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Colonial Cities of the Americas

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Naturally Artificial: Continuity and Change in the Street Network of Rio de Janeiro

Nature and historical landmarks complement the built environment in contemporary Rio de Janeiro. The Bay, the topography, and the vegetation blend together with Baroque churches, high-rise buildings, and even a repurposed aqueduct in the city's most famous postcards. Throughout Rio's history, these natural and cultural elements have both constrained urbanization and been surpassed by it. And, as Rio's function and importance to Brazil evolved significantly from a *feitoria* to the colonial capital, the built environment was changed to reflect shifts of power, economic function, and cultural values. The urban expansion of Rio de Janeiro was a process of surpassing and responding to nature and culture in a way to artificially repurpose the city's built environment according to the current geographies of power since its colonial form.

While there are many aspects of the city's built environment illustrating this process, I focus on the evolution of Rio's street network–the collection of walkable road segments and street intersections. Network analysis in urban areas was popularized among urban planning researchers in recent years due to its scalability and universality as a means to systematically study urban morphology and mobility.[1] From a historical perspective, these networks illuminate relationships of cultural and physical dominance established by the European colonial powers in the Americas. The Spanish urban grid–the *traza*–embodies some of the civility and racial supremacy principles guiding town formation in Latin America,[2] and the gradual expansion of New York City by the Dutch and then the British can be tracked by a careful analysis of the juxtaposed gridded and organic street patterns[3] for example. Through this paper, I examine how changes to the colonial

[1] Boeing, "OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks"
[2] Kagan, *Urban Images of the Hispanic World*, p.33
[3] Lecture notes

street network of Rio de Janeiro reproduce the current geographies of power.

I georeferenced historical maps and used the information available at ImagineRio to collect historical data on Rio de Janeiro, and the OSMnx Python library to collect data on contemporary Rio de Janeiro and perform network analysis. ImagineRio is a searchable digital atlas that illustrates the social and urban evolution of Rio de Janeiro, developed by a research team from the Spatial Studies Lab at Rice University. I draw upon three historical maps, shown in figures 1 to 3: *Planta da cidade de São Sebastião do Rio de Janeiro e suas fortificações* (1713), *Planta da cidade de S. Sebastião do Rio de Janeiro* (1775), and *Planta da Cidade de São Sebastião do Rio de Janeiro* (1808). I georeference these maps on the current Rio de Janeiro street layout and digitize the streets at each of these three years. OSMnx is a Python package to download geospatial data from OpenStreetMap and process real-world street layouts as topologically-sane networks, which allows for fruitful analysis.[4] Methodology is further detailed on the Appendix. I now analyze the meaning of patterns observed in the streets of Rio in 1713, 1775, 1808, and 2021 sequentially.

Fig. 1. Map of Rio from 1713, focusing on the fortifications of the town. The wall is labeled as S.

[4] Boeing, "OSMnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks"

Fig. 2. Map of Rio from 1775. Topography lines are shown to represent the mountains. Few remains of the wall are noted in the map.

Fig. 3. Map of Rio from 1808, at the end of the colonial period..

The 1713 street network, as shown in Figure 4, reflects the compact form of the colonial town and the centrality of the portuary function. The longest streets were oriented roughly North-South, following the shoreline. The colonial city was constrained by two mountains in these

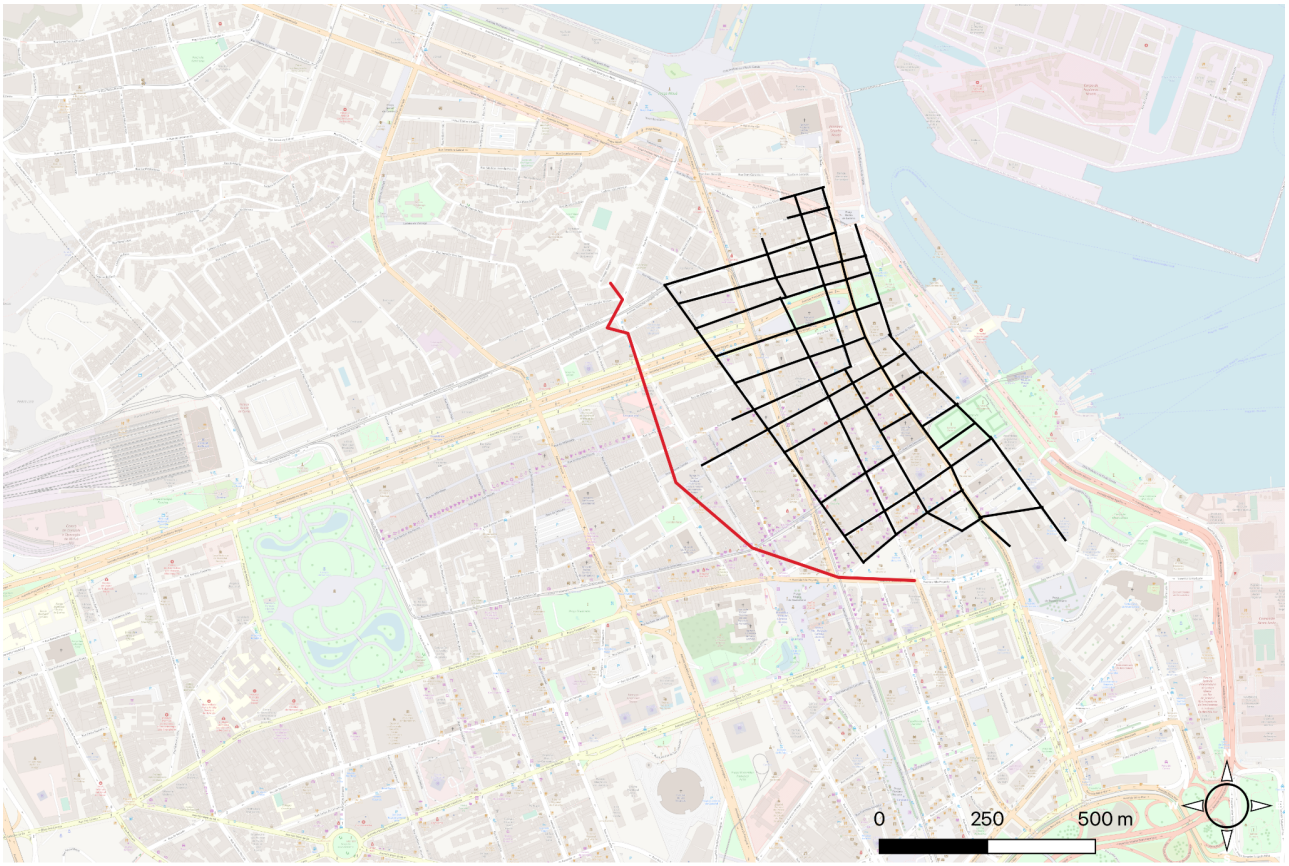

Fig. 4. Digitized street network from 1713. The city's wall is represented in red, also digitized from the same map.

directions–Morro da Conceição and Morro do Castelo–and a wall to the West. This layout maximized the interaction between the city and the port. Very interesting is the irregularity of the street lines. While the 90 degrees grid was often enforced in Spanish cities, the grid of colonial Rio was more ad hoc and, especially in the coastal streets, and seemed to adapt to the topography of the city. This is a common trait of Portuguese town planning in the Americas. Brazilian Historian Sergio Buarque de Holanda writes in his 1936 work *Roots of Brazil* that the Portuguese "lacked the pronounced tendency toward that ascetic rigidity" of the Spanish, and the "odd way in which the streets and dwellings of our cities were often arranged, when compared to those of Spanish America, undoubtedly reflects such an aversion to order".[5] This idea of the Portuguese colonizer as a lax and practical urban planner–although in many aspects more literary than historical–agrees with the street network of 1713 colonial Rio. The decision to keep the city closely aligned with the

[5] Holanda, *Roots of Brazil,* p.80

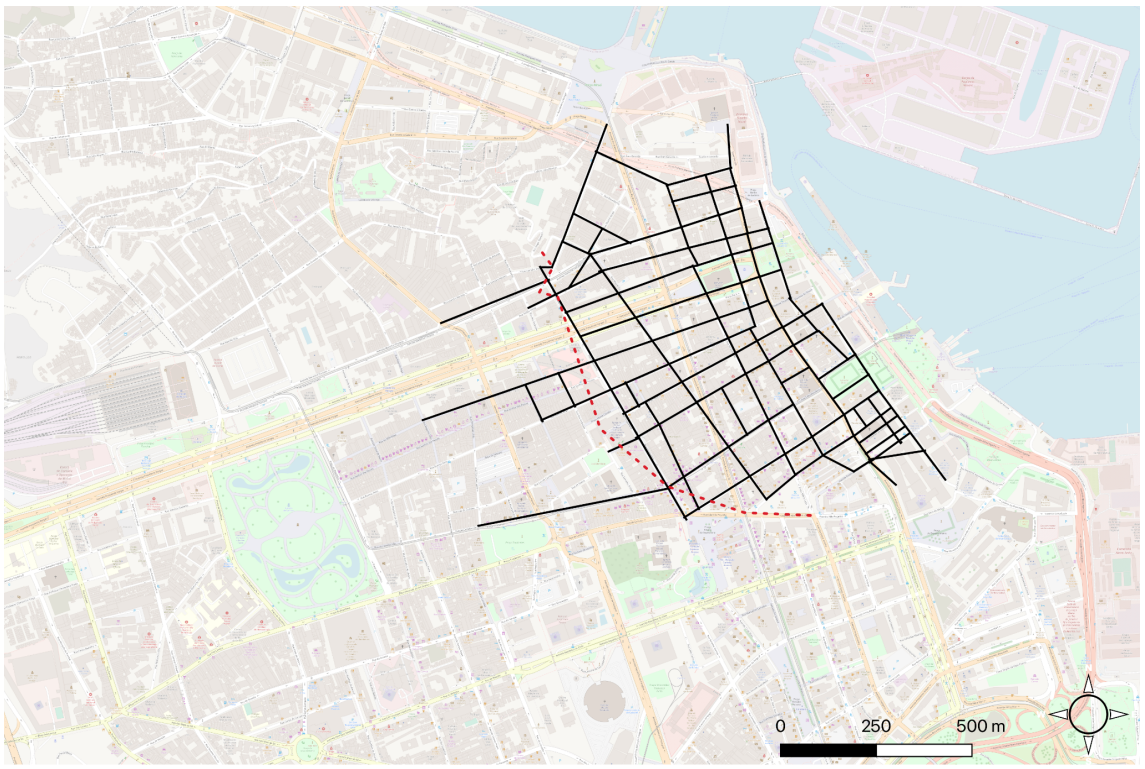

Fig. 5. Digitized street network from 1775. The East-West streets are extended away from the port and cross the line of the former wall (dashed line).

bay highlights the Portuguese's practical view of Rio, a city whose focal point should be the port. The earliest street network of Rio followed the topography, buildings, and function rather than serving as a blank canvas for the rest of the built environment.

As the city grew quickly in importance and population, the street network replicated itself in all places where it was possible. Figure 5 shows a digitized street network following a 1775 plant of Rio de Janeiro–a few years after the town was promoted to colonial capital, in 1763. The street network now fills the coastal region surrounded by the two mountains. A new row of city blocks appears West of the city; their non-parallel boundaries mirror the irregularity of the 1713 network. These blocks are supported by newly appearing axes of expansion: streets perpendicular to the Bay which cross the fading colonial wall. While many formerly-walled cities in America such as Lima and Montreal have wider roads reminiscent of their fortifications, the expansion of Rio only very loosely follows the trace of the colonial wall. In the 1775 street network, natural boundaries–Morro do Castelo, Morro da Conceição, and the Bay–prove themselves superior to the artificial

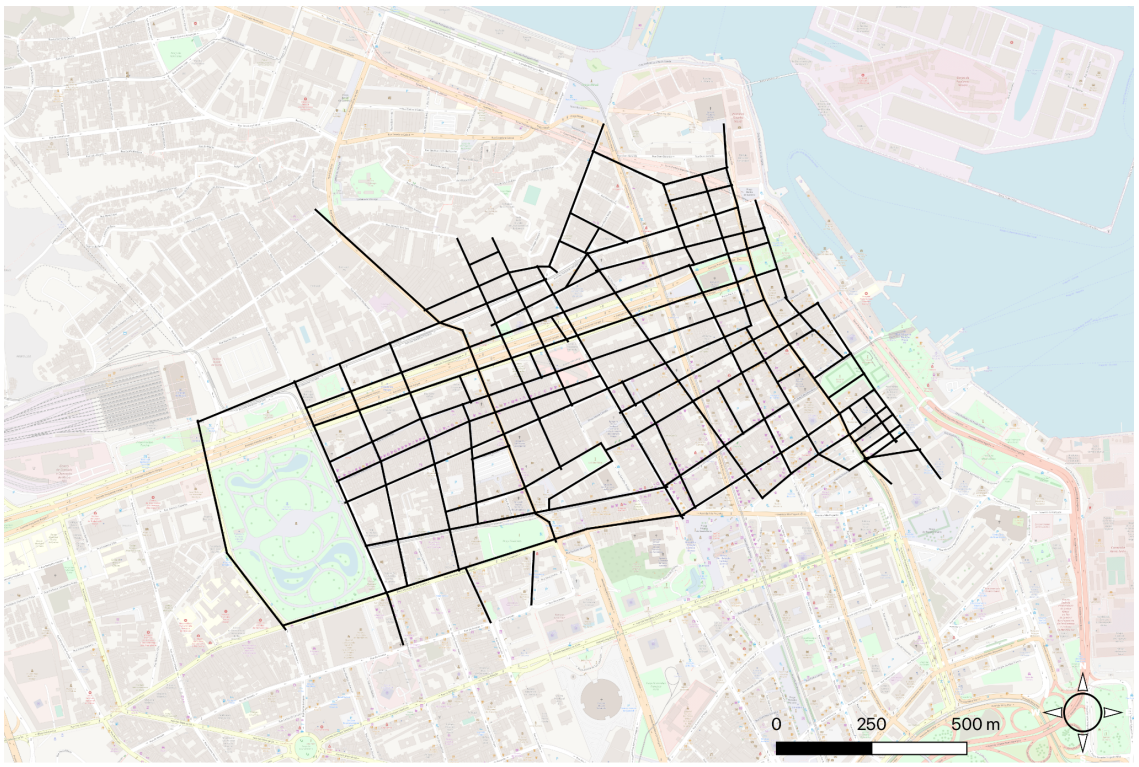

Fig. 6. Digitized street network from 1808. The city expands perpendicular to the sea, while preserving the colonial grid. Some signs of outwards expansion appear.

boundary–the wall–in limiting urban expansion.

In 1808, as the Brazilian colonial period was coming to an end, the street network continued the 1775 project of urban expansion and reinforced the orientation of Rio perpendicular to the Bay. As it can be seen in Figure 6, the East-West roads were prolonged until they reached Campo de Santana–a sort of town's commons or park, used first for pasture and later for public leisure. These prolonged roads are mostly straight, but frequent bends suggest that once again the expansion was organic and practical rather than an abstract appraisal of a rectilinear street network. They formed clear axes through which people, merchants, and goods could be transported from the port inland. Although flipped, the built environment of Rio was still relatively compact, framed by the Bay and the Campo along one axis and embracing the two mountains North and South. The street network of Rio at the end of the colonial period was submissive to the town's natural barriers.

Such submission seems absent in the contemporary street network, shown in Figure 7, as a consequence of twentieth century urban renewal projects. The demolition of Morro do Castelo, in

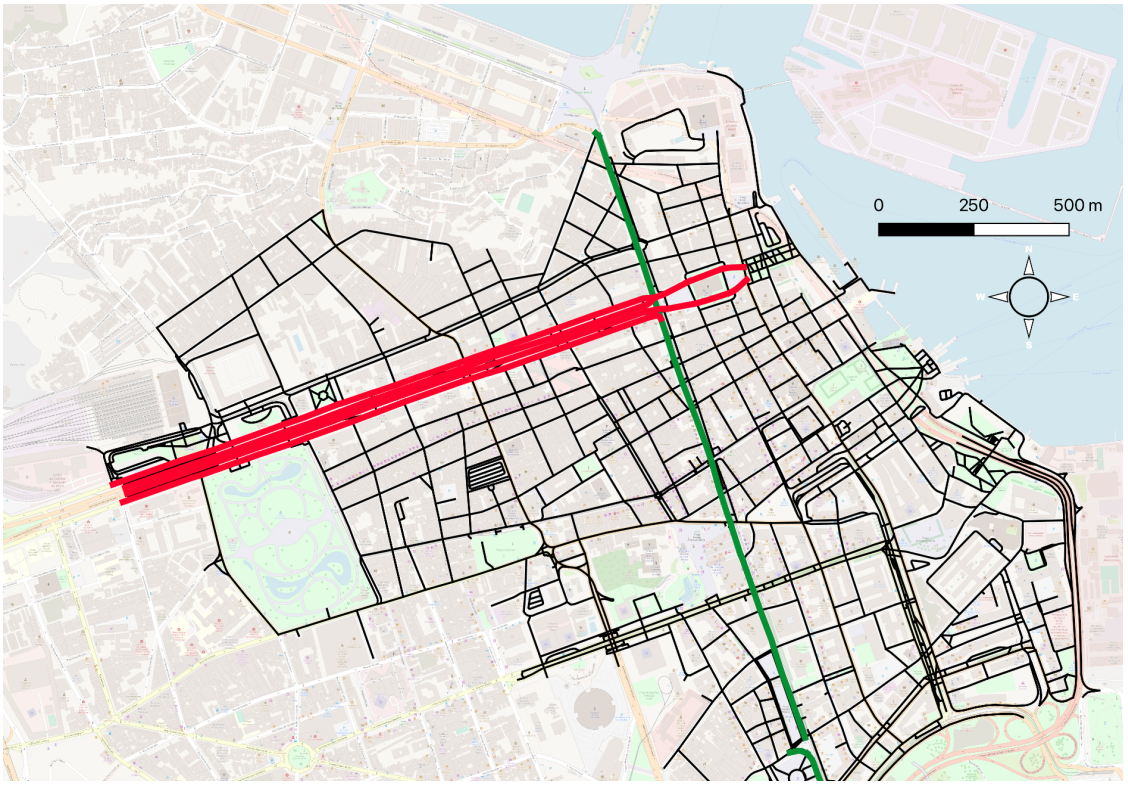

Fig. 7. Contemporary street network collected from OpenStreetMap. Av. Presidente Vargas is highlighted in red and Av. Rio Branco is highlighted in green.

1920, allowed the city to expand to the South, and the expansion of the shoreline with landfill contributed to the densification of streets in the colonial port.[6] These artificial manipulations of the natural environment were accompanied by artificial manipulations of the street network itself. The Central Avenue (now called Rio Branco) was built in 1905 by mayor Pereira Passos to be a Hausmann-like promenade of Brazil, representing a–very physical–rupture with Rio's colonial past and a celebration of the rising republic.[7] As seen on the map, the avenue cuts through the core of the colonial street network. Its disrespect to the pre-existing streets caused the demolition of many historic buildings. To assert the superiority of the Republican order, the so-far enduring colonial street layout was replaced by an unapologetically straight line, ironically much in the fashion of aforementioned Spanish colonial urban planning.

While Rio Branco was the new center of the town, Presidente Vargas Avenue was the new

[6] Simas, *O Desmonte do Morro do Castelo*
[7] Pimentel, *Rio Branco*

major transportation axis of Rio.[8] Finished in 1944 during the Estado Novo dictatorship, the avenue was an even more ambitious and controversial project than Avenida Central. Presidente Vargas would run East-West, turning an entire row of city blocks into four traffic lanes. The destruction caused by Avenida Presidente Vargas included the demolition of numerous dwellings, a public square tied to the birth of Samba, and one of the first baroque-style churches in Rio. These symbols of the colonial order were also being replaced by a new geography of power, now reinforcing technology and mobility. However, while Central Avenue and Presidente Vargas Avenue are iconoclastic, they also reinforce the dichotomy of the late colonial street network of Rio: a city whose center is close to the Bay, but whose only possible axis of expansion is orthogonal to it.

And, although the early colonial street network was compact and aligned to the shore, this axis of expansion has existed throughout the entire colonial period. I used the digitized street networks of colonial Rio to build a rose diagram for each of the maps, shown in Figure 8. The East-West street segments are the most frequent in all instances. This in part occurs due to the parallelism of these streets when compared to the North-South roads, which point at times to Northeast and at times to Northwest. Together, the sturdy and imponent “expansion axes” are more significant than the fragile and irregular main streets of the early colonial town. Comparing the rose diagram of 1775 and 1808, we notice how the North-South roads shrink in importance when compared to the expansion axes, as those have been prolonged. And, in contemporary Rio–when the increased capillarity of the street network fills the rose in many less significant directions–the expansion axis is not even shifted, since Avenida Presidente Vargas follows the direction of pre-existing streets; the North-South major direction shifts only slightly North, influenced probably by the construction of Avenida Central. Therefore, although urban renewal projects in Republican Brazil claimed to reject the colonial built environment and its cultural values, they artificially reinforced a street orientation that had been latent yet present since the early colonial period.

[8] Pimentel, *Avenida Presidente Vargas*

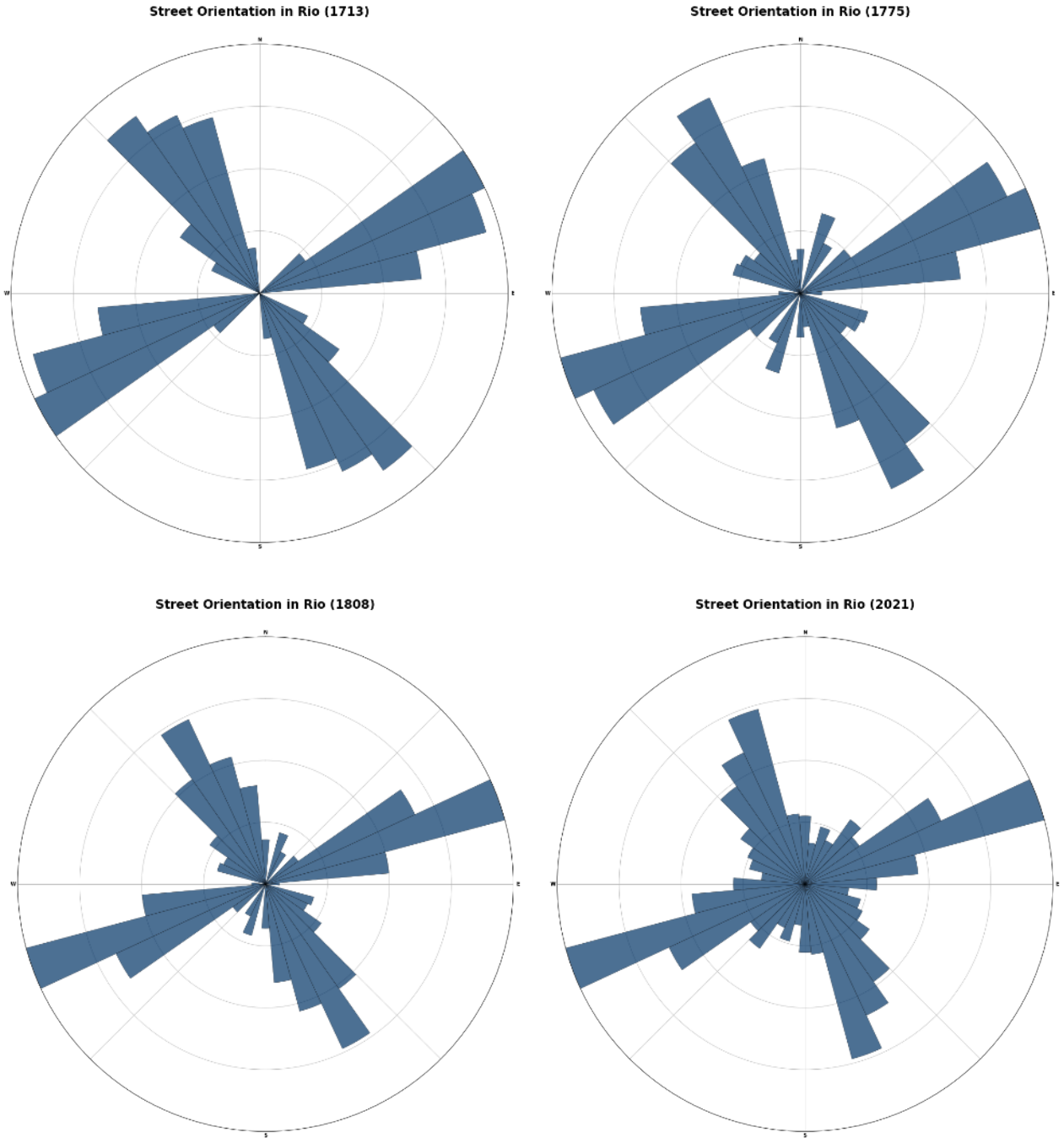

Fig. 8. Rose diagrams for the street networks of Rio in 1713, 1775, 1808, and 2021. The height (radius) of the bars corresponds to the weighted frequency–according to street length–of street segments pointing in a particular direction. For example, all street networks have most "unit meters of street" pointing in the SWW direction. Each bar corresponds to an interval of 9 degrees.

The evolution of Rio's street network relies on an increasing pattern of intentionality. The early colonial town seems to reflect the–perhaps anecdotal–lax and conforming urban planning

guidelines of the Portuguese colonizers, keeping itself flat along the port to enforce Rio's main urban function. As time passes, the expansion is enforced by nature, yet artificially flips the city's orientation according to an axis orthogonal to the Bay. Finally, with the 20th century reforms, symbols of the colonial order are very intentionally replaced by symbols of logic and modernity, while nature is surpassed by technological advancement. But this Republican iconoclasm is paradoxically only successful because it, in a sense, relied on two pre-existing urban patterns: the centrality of the portuary region and its orthogonal axes of expansion. Change in the street network of Rio, then, was dependent upon continuity. Colonial Rio, in this sense, is strikingly resilient. Just like the rocks of Morro do Castelo continue to be part of the city as landfill or like the Church of Candelária stands imponent amidst the busy traffic of Presidente Vargas, no ascetic rigidity was capable to fully change the street network of Rio de Janeiro.

Appendix: Methodological Remarks

Georeferencing: To georeference the maps I used QGIS. I added support points to the map and then used a linear polynomial transformation.

Digitization: To standardize the digitization, I used the current street network as a ground truth and then searched for streets that were already present in the georeferenced historical map. That is, if a historical road loosely followed a contemporary road, I considered it to follow exactly the contemporary road. This process imposes a bias towards continuity: some streets appear to be more curved and irregular on the historical map than on my digitization, for example. I decided upon this methodology because I am concerned about large-scale changes in the street network of Rio. I also recognize that my own georeferencing skills may not align the map perfectly with the geography and these maps were produced with often imprecise measurements and representations of reality.

Whenever a street had significant discrepancies from the current network, I used ImagineRio's own layer of digitized streets–unfortunately not yet an open access resource–as a visual aid. The ImagineRio research team has supplemented their digitization process with more accurate georeferencing, juxtaposition of several historical maps, and supporting historical research. Therefore in many cases they considered a historical road to follow a current road, even if it seemed odd according to my georeferenced map, I took their findings as the ground truth.

Contemporary Street Network: To collect the contemporary street network I used OSMnx. The tool downloads data from Open Street Maps and converts it to a network form. I filtered the streets corresponding to the neighborhood "Centro" (Downtown). I then proceeded to remove private and semi-private roads (according to the OSM tag), which essentially corresponded to parking garages. I also manually removed segments corresponding to bus stations, since they included convoluted roundabouts and loops which would influence the orientation calculation.

Rose Diagrams: The rose diagram I produce is adapted from a publication by Geoff Boeing[9] and incorporated into OSMnx. This type of plot, often called a polar histogram, displays the distribution of directional data. To produce it, I begin by "exploding" the street network shapefiles in QGIS: this tool will convert every polyline to a sequence of strictly straight line segments. Then, using the field calculator in QGIS, I compute the length and the bearings of each of these segments. The bearings–angles from the Northern direction–can be computed using the angle tools in QGIS.

The rose diagrams take as input the length and the bearings of each segment and weight the bearings according to segment length. The idea is that small segments should not contribute as much to the diagram as a major avenue. Therefore, each angle is repeated according to the length of the street so that every unit meter has a bearing associated with it. Then the circle is divided in bins (I used 40 bins so that every bin corresponds to a 9 degree interval) and all of these unit meters are placed in their respective bins. The final histogram is normalized so that the radius of the most prominent bin is always 1 and all other radii are relative to it.

[9] Boeing, *Off the Grid… and Back Again?*

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