AN ANALYSIS OF TERESINA-TIMON URBAN SYSTEM IN THE SOCIAL LOGIC OF SPACE PERSPECTIVE

MARIANA ALVES ADÃO; VALÉRIO AUGUSTO SOARES DE MEDEIROS; FREDÉRICO ROSA BORGES DE HOLANDA

ABSTRACT
Cities are a magnet for people and their center is a physical representation of the political and economic power of a society. Downtowns are places where objects and ideas converge, also acting as a balance for the urban structure organization: they attract flows and uses, presenting higher levels of vitality. The city of Teresina, in the state of Piauí (Brazil), has been the target of several projects intending to increase the efficiency of its urban physical space. The settlement, however, experience an urban sprawl process which results in a poor general connectivity scenario, high levels of urban voids and emergence of more distant neighborhoods far away from downtown. The effects are pronounced in mobility, generating direct and indirect impacts on the costs of transportation, housing/land and food: the quality of life progressively is reduced. Besides that, the proximity between Teresina and Timon, in the state of Maranhão, generates a complex dynamic that must be taken into account in any urban planning action. Based on these premises, the paper analysis the configuration of Teresina-Timon urban system from the point of view of Space Syntax approach, observing the urban expansion along the period 2010-2018, as well as analyses the subsystems, based on the administrative division. The city center, which belongs to the northern administrative region, is also investigated as a subsystem, since it is an area that is currently target of many projects to promote its vitality. Results have suggested that the geography of the urban site interferes in the configuration of the regions, and that the growing increasing distances from downtown to others areas give rise to many emerging centralities. It has also been noted that the center of Teresina presents better Space Syntax performance when compared to other regions and the system as a whole. The analysis allows a better global-local comprehension, highlighting how the configurational perspective can support future projects.

KEYWORDS
1. INTRODUCTION

The city is a people magnet, and downtown is the physical representation of a society economic and politic power (Rolnik, 1995). Downtown is the point where objectives and ideas converge, whose intention is to equilibrate and organize the urban structure - one can say they are magnets attracting fluxes and uses, meaning that economic activities, such as stores and service spots, tend to succeed when located on this region (Medeiros, 2013).

Teresina (PI – Brazil) has been the target of several projects intending to increase the efficiency of its urban physical space. The city, however, experience an urban sprawl process which results in poor general connectivity, high levels of urban voids and emergence of more distant settlements far away from downtown. The effects are pronounced in mobility, generating direct and indirect impacts on the costs of transportation, housing/land, food: the quality of life progressively is reduced. Besides that, the proximity between Teresina and the city of Timon, in the state of Maranhão, generates a complex dynamic that must be taken into account in any urban planning action.

Based on these premises, the paper analysis the configuration of Teresina-Timon urban system from the Space Syntax Theory point of view. The administrative division is considered so that North, South, East and Southeast Side of Teresina and Timon as an isolated component are investigated. The downtown district, which belongs to the Northern Administrative Region – also known as Center-Northern Region –, is also read as a subsystem, since it is an area that is currently target of many projects to promote its vitality. Such analysis aims at understanding how the urban grid works on both global and local levels, highlighting how the configurational perspective can support future projects.

2. THE CITY OF TERESINA

2.1. A Brief History of Urban Expansion Historical

The city of Teresina, capital of the Piauí State, was founded on 1852, at the encounter of two rivers – Parnaíba and Poti. It was the first Brazilian planned capital after the Independence Day, whose urban layout was designed by Counselor Saraiva, then the Piauí Province President. He intended to build an ordered, rational and, to certain level, “monumental” city. The beauty of the Parnaíba River, the plan generator point, worked as an urban architectural element (Gandara, 2011). The Corisco Plateau site also allowed the settlement of an orthogonal grid, limiting the 100 blocks initially planned, with “empty” spaces reserved to squares (Teresina, 2014).

According to Silva (2017), since 1889 the city started to grow beyond the Downtown borders, when a great number of people, running from the 19th Century drought, moved to the new capital of Piauí. Until 1950, the city expanded in on all directions (except West, due the Parnaíba River natural barrier), but the urban limits remained between the Parnaíba and Poti rivers.

From the 1950’s decade on, the intense urbanization and industrialization process in Brazil reflected in Teresina. Because of the construction of the Juscelino Kubitschek Bridge, connecting the Frei Serafim Av. to what is called nowadays Eastern Side, the urban grid started to occupy the right riverside of Poti, resulting in a robust change on people’s flow (Cardoso, 2006).

The foundation of COHAB-PI (Companhia de Habitação do Piauí, “Piauí’s Inhabitation Company”) in 1965, a BNH endeavor (Banco Nacional de Habitação, “National Bank for Inhabitation”), started the housing allotments implementation4, especially at the Southern Side, creating an urban expansion corridor (Cardoso, 2006).

From the 1970’s on, the city grew intensively. This resulted on a disperse site, with huge urban voids. There was also a reduction on Downtown’s importance, associated with the decentralization of economic activities and the expansion of the urban infrastructure to support the population.

2.2. Teresina Today

Teresina is still the capital of Piauí, one of the poorest Brazilian states. Located in the Northeastern Region of the country, the city presents a huge social and environmental vulnerability. The municipality

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4 From 1950 to 2000, 62 housing allotments were implemented on all city regions, summing almost 38,333 housing units (Silva, 2017).
shelters 861,442 inhabitants, has a R$ 14,762,475.95 (US$ 4,007,698.04\textsuperscript{5}) GDP (Gross Domestic Product) and a 0.751\textsuperscript{6} Human Development Index (IBGE, 2019). It is also the center of the Integrated Region for Economic Development (Região Integrada de Desenvolvimento Econômico – RIDE) Grande Teresina, composed by 15 cities\textsuperscript{7}. A strong provision of services trend (51.72% of the GDP) characterizes the city’s profile. Besides that, most of the population works on public service – the Public Administration (Town Hall and State Government) has always had a main role on the city development, both as an investor and as a major employer.

In the beginning of the 2000’s, the Office for Development Supervision Affairs\textsuperscript{8} was created, attached to the Town Hall’s Planning Secretary Office (SEMPLAN), aiming to decentralize the administration. One of them focused on the Rural Area (Office for Rural Development Supervision Affairs, or Superintendência de Desenvolvimento Rural – SDR) while the other 4 were meant to supervise the urban regions (Office for Urban Development Supervision Affairs, or Superintendência de Desenvolvimento Urbano – SDU, in Portuguese):

- SDU Centro-Norte (North Side): englobes 39 neighborhoods\textsuperscript{9} up to the North of Downtown and Westside the Poti River. The city’s Downtown is part of this region.
- SDU Sul (South Side): includes 35 neighborhoods South Downtown and Westside the Poti River.
- SDU Leste (East Side): 29 neighborhoods Eastside the Poti River and North to the João XXIII Avenue, except for 3 of them.
- SDU Sudeste (Southeast Side): 19 neighborhoods located in the Eastside the Poti River and South the João XXIII Avenue, except for the 3 belonging to the SDU Leste.

The North Side occupies 74.50 km\textsuperscript{2}\textsuperscript{10} and has 171.895 inhabitants. The average income is R$ 1,538.86 (US$ 417.77). This region is characterized by enormous urban voids: the Teresina Airport (THE – 128 hectares); the Projeto Lagos do Norte (North Lagoons Project, a urbanization program for waterlogged areas); the headquarters of EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária, or Brazilian Enterprise for Agrobusiness Research); the Parque Encontro dos Rios (an ecological park where the Poti and Parnaíba rivers meet) and the tannery Europa (on the Santa Maria da Codipi neighborhood, up the Poti river). North and East Side are connected by four bridges: Jucelino Kubitschek (Frei Serafim Av.), Ministro Petrônio Portela (also known as Ponte da Primavera), Mestre Isidoro França (Ponte Estaiada) and Leonel Brizola (Ponte do Mocambo). There is also the Mariano Castelo Branco Bridge (Ponte do Poti Velho), connecting the North Side neighbourhoods of Poti Velho and Santa Maria da Codipi across the Poti River.

On South Side there are 35 neighborhoods\textsuperscript{11}, summing up 78.26 km\textsuperscript{2}\textsuperscript{12} - this is the biggest region out of the four sides. Up to 2010\textsuperscript{13}, 240,721 people lived here and the average income reached R$ 1,429.09 (US$ 387.97). This is a densely populated region and one with the highest rates. The Albertão Stadium and the State Government Administrative Center are located there, as well as the Vila Irmã Dulce, on the Angelim neighborhood, a Brazilian emblematic case of irregular ground occupation\textsuperscript{14}. It is connected to the East Side via the Wall Ferraz Bridge, and to Southeast Side, via Presidente Tancredo Neves Bridge.

East Side, the wealthiest city zone\textsuperscript{15}, it’s also the most socially unequal – on 2010, while neighborhoods like Joquei had average incomes up to R$ 10,000.00 (US$ 2,714.79), people living on Verde Lar had only R$ 644.00 (US$ 174.83). Nowadays, East Side englobes 29 neighborhoods\textsuperscript{16}, that summed

\begin{itemize}
    \item [5] Translation Note: conversions according to the quotation on January 9th, 2019. R$ 1 = US$ 0.27 (MSN Money, 2019).
    \item [7] The RIDE englobes the following cities: Teresina, Timon, Altos, Beneditinos, Coivaras, Curralinhos, Demerval Lobão, José de Freitas, Lagoa Alegre, Lagoa do Piauí, Miguel Leão, Monsenhor Gil, Pau D’Arco, União and Nazaré.
    \item [9] The neighborhood Piçarras is a particular case, because it belongs to both SDU Centro-Norte (North Side) and SDU Sul (South Side), depending on the area. For this paper, the neighborhood was classified as belonging to NORTH SIDE.
    \item [10] Corresponding to the neighborhood’s areas sum – does not correspond to the exact area considered at the coefficients calc (urban system area).
    \item [11] For further considerations, the neighborhood Piçarras was included to the North Side.
    \item [12] Neighborhood areas sum.
    \item [15] On 2010, according to the CENS (IBGE), the average monthly income was R$2,692.13 (US$ 730.86), the highest one out of the four regions.
    \item [16] Four of them were created on 2013.
\end{itemize}
149,324 inhabitants back on 2010 (a 2,287.43 inhabitants per square kilometer density). The neighborhoods sum a 65.28 km² area.

Here are located the most valued commercial routes, plus two out of the three city malls. It is also the home of the Universidade Federal do Piauí (UFPI – Federal University of Piauí), of the new headquarters of Federal and State Public Ministry (these institutions are moving from Downtown to East Side), and other public offices. The main city post-card is located in this region, the Ponte Estaiada (Mestre Isidoro França Bridge, connecting East to North Side). Other connections across the river are made via the Ponte da Primavera, Ponte do Mocambo (both to North Side) and to South Side via Ponte Wall Ferraz.

Southeast side is the smallest administrative region (43.53 km²). It emerged once the disruption of East Side on the early 2000’s and covers 19 neighborhoods only. Although the least populated on IBGE’s CENSO 2010 (135,503 inhabitants)\(^{17}\), it was the most densely populated (3,112.86 inhabitants per square kilometer) and the poorest one (R$ 989.97 – US$ 268.76).

At the present time, the region is highly densified (as it can be observed on its urban grid), despite the existence of less populated neighborhoods on the Poti riverside, as Redonda, Comprida and Extrema. It is also the birthplace of the biggest urban communitarian vegetable garden on Latin American (23 hectares, 400 producers), the “Horta do Dirceu”. It is directly connected to South Side, through the Anselmo Dias Bridge – discharged on José Francisco de Almeida Neto Avenue, the main avenue of the Dirceu neighborhood – and via Presidente Tancredo Neves Bridge – leading to the Tancredo Neves Neighborhood, which dwells the city bus station.

Downtown is delimited by the avenues Maranhão, Miguel Rosa and Joaquim Ribeiro. Between 1991 and 2010, it lost almost 60% of its inhabitants\(^{18}\) (from 20,345 to 12,180), denoting a problem with the existing infrastructure, once it is a totally urbanized area and with excellent configurational performance.

3. THE CITY OF TIMON, MA

Timon, a city on the State of Maranhão, is constituted by 46 neighborhoods: the 9 older of them form the historic city center. Since it is the oldest area and has the strictest relationship to Teresina, the Parque Piauí neighborhood is said to be the city downtown. Such relationship is physically established through the Ponte Metalica (João Luís Ferreira Bridge), which meets Teresina’s Downtown directly, on the Miguel Rosa Avenue. 155,460 inhabitants were registered in Timon on the CENSO 2010\(^{19}\), with an 88.09 inhabitants per square kilometers density\(^{20}\). Today, the city is part of the RIDE Grande Teresina.

According to Sousa (2014), Timon’s growth is closely linked to its proximity to Teresina, especially from the 1960’s on, when families moved from the rural to the urban zone of the city. On the 1970’s and early 1980’s, Timon had a precarious urban infrastructure (little water and sewage supply) and few paved streets, situation worsened by the second half of the 1980’s and early 1990’s, when the urban grid “explodes” without order, reinforcing the “dormitory city” stigma. At that time, the housing allotments implementation aggravated the peripheralization of the area, particularly with the Boa Vista and Joaquim Pedreira allotments, as well as the construction of Residencial Canaã, the first 3+ floors apartments edification agglomerated.

At the present time, Timon has evolved its urban vocation to commerce and retail. The Downtown remains the home of the city’s wealthiest families that lives next to irregular urban settlements. High standard gated communities have been built on the city surroundings. The instauração of the industrial district has attracted enterprises tempted by the city low taxes compared to Teresina (Sousa, 2014).

Besides the Ponte Metalica, two other bridges between connect Timon and Teresina: Ponte da Amizade (Presidente José Sarney Bridge, also connecting Timon to Downtown Teresina) and Ponte Nova (Presidente Médici Bridge), that connects the Presidente Médici Avenue (South Side Timon) to the Tabuleta neighborhood (South Side Teresina).

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\(^{17}\) However, it has been growing throughout the last decade, since it is next to East Side, but has lower land prices.


\(^{19}\) Estimated population for 2018: 167,973 inhabitant (IBGE).

\(^{20}\) Total district area: 1,764.612 km² (IBGE).
4. METODOLOGY

The main objective of this paper is to analyze the urban evolution of Teresina since 2010, based on an updated version of data collected by Brito & Medeiros (2014), under the Theory of Social Logic of Space perspective. In the study, Timon is included as well, once both cities are clearly conurbated. The four Teresina regions (North, East, South and Southeast) mentioned before are also analyzed, plus Downtown, as different sub-systems.

Firstly, the analyzed area was selected considering a satellite image from Google Earth, taking into account the occupied zone for both urban grid. Then, the axial lines were drawn via software QGIS, based on the Space Syntax premises. On this case, vehicles and pedestrian lanes were considered. Districts not yet occupied, but already presenting a street network were also registered.

With the newly-produced axes map in hand, the DepthMap software was used to generate the axial map, proceeding with the analysis of some aspects among the geometrical and topological coefficients, comparing those with the historical data registered by Brito & Medeiros (2014): area/system compactness, integration, connectivity, synergy and intelligibility.

Since Teresina is administratively divided in regions, some isolated analyses were also performed, one for each of the four Teresina zones (North, South, East and Southeast Side), plus Downtown and Timon (MA), resulting in six “urban subsystems” (see Figure 1).

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21 Both cities work symbiotically, although belonging to different states and being separated by the Parnaíba River.
22 SRC: EPSG 3857 – Datum WGS 1984 / Pseudo Mercator.
23 Version 2.18.11 – Las Palmas.
24 Satellite Image: Bing Satellite (corresponds to the 2016 urban situation).
Figure 1 – Axial Map of the six urban subsystems in Teresina: North (pink), South (green), East (yellow), Southeast (blue), Downtown (purple) and Timon city (red). Produced by the authors.
5. RESULTS

5.1. Teresina – Timon Urban System

Figure 2 shows Teresina urban grid evolution since the last analysis (2010 – system area: 200.1 km²) up to the present day (2018 – system area: 330 square kilometers). Now there’s the consolidation of the neighborhoods on the far ends North (Chapadinha, Aroeiras), South (Portal da Alegria, Pedra Múida, Angélica), East (Novo Uruguai) and Southeast (Todos os Santos). South Side was occupied during this time, reducing the previous void on Angelim neighborhood.

![Urban grid evolution from 2010 (left) to present day (right).](image)

5.2. Topological variables

The integration map of Teresina shows a still discontinued urban grid, sprawled afar from the original urban core. Downtown remains the most integrated area, just as the North and South Side neighborhoods immediately close to it. East Side, home of the wealthiest part of the population, still has a global importance, although discreetly less than what was observed on the previous analysis (more yellow lines).

When Timon urban grid is taken into account, one can observe how Downtown Teresina keeps its critical importance for the whole system. Timon’s presence also affects Teresina’s system, since it increases, however very discreetly, the integration on neighborhoods beyond Poti River (lines that before were dark blue now are presented with lighter tones, and white blue lines become greener, indicating greater integration to the system). It also decreases, very discreetly, the relevance of East Side lines (from red/orange lines to orange/yellow lines).

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26 Brito & Medeiros (2014).
27 Town Hall Act no. 4.423, July 16th, 2013.
28 The Novo Uruguai (East Side) and Todos os Santos (Southeast Side) neighborhoods have been occupied by high standard gated communities.
29 East Side has been conceived to concentrate the most expensive lands since the 1970’s (CASTELO BRANCO, 2012).
Figure 3 – Global Integration Map (INThh) of the Teresina-Timon urban system (present day). Produced by the authors.
On the following table (Table 1) the obtained results (coefficients) are shown:

Table 1 - Topological variables comparison

<table>
<thead>
<tr>
<th>TOPOLOGICAL COEFFICIENTS</th>
<th>YEAR</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010\textsuperscript{30}</td>
<td>2018</td>
<td>2018</td>
<td>Brazil</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Teresina</td>
<td>Teresina + Timon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GLOBAL INTERACTION (Rn)</td>
<td>0.749</td>
<td>0.703</td>
<td>0.717</td>
<td>0.764</td>
<td></td>
</tr>
<tr>
<td>CONNECTIVITY</td>
<td>4.628</td>
<td>4.500</td>
<td>4.447</td>
<td>3.900</td>
<td></td>
</tr>
<tr>
<td>INTELLIGIBILITY</td>
<td>7%</td>
<td>5.3%</td>
<td>5.6%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>SYNERGY</td>
<td>23%</td>
<td>20.83%</td>
<td>23.04%</td>
<td>36%</td>
<td></td>
</tr>
</tbody>
</table>

The global integration value (\(R_n\)) only for Teresina decreases from 2010 to 2018, still under the Brazilian average found by Medeiros (2013). However, when analyzing the system Teresina + Timon, there’s a small rise (from 0.703 to 0.717), confirming Timon’s urban grid influence over the system, since it is more integrated than Teresina’s\textsuperscript{32}.

The connectivity value also decreases from 2010 (4.628) to 2018 (4.500), despite the orthogonal aspect of the new allotments – actually, the new urban tissue is more about informal settlement, especially in empty spaces between neighborhoods (named by IBGE as subnormal agglomeration). The system Teresina + Timon also shows a fall (4.447), since Timon has many irregular allotments on its urban grid, with roads not following the apparent official streets orthogonality\textsuperscript{33} - however, it is still above the Brazilian average (3.900).

The intelligibility value correlates the connectivity (CONN) and global integration (\(R_n\)), indicating whether the more integrated lines are also the most connected, in other words, if they have more crossroads (Holanda, 2002). Such rate shows how easy it is to guide oneself inside a system and, therefore, apprehend it as a whole – a break on the space continuity (i.e., a change on the previous geometry) hinders the self-localization of an individual on the urban context (Medeiros, 2013). Observing the obtained values, it is noticeable that Teresina’s intelligibility has dropped between 2010 and 2018 (from 7% to 5.3%), inasmuch as the urban grid extended and fragmented itself since the new allotment’s implementation – what tends to lessen the amount of global lines. When Timon is considered, the intelligibility receives a small stretch (from the previous 5.3% to 5.6%) – once this city has few urban voids and some notable lines, primarily next to the Ponte Nova (Engenheiro Antônio Noronha Bridge, which connects South Side Timon to South Side Teresina).

Synergy, just as intelligibility, is also a derived coefficient – on this case, from the global integration (\(R_n\)) and local integration. Its purpose is to show how a system repeat the global arrangement on a local level: as the difference between the global and local levels attributes grows, the synergy decreases, while the system’s mazy tendency increases (Medeiros, 2013). In Teresina, there was a synergy fall (from 2010’s 23% to 2018’s 20.83%), product of the urban grid sprawl afar from the integration core. Adding Timon to the system “equilibrates” the arrangement: synergy grows to 23.04%. The numbers, however, are still under the Brazilian average (36%).

\textsuperscript{30} Brito & Medeiros (2014).
\textsuperscript{31} Medeiros (2013).
\textsuperscript{32} Timon global integration value (INTth) is 0.985 (average).
\textsuperscript{33} This is about old settlements, older than formal urban tissue, caused by the urban expansion in 1970s, not followed by the provision of infrastructure (Sousa, 2014).
5.3. Geometric variables

The geometric coefficients indicate the urban density – indicating whether the city is sprawled or not, what leads to direct and indirect maintenance costs. In other words, here it is observed the *compactness* through the entire analyzed system. The Table 2 displays the obtained results.

Table 2 - Geometric coefficients comparison

<table>
<thead>
<tr>
<th>GEOMETRIC COEFFICIENTS</th>
<th>2010&lt;sup&gt;34&lt;/sup&gt;</th>
<th>2018 Teresina</th>
<th>2018 Teresina + Timon</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM TOTAL AREA (km²)</td>
<td>200.1</td>
<td>330</td>
<td>413.81</td>
</tr>
<tr>
<td>NUMBER OF LINES/AXES</td>
<td>8.470</td>
<td>11,190</td>
<td>13,689</td>
</tr>
<tr>
<td>AVERAGE LINE/AXIS LENGTH (meters)</td>
<td>360.96</td>
<td>319.73</td>
<td>316.02</td>
</tr>
<tr>
<td>NUMBER OF AXES LINES PER KM²</td>
<td>42.33</td>
<td>33.91</td>
<td>33.08</td>
</tr>
<tr>
<td>LINES/AXES LENGTH PER SQUARE KILOMETER</td>
<td>15.28</td>
<td>10.84</td>
<td>10.45</td>
</tr>
</tbody>
</table>

On the 2010’s Brito & Medeiros analysis (2014), it was verified that Teresina was increasing its number of axes per square unit – it was the biggest value found on the diachronic analysis) --, but the lines were shortening, indicating that the system was growing disjointedly.

From that year to present day, the number of lines and the total area increased, respectively, to 32% and 65%, i.e., today the city has less lines per area (from 42.33 to 33.91) and less road kilometers by square unit, what is connected with the urban grid sprawl. With the Teresina + Timon structure, the total system area doubles in comparison to the 2010 data, but the global performance falls.

5.4. Subsystems’ performance

5.4.1. North Side:

a. Topologic Coefficients

North Side’s global integration map (*R*<sub>n</sub> – right of Figure 4) attests that the most integrated roads are West side the Teresina Airport. It’s worth pointing out that the *Mestre João Isidoro França Avenue*<sup>35</sup> (the continuity of the *Poti Velho Bridge*) is a completely integrated roadway (red color), since it is the city’s growth vector up to above the *Poti* River, although it crosses a huge urban void (the tannery region). The *Aroeiras* neighborhood, on the limit with East Side (*Pedra Mole* neighborhood), and *Chapadinha*, the Northeast neighborhood, are the most segregated places (blue color on the map). This side’s global integration coefficient (*R*<sub>n</sub>) is 0.712, almost the same as Teresina + Timon system.

Regarding the average connectivity, the zone shows a 4.307 performance (less than the system one). Looking at the map (left on Figure 4), there are connectivity cores (hot colored lines, like orange and red) close to the airport and at the Northern urban center. The *Mestre Isidoro França Avenue* – a very integrated roadway that cuts an urban void –, is not very much connected (dark blue).

The North Side’s intelligibility is only 6.5%, but higher than the value found for Teresina (5.3%) and for the Teresina + Timon system (5.6%). Besides that, its synergy reaches 30.83%, showing that the locally important roadways have some impact on the global context.

<sup>34</sup> Brito & Medeiros (2014).

<sup>35</sup> Translation Note: The Avenue’s original denomination is *Alameda*, a type of *boulevard* (broad arborized avenue with multiple lanes).
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Figure 4 – North Side of Teresina connectivity (left) and global integration maps (right). Produced by the authors

b. Geometric Coefficients

When we take a look at North Side Teresina area, the urban voids pop up (the airport, the EMBRAPA, the tannery, the lagoons and environmental parks mentioned before), as well as their impacts on the urban arrangement: on total, 2,766 lines were marked, with an average length of 295.65 meters – less than the city’s and the Teresina + Timon systems average. The North Side grid allows one to identify the allotments’ profile: long roadways crossing the urban voids, orthogonally subdivided, but with few/none connection to each other. Such setting is pronounced by the number: on the 82.279 km² area, there are 33.62 axes per square unit, and only 9.94 roadway kilometers/square unit.

5.4.2. South Side

a. Topological Coefficients

South Side’s global integration map ($R_n$) (Figure 5, on the left side) shows that the region closest to Downtown Teresina seems more integrated on the urban system’s global context: the neighborhoods of Vermelha, Nossa Senhora das Graças, Piçarra, Cristo Rei, Monte Castelo and Macaúba – all highly disputed on the real estate market, but not much connected to the South Side subsystem. On the other hand, neighborhoods far from the city core, as Parque Jacinta, Parque Juliana and Brasilar are more integrated. This region’s integration core is the Prefeito Wall Ferraz Av. (red colored), the city’s South growth vector.

The subsystem reached a 1.033 global integration value – highly above the urban average. This can be explained because the South Side is a very urbanized area with few urban voids (differently from North Side). Nearby the Poti River are the most segregated areas on the global context – those who are not inside the official urban perimeter, but already show ground mark delimitations for future allotments.

Its connectivity coefficient (CONN) is 4.462 – higher than North Side’s, but still smaller than the urban system average. Looking at the map (Figure 5, on the right side), one can observe that the Prefeito Wall Ferraz Av remains highlighted as one of the most connected roadways, just like the two borderline streets to the Promorar neighborhood: the Valfrido Salmito St to the North, and the Odilon Nunes St, to the South. Lourival Parente neighborhood has a slight impact on the subsystem’s connectivity (some lines are shown as light blue), as well as the Barão de Gurgueia Av and the Prof Valter Alencar Av.
(both light green marked, up to the North, nearest Downtown). Neighborhoods far away from Downtown Teresina, as Portal da Alegria, show green lines, indicating roadways with increasing importance to hard access locations.

This zone’s high global integration will directly affect the intelligibility and synergy values. To the first, a 10.98% index was found (above the urban average, although under the national average). To the second, an impressive 47.19% value proves that, besides the visible allotment’s demarcations, South Side has been organized quite cohesively.

![Figure 5 – South Side of Teresina global integration (left) and connectivity (right) maps. Produced by the authors](image)

6. Geometric Coefficients

South Side happens to be the biggest out of the analyzed subsystems (a 128.934 square kilometers area), suggesting it has grown afar from the system’s integration core (in comparison to the neighborhood areas, it also indicates a strong growth tendency, since urban voids lots on allotment process were identified. It has the major number of axes from the studied subsystems (3,917). However, once it englobes an unofficial area (the one beyond the city perimeter), the number of axes per square unity ends up as the smallest one (only 30.38), as much as the number of roadways/square unit (9.99 – under the urban average, but close to Teresina + Timon system).

6.1.1. East Side

a. Topologic Coefficients

The East Side’s part closest to the Poti River appears to be very integrated on the Teresina’s map (Figure 3) and in the Teresina + Timon urban system map as well – this is the wealthiest neighborhoods area. Taking a look at the subsystem, the East Side’s global integration map (Rn -Figure 6) shows a region with less urban voids than the two previous ones (the Zoobotanic Park, by the river, is a big “empty” cut off inside the deeply occupied area). This side global roadway is the Presidente Kennedy Av (red marked), the city’s growth vector up to the city of União, which is part of the Integrated Region for Economic Development (RIDE). Locally, the neighborhoods nearest to Downtown Teresina are not marked as the zone’s global elements – indeed, such role is played by the central zone’s neighborhoods, as São Cristóvão, Morada do Sol, Planalto and Piçarreira (marked with hotter color lines).
Besides the Presidente Kennedy Av, the roads around that avenue are very integrated, especially at the high middle-class neighborhoods, like São Cristóvão, Horto and Morada do Sol – all oranges in the map. Also Homero Castelo Branco Av., a traditional address to rich houses in the past/rich commercial enterprises nowadays. As a less integrated highlight, the lower middle-class neighborhood of Pedra Mole (blue marked, by the North Side’s borderline) is also shown as scarcely integrated to the complete urban system. The zone’s global integration value reaches 0.946 – a regular performance.

Regarding the connectivity map (CONN - Figure 6), the Presidente Kennedy Av emerges as well, but not as much as on the INThh map (Rn). Here, the most connected roadway is Zequinha Freire Av, borderline of the lower middle-class and low-class neighborhoods of Satélite, Vale Quem Tem, Porto do Centro and Verde Lar. The wealthiest neighborhoods (down to zone’s southwest) have a light connectivity effect (light blue/green/yellow). The average connectivity coefficient found was 4.336 – under South’s Side average, but above North’s.

A 8.5% intelligibility coefficient was found – highly above the total urban system’s average, suggesting a fragmented urban grid, like the other Sides, but less severe than North’s situation. The synergy performance reached 36.72% (similar to the national average), indicating a tendency to local centralities enhancement, especially with the sprawl up to North and Northeast.

![Figure 6 – East Side of Teresina connectivity (left) and global integration maps (right). Produced by the authors](image)

b. Geometric Coefficients

The Eastern subsystem has a 78.58 square kilometers: not very different from the urban neighborhood’s area (65.50 square kilometers), showing that the region is growing on a not so sprawled pattern (since this is the wealthiest population’s home, real estate prices are the highest). 2,940 lines were identified (the second highest number; the first one is South Side), with a 37.41 axes per space unit – behind Downtown Teresina. These axes’ length average is 310.533 meters, caused by the fragmentation on less orthogonal neighborhoods due to the topography (as Piçarreira, Samapi and Satélite). The roadways per space unity performance is 11.62, above the global urban system’s average.

6.1.2. Southeast Side
Southeast Side’s main highlight is its cohesive urban grid by its central area. On the global integration map \((Roi)\), the top of Figure 7, one can notice that the global roadways are also the most widely known: *Noé Mendes Av*, crossing the subsystem from East to West, and *Joaquim Nelson Av*, crossing the subsystem from North to South, dividing the neighborhoods of *Itararé* (Westside) and *Parque Ideal* and *Novo Horizonte* (Eastside). The less integrated neighborhoods are *Flor do Campo*, *Verdecap* and *Bom Princípio*, all marked as dark blue, Southeastern of the map. The final global integration coefficient was quite satisfactory considering the sample: 1.119 (lower only than Downtown Teresina).

On the connectivity map (bottom of Figure 7), the two important roadways on global integration are also shown as the most connected ones: *Noé Mendes Av*, on red, and *Joaquim Nelson Av*, a little less connected (yellow). The *José Francisco de Almeida Neto*, also known as “Dirceu’s main avenue” also pops up to the viewer, since it is the region’s commercial core. On the most integrated neighborhoods, Southeastern the map, the main avenues are highlighted in green, indicating that, on this “downtown and zone’s core afar” context, those are very connected roadways. Southeast Side’s final average connectivity value is the highest out of the four studied subsystems: 4.820.

Besides being higher than the global urban system average, this subsystem’s intelligibility average is low: only 8.5%, the same value founded in Teresina’s East Side – as seen on the previous regions, each neighborhood has a roadway division of their own, asunder the whole. But here, unlike others, most of
the urban tissue was made by planed settlement: just a few places are informal occupations. The synergy also didn’t have the best performance: 32.98%, higher only than North Side’s total.

b. Geometric Coefficients

Here, the evaluated area corresponds to 42.06 km², less than the neighborhoods area sum (43.5 km²): the Town Hall itself englobed an unoccupied area on the 2013’s official neighborhoods delimitation, attesting that the Public Power intends to spread/occupy this area. The total number of lines was the smallest in the sample (1,501), resulting on a 35.69 axes per square unit density. The urban grid’s densification and the long and continue lines existence are confirmed by the 330.941 meters of average length and by the 11.81 kilometers of axes/space unit (the best performance so far).

6.1.3. Downtown Teresina

Figure 8 – Downtown Teresina global connectivity (left) and global integration maps (right). Produced by the authors

a. Topologic coefficients

Once this area corresponds to the original city core, and since it has a small area (only 3.86 km²), Downtown Teresina has performance above the average36. On the global integration map (\(Rn\) – right on Figure 8), there is only a single dark blue line (the bridge) indicating less integrated roadways. The longer lines, that cross the system from North to South, are shown as the most important ones: Barroso St (2.32 km), Treze de Maio St (2.27 km) and Alvaro Mendes St. (1.9 km). Downtown’s global integration average is 2.227.

Downtown’s roadways medium connectivity (left on Figure 8) has also a high performance: 6.98. This is explained because these are straight lines, orthogonally arranged, with few breaks caused by curves37.

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36 It is worth noting that it happens to be the very city integration core, from both Teresina City and Teresina + Timon system as well.

37 Only two roadways “break” the pattern: the Miguel Rosa Av, that goes around the neighborhood, and José dos Santos e Silva Av. The first was initially conceived to follow the ferry line, which would connect Teresina to the city of Paulistana, down to Southeast the State. The second avenue was, up to 1960, the Barroça stream, cleaned out as an embellishment strategy (SEMPLAN, 2018).
The secondary parameters follow the good performance: 70.97% of intelligibility and 93.04% of synergy, so this is a special area within the system.

b. Geometric coefficients

A small area (3.86 km²), with orthogonal and straight lines (162 lines, with 530.54 average length – almost twice the urban average), has a 41.97 axes/space unity density and 22.27 km of axes/square unit, enunciating a very functional subsystem.

6.1.4. Timon, MA

![Figure 9 – Timon global integration (left) and connectivity maps (right). Produced by the authors](image)

a. Topologic coefficients

Timon’s urban grid is characterized by few urban voids, prevailing an orthogonal layout. However, the city’s urbanization history justifies the irregular and non-paved lines on peripheral agglomerates, especially on its urban system core – between the two Northern bridges connecting to Teresina. The global integration map (Rn – left of Figure 9) shows that such region is very integrated, but, down to the South, close to the Engenheiro Antônio Noronha Bridge (also known as Ponte Nova), part of the integration spreads itself, marked on orange to red lines. The two parts of the core are linked by the Presidente Médici Av, also highlighted on the map. The average global integration coefficient found was 0.985 (above the Teresina’s average).

Apropos of connectivity (CONN – right on Figure 9), it was observed that the old city downtown (North zone) has the most connected lines, including the top one (Tenente Antônio Correia da Silva St). Southside Timon also shows a very connected roadway: the urban part of BR 226 (continuity of the

38 The LESS integrated area to the urban context, on the Global Integration map.
39 Translation Note: BR is the known abbreviation for Brazilian Roadway, crossing different states.
Proceedings of the 12th Space Syntax Symposium

Ponte Nova and Presidente Getúlio Vargas Av, on Teresina). The lines’ average connectivity is the smallest among all the studied subsystems: 4.203.

The urban grid, fragmented by the informality/unofficial occupations, does not affect the secondary results, which show a satisfactory performance. Timon intelligibility reaches 13.76% (the highest in the analyzed areas, apart from Downtown Teresina), indicating the power of the regular grid; synergy reached a 62.19% result, indicating this as the most cohesive subsystem, even more than the national average founded by Medeiros (2013 - 36%).

b. Geometric coefficients

For this research, the selected area sums 76.97 square kilometers. 2,501 lines were found, resulting a 32.49 axes/km² density – a low coefficient within the analyzed systems. The average axes length is 299.20, the second smallest in the sample, caused by irregular streets from the historical land invasions that happened decades ago. The line’s length per space unit is the lowest: 9.72, reinforcing the fragmentation of informal roadways on prejudice of formal/official streets. The findings point out that the marked axes are not completely paved streets, but on allotment process instead, part of the city’s expansion.

7. CONCLUSIONS

The final values are organized on Table 3, showing both the subsystem’s values and the global ones.

**Table 3 - Topologic and Geometric Coefficients Synthesis for Teresina (Whole System and Subsystems)**

<table>
<thead>
<tr>
<th>COEFFICIENT</th>
<th>SUBSYSTEM – YEAR 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>North Side</td>
</tr>
<tr>
<td><strong>GLOBAL INTEGRATION</strong></td>
<td></td>
</tr>
<tr>
<td>(Rn)</td>
<td>0.712</td>
</tr>
<tr>
<td><strong>INTELLIGIBILITY</strong></td>
<td>6.50%</td>
</tr>
<tr>
<td><strong>SYNERGY</strong></td>
<td>30.83%</td>
</tr>
<tr>
<td><strong>SYSTEM’S TOTAL AREA</strong></td>
<td>82.279</td>
</tr>
<tr>
<td><strong>NUMBER OF LINES/AXES</strong></td>
<td>2,766</td>
</tr>
<tr>
<td><strong>AVERAGE LINES/AXES’ LENGTH</strong></td>
<td>295.65</td>
</tr>
<tr>
<td><strong>NUMBER OF LINES/AXES PER KM²</strong></td>
<td>33.62</td>
</tr>
<tr>
<td><strong>LINES/AXES’ LENGTH (km) PER KM²</strong></td>
<td>9.94</td>
</tr>
</tbody>
</table>

Teresina is known as a sprawled city with low density. This scenario creates robust direct and indirect impacts over costs of transportation, housing/land, food and infrastructural development: more and
more allotments are built far away from Downtown, which, on the other hand, is experiencing a populational deflation what means a waste of urban resources. Meanwhile, the peripherical locations, due to the distance, time and financial resources, have been reorganized onto local centralities more and more independent.

One can observe that Teresina’s area growth, from 2010 to 2018, was not followed by the urban grid: it is possible to see some allotments more far away from Downtown, producing an expensive city with remarkable voids. In some cases, the site’s geographical attributes interfere in its occupation, but the official rise on neighborhoods by the city borderline reflect the urban unbridled expansion.

Throughout Teresina as a global system, the following urban layout can be perceived: critical roadways separate the neighborhoods and, inside these neighborhoods, lines disconnected from the global context appear – recalling the patchwork pattern explained by Medeiros (2013).

Watching the subsystems individually, it is worth noting that:

North Side has performances directly affected by the Poti River cut. The low synergy is a result of the new centrality rise up in the extreme North, totally segregated– both spatially and financially. It is the most “fragile” area among the analyzed subsystems, affecting Teresina + Timon performance.

South Side has some urban voids, but, since it is not cut by any natural barrier, a less disperse growth was possible. However, the city is “torn away” from the city urban core, with many locally important centralities – mainly because it is the city’s biggest region and also the most populated.

On East Side one can point out that, indeed, the way how urban allotments are organized on the space is a product of the social relations. On the maps, the highest income areas are visibly highlighted – they have the most integrated streets and avenues, which offer the best roadway options and that, on Teresina’s global system, had their importance already highlighted, side by side the city’s Downtown. The urban grid follows an orthogonal, yet very disconnected pattern, as an impact of the successive allotment process. It is also visible that, on East Side, where the majority of the terrain is plain40, there are many acute angled crossroads, when the city’s main pattern displays a straight angle preference, except for the occasions where the site’s topography and/or a water body presence generates a more sinuous line.

On Southeast Side it is also notorious the rise of a centrality “torn away” from the main urban grid. It is, after all, an expansion zone, reflection of the income’s concentration on East Side (proximity + lower real estate prices).

Teresina Downtown is a completely underused structure, once it shows outstanding setting performances, being globally integrated on both analysis (Teresina and Teresina + Timon), besides its constant and worrying populational decrease.

On Timon, here studied as a subsystem on its own, there are two cores: the old and the new, representing the past and present power structures, respectively. Thus, the transformation of the urban dynamics must be cautiously perceived by the Public Power, in order to avoid possible future interest conflicts that might reflect on the city itself. It is also notable the city’s real estate speculation process, a repercussion of its recent expansion flows.

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40 It is also a spate passive area.
REFERENCES


