard deviations.

5 - RESULTS

Only some of the research results will be presented here. The remaining results will be available on the website of the Laboratory of Cartography: [HTTP://geocart.igeo.ufrj.br](http://geocart.igeo.ufrj.br).

5.1- 1769 Map

Table IV shows the linear, angular values and their respective differences. Units in meters.

Table IV – Differences between the real and calculated distances.

Pt. Base	to	Dig Map Dist	Fathom Dist	Calc Dist	Real dist	Difference
Mosteiro de São Bento	Ig N. S. Bonsucesso	5,21	574,38	1263,66	1274,63	10,97
	Palácio Episcopal	2,51	277,05	609,51	593,71	-15,80
	Ig N. S. de Glória	11,11	1224,37	2694,71	2711,22	16,50
	Ig Santa cruz dos Militares	2,14	235,89	518,30	511,89	-6,29
	Cap. S. Francisco de Prain	2,47	272,89	599,92	636,01	36,09
	Ermida Ig Sta. Luzia Pta. E.	6,03	670,53	1475,17	1481,62	6,46
	Ponte Esq. Aqueduto	7,91	872,09	1918,59	1938,48	19,90
	Conv. Sto. Antônio	4,61	508,75	1119,27	1129,65	10,39
	Pta. Dir. Chafariz. M. Valentin	2,93	322,65	709,86	727,35	17,49
NS Bonsucesso	Palácio Episcopal	5,98	660,00	1452,00	1476,68	24,69
	Ig N. S. de Glória	7,13	785,24	1729,72	1743,81	14,09
	Ig Santa cruz dos Militares	3,36	371,07	816,36	724,90	-91,46
	Cap. S. Francisco de Prain	6,71	739,81	1627,59	1658,36	27,76
	Ermida Ig Sta. Luzia Pta. E.	1,69	186,18	409,60	420,90	10,90
	Ponte Esq. Aqueduto	5,46	601,36	1324,10	1366,91	42,81
	Conv. Sto. Antônio	3,67	405,22	891,48	907,90	16,02
Pta. Dir. Chafariz. M. Valentin	2,38	262,63	577,79	553,21	-24,58	
Pt. Esq. Aqueduto	Palácio Episcopal	6,61	729,27	1604,40	1653,40	49,00
	Ig N. S. de Glória	3,80	418,78	921,32	949,90	28,58
	Ig Santa cruz dos Militares	5,97	655,81	1448,94	1411,71	-37,22
	Cap. S. Francisco de Prain	7,54	831,37	1829,01	1836,57	7,56
	Ermida Ig Sta. Luzia Pta. E.	3,87	426,60	938,52	973,18	34,66
	Conv. Sto. Antônio	3,29	363,35	799,37	809,13	9,76
	Pta. Dir. Chafariz. M. Valentin	5,80	639,36	1406,60	1456,64	50,24
Ig N. S. Bonsucesso	5,46	601,36	1324,10	1366,91	42,81	

This map was considered possible to obtain the greatest discrepancies, both in regard to linear measures, as for the angular ones. There were quite high differences, such as, for example, the Igreja da Santa Cruz dos Militares (Church of the Holy Cross of the Army).

Errors of up to ± 20 m were considered reasonable, given the characteristics of the map. It was found, however, that the relations between the values observed and those of comparison differed only in the third decimal place.

The average error found in the distances analyzed was 16.11 m with a standard deviation of ± 34.26 m.

Similar tables were developed to all others maps analyzed.

5.2 – 1812 Chart

The values obtained were significantly smaller, although quite significant errors still arose.

The average error found in the distances analyzed was 33.49 m with a standard deviation of ± 30.95 m.

5.3 - 1875 Chart and 1906 Chart

The analysis of the results of these two sheets is presented as one due to the process used, which was the same, considering that on the first sheet there was no indication of scale and on the second, only the associated numerical scale of 1: 10 000.

A scaling factor was calculated for each sheet, choosing a distance that would leave no doubts as to the placement of the control points, and all other distances were determined by applying the specified value, multiplied by the calculated factor.

The base distance chosen was the one determined between the Monastery of São Bento and the Episcopal Palace.

The 1875 sheet showed the average error value of -13.64 m, and standard deviation of ± 35.82 . The 1906 sheet presented an average error of -9.12 m and standard deviation of ± 45.09 .

One point presented too large an error, leading to the conclusion of a possible misidentification, in view of the systematicity of the error in the same place.

These sheets presented the best performance, showing that both assessment processes and those of map construction have a close connection in precision and quality.

6 - CONCLUSIONS

The methodology presented proved to be competent and robust in the analyses performed. In the case of a test, we can affirm that it reached the proposed objectives.

However, its application can be improved through the following proposals:

- consolidating the comparative analysis in relation to the angular values of the network;
- improving the identification of control points on the maps analyzed considering the occurrence of possible identification errors;
- defining a linear and angular distortion factor for each of the maps studied.

Thus the methodology will be effective and efficient for the proposed objectives.

Also, the methodology can be extended to other locations, which will consolidate it permanently.

BIBLIOGRAPHIC REFERENCES

MARQUES, M.S. – Cartografia Antiga: Tabela de equivalências – Cálculo de Escalas de Valores de Coordenadas Geográficas. Publicações Técnicas. Ministério da Cultura, Lisbon, 1931.

FORTES, M.A. – O Engenheiro Português, Tomo Primeiro. Lisbon, 1728.

BARREIROS, E. C.; Atlas da Evolução Urbana da Cidade do Rio de Janeiro; Instituto Histórico e Geográfico Brasileiro, Rio de Janeiro, 1965

ABREU, M. de A., A Evolução Urbana do Rio de Janeiro, Rio de Janeiro, IPLANRIO, 1987

CENTRO DE ARQUITETURA E URBANISMO DO RIO DE JANEIRO, Do Cosmógrafo ao Satélite: Mapas da Cidade do Rio de Janeiro, UFRJ, FUJB, 2000

FUNDREM, Fundação do Desenvolvimento da Região Metropolitana, Mapeamento 1: 10 000, 1975

IPP, Instituto Pereira Passos, Mapeamento Cadastral do Rio de Janeiro, 1998-2004

LAMEGO, A. R., O Homem e a Guanabara, IBGE – Conselho Nacional de Geografia, 1964

MENEZES, P. M. L., Notas de Aula de Cartografia e Cartografia Temática, Não publicadas, Curso de Graduação em Geografia, Dep de Geografia, UFRJ, Rio de Janeiro, RJ. 1996.

MENEZES, P. M. L., Notas de Aula de Cartografia Temática, Não publicadas, Curso de Graduação em Geografia, Dep de Geografia, UFRJ, Rio de Janeiro, RJ. 1996.

MENEZES, P. M. L. Aquisição, Tratamento e Armazenamento de Cartas Topográficas Digitalizadas, Tese de Mestrado, IME, RJ. 155 pp. 1987.

OLIVEIRA, C., Dicionário Cartográfico, IBGE, Rio de Janeiro, RJ. 1980.

SARTHOU, C., Passado e Presente da Baía de Guanabara, Livraria Freitas Bastos S.^a, Rio de Janeiro, 1964