

Covid-19 and its propagation dynamics in Ceara (Brazil) urban network

*A Covid-19 e sua dinâmica de propagação na rede urbana
do Ceará, Brasil*

*La Covid-19 et sa dynamique de propagation dans le réseau
urbain de l'état du Ceará, Brésil*

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Abstract

The text proposal aims to apprehend some experiences of the SARS-CoV-2 virus propagation in Ceara state from its urban network. The starting point is the notion that circulation and velocity are important vectors for the Covid-19 dissemination in the territory, where the flows of people and objects with different frequencies maintain relations among cities with many sizes and functions. Information related to the virus diffusion in the urban system is interpreted using data collected by the Ministry of Health (IntegraSUS) and the Health Department of Ceara State. By reading the spatial discontinuities and indicating an observation plan that skips scales and articulates points aligned according to their spatial interactions, the urban network approach contributes greatly to the vision that captures density, connectivity and circulation, which are the factors presented as responsible for the spread of the disease.

Keywords: Covid-19, Urban Network, Ceara.

Resumo

A proposta deste texto é apreender algumas experiências da propagação do vírus SARS-CoV-2 no estado do Ceará a partir das tessituras de sua rede urbana. Parte-se da noção de que as circulações e as velocidades são importantes vetores de disseminação da Covid-19

no território, onde os fluxos de pessoas e objetos com diferentes frequências mantêm relações variadas entre cidades de muitos tamanhos e funções. São interpretadas informações do Ministério da Saúde (IntegraSUS) e da Secretaria da Saúde do Estado do Ceará, segundo sua difusão no sistema urbano. Por ler as descontinuidades espaciais e indicar um plano de observação que salta escalas e articula pontos alinhados em função de suas interações espaciais, a abordagem da rede urbana contribui sobremaneira na visão que captura a densidade, a conectividade e a circulação, exatamente os fatores que se apresentam como responsáveis pela disseminação da doença.

Palavras-Chave: Covid-19, Rede Urbana, Ceará.

Résumé

Le but de ce texte est d'appréhender certaines expériences de propagation du virus SARS-CoV-2 dans l'État du Ceará à partir du tissu de son réseau urbain. Cela part de l'idée que les circulations et les vitesses sont des vecteurs importants de la propagation du virus Covid-19 sur le territoire, où les flux de gens et d'objets de différentes fréquences ont maintenu des relations entre des villes de variées tailles et fonctions. Les informations du Ministère de la Santé (IntegraSUS) et du Département de la Santé de l'État du Ceará sont interprétées, selon sa diffusion dans le système urbain. En lisant les discontinuités spatiales et en indiquant un plan d'observation qui saute les échelles et articule des points alignés en fonction de leurs interactions spatiales, l'approche des réseaux urbains contribue grandement à la vision qui enregistre la densité, la connectivité et la circulation, exactement les facteurs qui se présentent comme responsables de la propagation de la maladie.

Mots-clés: Covid-19, Réseau Urbain, Ceará.

Introduction

A rapid spread of Covid-19 disease has left indelible marks on the world population since December 31, 2019 when the Chinese authorities reported an infectious outbreak emergence caused by a new coronavirus strain. In order to curb the disease transmission as well as to avoid the health system saturation, governments acted quickly implementing a drastic reduction in mobility and social interaction through the imposition of home confinement and a ban on various socioeconomic activities.

According to some researches published by Brazilian and British institutions (CÂNDIDO et al., 2020), the new coronavirus, identified as SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2), arrived in Brazil through more than one hundred different entries, most of them located in capital cities with the highest quantity of international flight flows coming from Europe. Among the capital cities, Fortaleza (Ceara), which is an air hub, São Paulo, Rio de Janeiro and Belo Horizonte are some prominent cities.

In line with the observation that related the disease spread with the numerous globalization flows, several studies have been published, even with a short time period of the virus spread¹. In general, these studies argue that circulation and velocity are important vectors for the SARS-CoV-2 spread in the territory, especially in a world where the crossing between the most diverse scales of life and of economy are expanded

¹ See, among others, Aguiar (2020), Guimarães et al. (2020), Méndez (2020) and Sposito and Guimarães (2020).

(GUIMARÃES et al., 2020), and also where the constant people movement makes the means of transport important mechanisms for the contamination network.

Such means of circulation, which articulate multiple places at a high speed, are capable of transporting the viruses far away from their origin, making possible their spread “by leaps and bounds” (MENDEZ, 2020), in other words, they can move from “a region to another in the territory”, crossing continents and oceans in a short time, connecting places which have infrastructures as airports and ports (SPOSITO and GUIMARÃES, 2020).

This way, due to the globalization influence and in the context of a society marked by hyper mobility (MENDEZ, 2020), a virus spread, like the SARS-CoV-2, is linked to the circulation and connectivity among different places, becoming the spatial networks and interactions as important as the extension, location and territorial continuity of the phenomenon (GUIMARÃES et al., 2020).

Thus, the network of cities is an important scale for approaching the virus spread because “it is, more than ever, the network on which all the others are structured” (SPOSITO and GUIMARÃES, 2020, p. 1), including the transport network. Therefore, the Covid-19 dissemination tend to occur according to the urban system diffusion, involving cities with different functionalities and sizes, where the flows of people and objects, with dense movement frequency, maintain close relations.

It is a propagation that can take place through conventional hierarchical diffusion processes of the network, when it encompasses articulated cities in line with the gravitational models or from more complex urban interactions, when the contagion follows diffusion paths that connect different points without passing through intermediate places, respecting a great number of bonds defined by several motivations.

This paper proposal is to capture some experiences of the SARS-CoV-2 spreading in Ceara state from its urban network. We aim to understand the virus spread through the polarization of the urban centers, the populational displacement rhythms and the articulation among the flows, points and traffic nodes, which define the arrangement of Ceara urban network. This paper interpreted the information made available by the Ministry of Health (IntegraSUS) and by the State Health Department of Ceara, by systematizing the data on contamination and people death from March to June 2020, period that represents the most critical disease phase in the state.

The paper is divided into five parts. Besides this introduction, a second item presents the genesis, the evolution and the current articulation of the urban network in Ceara, revealing its relationship arrangement. A third item points out the centralities and dispersion of the health services in Ceara territory, by identifying the largest population displacements in search of these services. The fourth item systematizes the information on contamination and people death in the state spatial configuration provided by IntegraSUS. A relation between such data and the urban network interactions is made in the fifth item, pointing out patterns of tradition or subversion. After such discussions, the conclusion is presented.

The Ceara urban network and its system of cities

The Ceara urban network formation is particularly linked to the development of some activities related to livestock and cotton planting for the foreign market, considering that the urban centers which are best served by roads had their commercial plaza better developed, as well as, they better distributed goods and services to neighboring areas (SOUZA, 2005).

In a semi-arid area, such spatial organization provided to Ceara urbanization a structure marked by political and opportunity inequalities, in which few urban centers diversified their services and widened their influence area. When they did it, they centered their economic activities on trade, complementing the role played by livestock and subsistence agriculture (SOUZA, 2005; SILVA, 2000).

This arrangement of urban networks and flows was consolidated when Fortaleza extended its regional influence over all of Ceara state in the middle of the 19th century. Due to its political centrality and location along the coast, Fortaleza became the drainage and runoff center of agricultural production of greater value in the province. Thus, with the main routes converging to Fortaleza coast, the capital city intensified its activities over the countryside, expanding its control over other regions. Throughout the 20th century, the centralities were reinforced, increasing Fortaleza's economic and political-administrative control over the state's territory (SILVA, 2000).

The configuration of this relation system reproduced a logic that concentrated economic activities in the most favored areas. On the one hand, the induction effects in favor of the capital were maximized, whose centrality strengthened by the provision of superior services favors the Fortaleza Metropolitan Region cutout over the other regions in Ceara. The centrality was already expressive, and with the last decade dynamics, the new urbanization rhythms only emphasize the metropolitan notoriety as a locus of technical and operational density of flows and services.

It is for that reason that, in the context of Ceara urban network, Fortaleza is still a node to which the main regional highways converge. They drain most of the people, goods and products flows into the metropolis. According to Pequeno et al. (2020), this fact reaffirms that "the disparities in economic and social development among Fortaleza, the medium-sized cities and the regional centers are huge, since a large part of the demand for services and commerce in Ceara is met in the capital" (PEQUENO et al., 2020, p. 6)².

For Costa and Amora (2015), this centralization places Fortaleza in wide system of cities, playing an intermediate role between nearby regions and global places. At the same time, there are absences of other hierarchical levels between the capital city and

² "According to IBGE estimates, Fortaleza population exceeds the 2.6 million mark, corresponding to almost 30% of the population state. It is the densest Brazilian capital city, one of the 10 densest municipalities in the country. Fortaleza also commands a metropolitan region with more than 4 million inhabitants, composed of another 18 municipalities" (PEQUENO et al., 2020, p. 6).

other urban network cities, which is a common spatial pattern in Brazilian North and Northeast regions.

On the other hand, in a smaller proportion in comparison to Fortaleza, non-metropolitan regional centers also register concentration in relation to other regions in the state. Even though the centrality being smaller, the rhythms in both Sobral and in CRAJUBAR region (an urban agglomeration formed by Crato, Juazeiro do Norte and Barbalha cities) are significant, confirming that, outside the metropolitan environment, the urban dynamism chooses second order polarized areas to develop its commanding capacity. This way, the two mentioned regions participate with indicators below the metropolitan performance in the concentration of urban rhythms. On the other hand, they are distant from the predominant pattern in other Ceara regions.

It is also relevant to mention the timid expressions of little affected regions by the social and economic activities expansion. They illustrate how some few municipalities feel the advancement effects of a greater complexity goods and services supply. When this fact happens, either the mentioned regions are on the state coast, being better served by tourism services, or the municipality is under influence of a greater expression center that breaks with the traditional urban hierarchy interactions.

During this Covid-19 pandemic period, the Brazilian Institute of Geography and Statistics (IBGE) published a new edition of a classic study on Brazilian urban networks called *The Regions of Influence of Cities* (IBGE, 2020a)³. REGIC 2018's approaches are based on the Christaller's concept of "central places" and Rochefort's concept of "relationships life", defining a cities' influences network according to companies' location linked to business management, supply of services and equipments which serve other urban centers (IBGE, 2020a).

In relation to Ceara, REGIC 2018 classifies the cities' network encompassing a metropolis 1C (Fortaleza), a regional capital city B (AP Juazeiro do Norte), a regional capital city C (AP Sobral), a subregional center A (Iguatu), eleven subregional centers B (Aracati, Baturité, Camocim, Crateus, Itapaje, Itapipoca, Limoeiro do Norte, Pacajus, Quixada, Russas e Tiangua), six centers of zone A (Brejo Santo, Horizonte, Ico, Quixeramobim, São Benedito, São Gonçalo do Amarante) and eight centers of zone B (Acopiara, Canindé, Guaraciaba do Norte, Ipu, Mauriti, Mombaça, Santa Quitéria and Taua) (IBGE, 2020).

Such division confirms what has already been said about Fortaleza and its wide reach in the city system, besides legitimizing the absence of many hierarchical levels between the metropolis and the other urban centers. As a result, there is a great disparity in the territory and also a high concentration of services and products in the capital city, being translated into space through strongly centralized regional urban arrangement, marked by a great convergence of transport networks and of flows to a single urban center.

³ The first REGIG research edition is from 1972 (based on data from 1966) and it was called "Division of Brazil into Urban Functional Regions". The nomenclature "Regions of Influence of Cities" was used only from the second edition on, in 1987. Its other editions dates from 1993 and 2007.

Did this fact have anything to do with the way that SARS-CoV-2 spread through Ceara? Did it result in a scope, in a contamination potential and in a diversified mortality rate? Did it represent a Covid-19 dissemination equivalent to the spatial distribution of the health service offer/quality?

The next section brings the answers to the above questions by focusing the discussion on characterization of the health system offer and quality in line with the Ceara urban network.

Ceara urban network structure based on the health services

Due to the data update and the identification of health equipment and services most sought after by different urban centers, REGIC 2018 (IBGE, 2020b) allows an approach and a classification of Ceara urban network based on this theme. These data are provided by the Ministry of Health and by the Oswaldo Cruz Foundation (Fiocruz). The data were systematized by IBGE, allowing to indicate the centrality of health services in the territory, besides revealing the largest population displacements in search for health services within the regional urban space.

In order to perform the analysis presented in this section, we identified the amount and the reasons for displacements in order to access health services: a) a pattern of low-medium complexity; b) and another pattern of highly complexity. This way, it is possible to apprehend the urban centers polarization capacity and their populational displacement rhythms, as well as the articulation among flows, points and traffic nodes, which define the Ceara urban network arrangement in the selected dimension.

The procedures that do not involve high technology and high cost in health care are included in the “low-medium complexity services” category. Examples of such procedures are medical and dental consultations, clinical exams orthopedic and radiological services, physiotherapy, minor surgery and services that do not imply hospitalization (BRASIL, 2009).

According to REGIG 2018 classification and based on this pattern, the Ceara urban network arrangement defines Fortaleza and Sobral as the cities of the greatest polarization in Ceara. Fortaleza metropolis meets the demand of 4.936.785 inhabitants, who live in a total of 31 municipalities, while Sobral meet 952.699 inhabitants even though polarizing a greater number of municipalities, 34 in total. Concerning to centralization potential, other relevant cities are: Juazeiro do Norte (with 595.551 inhabitants, living in 15 municipalities), Iguatu (encompassing 296.380 in 11 municipalities), Crateús (with 185.707 inhabitants in nine municipalities) and Limoeiro do Norte (with 167.697 inhabitants, living in ten municipalities).

In relation to the to the population dependence degree which requires these low-medium complexity services through the number of cities where it is consumed, it was possible to find the maximum concentration degree (100%) in some municipalities. This mean that, there is only one important destination for the municipality that seeks this service. Such result occurs in Barro and Porteiras (polarized by Brejo Santo), Eusebio and

Caucaia (polarized by Fortaleza), Caririáçu (polarized by Juazeiro do Norte), Quixelo (polarized by Iguatu), Alcantara, Coreau, Meruoca and Moraujo (polarized by Sobral).

Even without the certainty if all residing people in the indicated municipalities will use the low-medium complexity health services in the urban centers where they are taxed on, the general trend of displacements strengthens the Ceara urban network's traditional arrangement. In other words, Fortaleza, Sobral and Juazeiro (which serve respectively 35,7%, 14,8% and 9,2% of the state population) are highlighted. The metropolis and the two medium cities confirm their centralities for the mentioned type of service.

The "high complexity services" analysis points to a slightly different behavior in the territory. According to the Unified Health System (SUS), these services bring together a set of procedures that use high technology and high costs (BRASIL, 2009). Thus, due to its nature, the tendency to a great spatial concentration and to a smaller supply distribution is confirmed in relation to the numbers of cities. Only ten in an amount of 184 municipalities in Ceara are able to offer high complexity health services, and even so, there are considerable differences among them.

Fortaleza is by far the city with the greatest regional polarization, serving 4.527.491 inhabitants, residing in 106 municipalities. Sobral follows Fortaleza, offering services to 895.775 people, spread over 36 municipalities. Two other centralities complete the regional demand for high complexity health services: Juazeiro do Norte/ Barbalha agglomeration, which serve 816.672 inhabitants in 30 municipalities (Juazeiro do Norte with 482.286 inhabitants in 15 municipalities and Barbalha with 334.386 inhabitants in 15 municipalities); and Iguatu, offering services to 92.956 people, with a direct influence in five municipalities.

Among other indicators, the high centralization degree in Fortaleza is expressed in the variable from the eleven municipalities that consider the metropolis as the only destination in case of demand for high complexity services. The municipalities are located in Fortaleza Metropolitan region such a Aquiraz, Cascavel, Caucaia, Eusébio, Horizonte, Maracanaú, Pacatuba and Pindoretama, but they are not limited to it. Some municipalities as Amontada, General Sampaio, Paracuru and Sobral also elect the capital city as priority in offering the high complexity services.

Unlike low-medium complexity health services, spatial and interactional flows among urban centers present two major factors: a) spatial distance and contiguities are less relevant; b) the speciality and quality of the services offered by the hub city have a much more significant role.

Figure 01 shows a spatial representation of the two service distribution patterns within the Ceara urban network. It is possible to notice the differences in spatial arrangements when the two cartograms are compared. Encompassing the low-medium complexity health services, Cartogram A identifies a greater dispersion of flows in the urban network, with a greater participation of the cities with different sizes and shorter distances. Microregional displacements, including cities from neighboring states, are

affirmed as much as the longest displacements to centers such as Fortaleza, Juazeiro do Norte and Sobral. In Cartogram A, it is also possible to identify Sobral as a highlight in relation to its direct influence area. The city is highlighted, even compared to Fortaleza, due to the fact that it polarizes more municipalities with priority 1, that means, those that concentrate between 80% and 100% of people deciding to move in order to access low-medium complexity health services.

Meanwhile, Cartogram B presents another configuration, territorializing flows for high complexity health services. In this case, Fortaleza reveals its metropolis power, since it clearly centralizes most of the flows for the access to these services. Another representative data is that the centrality occurs in several scales, either in Ceara state dimension, draining micro, meso and macro regional flows, or in the North and Northeast regions dimension, attracting displacements from different states. Cartogram B also presents Sobral and CRAJUBAR as important centers for attracting flows of high complexity health services. Even though they do not offer the same specialties as Fortaleza, it is possible to notice that there is a strong attraction of demand located in municipalities from the north regions in Ceara and in Piauí, in the case of Sobral; and in the south regions in Ceara and in Piauí, and west of Pernambuco, in the case of Juazeiro do Norte.

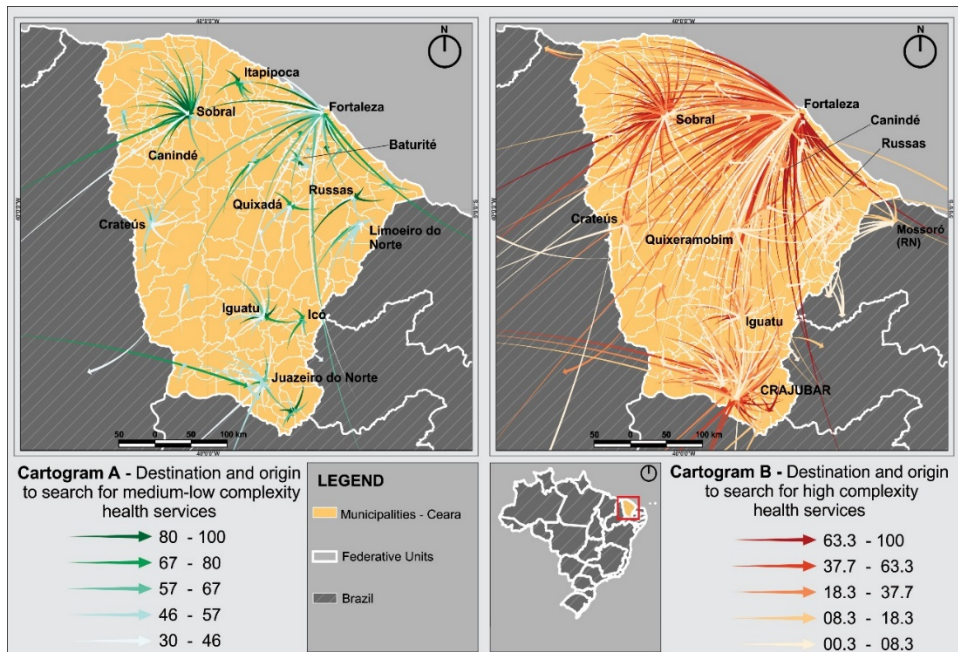


Figure 01: People flows with origin and destination displacements in cities for access to low, medium and high complexity health services – Ceara (2018).

Source: REGIC 2018 (IBGE, 2020b). Map base: IBGE, 2019; Geographic Datum: SIRGAS 2000; Elaboration: Eudázio Sampaio.

In order to better understand the quality of the services that characterize the urban network and the attractiveness level of its centers, REGIC 2018 developed the “attraction index” (IA) from the city. The index is calculated from the relationship between the residing interviewed population in each municipality and the percentage of destinations which offer the services under analysis. In Figure 02, the cartograms represent Ceara urban network structure from the “attraction index” for low-medium and high complexity health services.

The cartograms indicate not only first order of frequency interactions (priority 1), but also lesser intensity interactions, being very representative about the importance degree of different Ceara cities in the urban network organization. Even if there is the confirmation of the high centrality exercised by Fortaleza in relation to the health service offer in general, demonstrating its isolated position in relation to other centers, the cartograms also indicate the different gradation of the attraction indexes in the most diverse cities, revealing the role they play within the scope of the state and of the influence regions.

Cartogram A is organized based on a scale of the attraction indexes of urban centers for low/medium complexity health services. It is possible to observe a relative urban centers territorial distribution with some offer for those services, even if it is the predominance from cities with a low attractiveness degree (between 0 and 2), such as Iguatu, Crateus, Crato, Barbalha, Brejo Santo, Quixeramobim, Quixada, Caninde, Russas, Limoeiro do Norte, Aracati, Itapipoca, Camocim, among others. Juazeiro do Norte is at a higher scalar level, between 2 and 4, since the city is considered the largest hub for this type of service in the state southern region. Sobral, in turn, reveals its centrality potential, being spread over a much larger dimension than the others cities located in the countryside region. Sobral has an attraction index between 8 and 10, which means that it is closer to Fortaleza polarization capacity. Fortaleza takes the lead of the attractions for these services once it presents an attractiveness degree above 12.

The biggest characteristic of low medium complexity health services is an intensive and low cost technology use in medical care, in order to allow a greater diffusion of these activities in the territory. However, observing Cartogram 1, it possible to notice that the semi aridity condition and the disjointed structure of the Ceara urban network are imperative due to the predominance of large voids in the territory to meet the demand although a tendency towards easier diffusion of low-cost services.

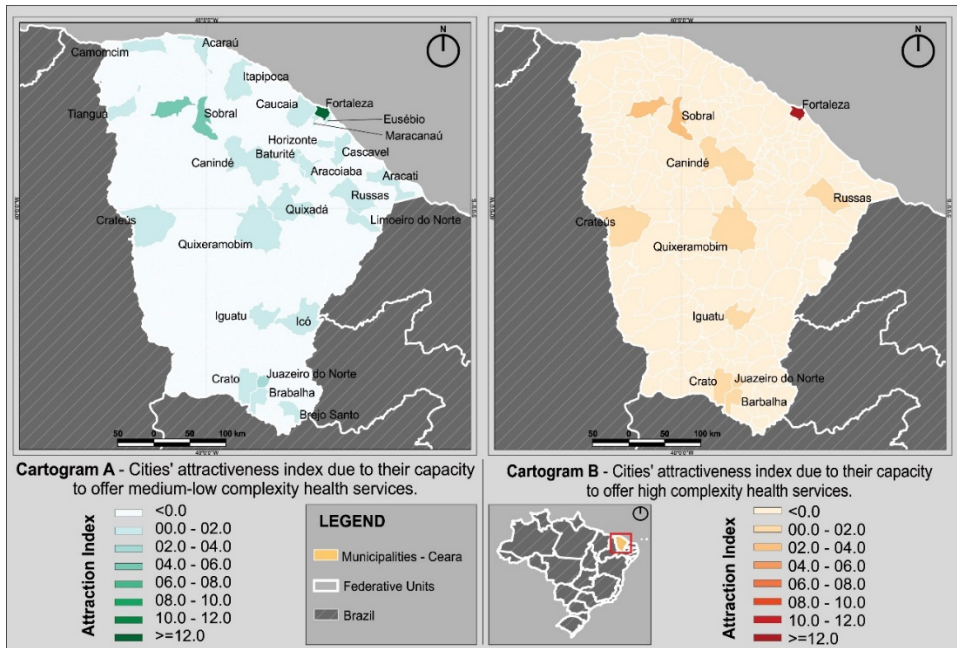


Figure 02: Ceara Cities' Attraction Index in relation to the use of low, medium and high complexity health services – Ceara (2018).

Source: REGIG 2018 (IBGE, 2020b). Map base: IBGE, 2019; Geographic datum: SIRGAS 2000; Elaboration: Eudázio Sampaio.

Cartogram B represent the attraction index for high complexity health services, having a smaller distribution of populational attraction centers for these services in the state. Thus, only ten cities in Ceara have the conditions to meet a demand for services with high complexity level, but their distribution across the territory is an indicative of a relatively balanced arrangement, especially due to their equidistance. This fact demonstrates an effective regionalization of the attraction urban centers, being able to stimulate the setting of an infrastructure for flow circulation and for a wide offer of equally efficient services, mainly if the public institutions collaborate for the effectiveness of this configuration.

In the centrality order, due to the services' specialization, only three groups of municipalities show results. Fortaleza remains important and isolated, with an attraction index above 12 and a coverage degree that encompasses the entire territory. Sobral has an attraction item between 2 and 4, polarizing some municipalities in the Acarau Valley, Ibiapaba Region, North Coast and part of the Inhamus Region. Finally, in the range between 0 and 2, the highlighted regions are: Crato, centralizing the Inhamus region; Caninde and Quixeramobim, which centralize the municipalities in Central Hinterland; Russas, which centralizes the Lower Jaguaribe region; Iguatu, with the Center-South municipalities; and the CRAJUBAR, which influences the entire Cariri region.

Ceara urban network analysis can greatly help in understanding the carrying capacity of people flows presented by the main cities, considering the information from REGIC 2010 (IBGE, 2020b), especially when it identifies the health equipment and services most in demand in different urban centers. By defining the level of attraction and infrastructure of health services that certain regions have within the cities' network, it is possible to rationalize the Covid-19 spread and contamination/death intensities in different scales, facilitating the control.

With numerous interaction deficiencies, irregular and disproportionate centrality degrees, as shown by the cartograms of Ceara case, a disjointed urban network will inevitably overload the few centers of greatest relevance, as it is for them the sick population tend to flow. All of this, added to the traditional social and economic polarity performed by certain cities with greater dynamisms in trade and services and natural people agglomeration, tends to concentrate/ enhance the Covid-19 contamination in the urban centers, making them true points of attraction and spread of the disease.

The geographic interpretation of information about the Covid-19 genesis and dissemination in the context of regional urban articulation in Ceara verifies whether this trend is confirmed or not.

The Covid-19 dissemination in the territory

This section interprets the information provided by the Ministry of Health (IntegraSUS) and by the Ceara State Health Department about Covid-19 in Ceara in relation to its spread across the territory. Data on people contamination and deaths were systematized, encompassing the period from March to June 2020, which represents the first phase disease in the state⁴, when the indicators grow greatly, impacting in the health system which does not meet the demand for care due to the strong pressure caused by the contaminate people's flow what requires actions from the state government, expanding the service infrastructure, imposing restriction on vehicles circulation between the municipalities and establishing a strong people social isolation in cities.

The new coronavirus enters in Ceara between the end of February and the beginning of March 2020, mainly through international flights from Europe (Ministry of Health, 2020). The first cases were confirmed on March 15, 2020. The first contaminated people were two men and a woman. It is important to note that, after being update, the available data showed that there were, at least, 514 confirmed cases on March 15 in Ceara (SCIENTIFIC COMMITTEE TO FIGHT CORONAVIRUS, 2020). The cases were mainly concentrated in Fortaleza Metropolitan Region, with 356 cases, that is 69% in total. In the same date, there were also infected people in Sobral, Juazeiro do Norte e Iguatu, as shown in Figure 03.

⁴ This phase represents the greatest Sars-CoV-2 virus spread period in Ceara, covering its contamination peak. From the second half of July/2020 on, new cases number decelerated, growing a little later, falling again without interruption until the beginning of October/2020, when this paper is finalized. Meanwhile, in the same time interval, deaths numbers only decreased, indicating the second phase of the disease spread in the state.

One month later, in April 15, the state already counted 9.096 cases, equivalent to 32% of the total cases in Brazil, being the third federative unit in number of infected people⁵. It is 1.769% growth in comparison to data from March 15. Furthermore, 189 deaths were registered, being the first one confirmed on March 26, 2020. Of the total death cases, the absolute majority was concentrated in Fortaleza, since the capital city had 6.770 infected people (74%) and 143 deaths (75%) (see Figure 03). The cartogram for April 15 also shows that there is a case and death dispersion to other Ceara regions. In addition to Fortaleza Metropolitan Region, which encompasses Caucaia (326 cases and 7 deaths) and Maracanaú (234 cases and 6 deaths), other important Ceara municipalities were affected, such as Sobral (160 confirmed cases and 2 deaths) and Itapipoca (42 cases and 0 deaths), both located in the North region; and Iguatu (28 confirmed cases and 5 deaths) in the Center-south.

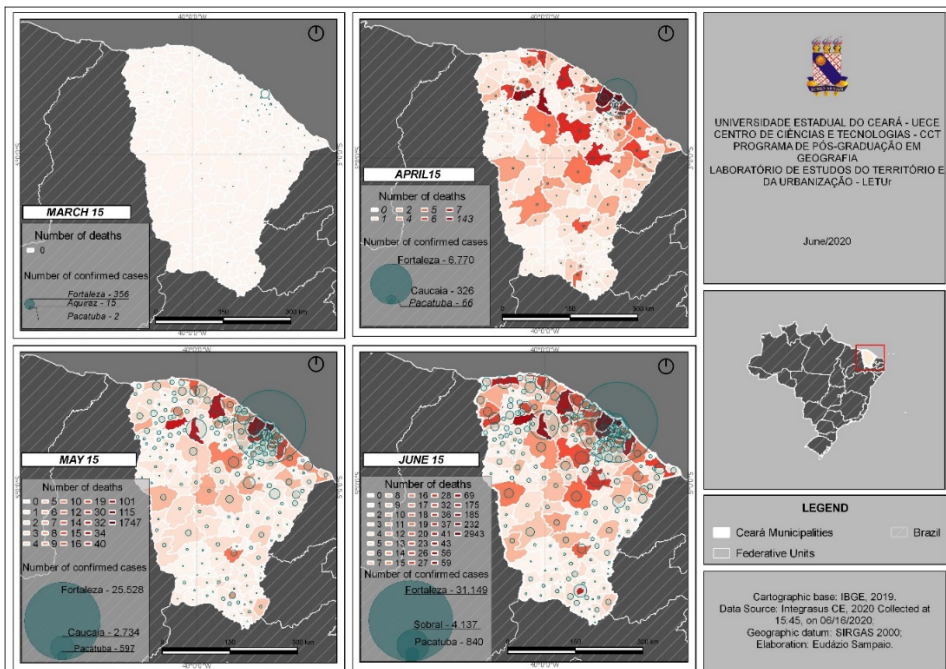


Figure 03: Time-spatial distribution of confirmed infected and death people's cases by Covid-19 – Ceara (03/15, 04/15, 05/15 and 06/15).

Source: Ceara State Health Department (Ministry of Health, 2020) Map base: IBGE, 2019; Geographic datum: SIRGAS 2000; Elaboration: Eudázio Sampaio.

The most significant advance takes place between April 15 and May 15, when the infected and death people numbers grow greatly in Fortaleza Metropolitan Region as

⁵ According to data from the Ministry of Health (2020), on this date, Brazil presents 28.320 cases and 1.736 deaths.

well as in the main urban centers in Ceara, also presenting higher contamination and death rates. In this period, the state registers 53.336 cases (an increase of 586% in one month) and 2.561 deaths (an increase of 1.355%). It is also the most critical moment in Fortaleza, with 25.528 cases (48% of the total in the state) and 1.747 deaths (68%). These indicators correspond to a considerable increase (377% of cases expansion and 1.221% of deaths expansion) in the face of a reality that had been critical for about a month. Isolation measures had already been taken by the state government, but they had not had an effect yet.

In Figure 03, the Cartogram of June 15 shows the most critical phase of Covid-19 in Ceara. In percentage terms, the advances are not as significant as the period from April 15 to May 15, considering that there is an expansion of 152% in the number of infected people and of 198% in the number of deaths. However, the accumulation of cases (81.289) and deaths (5.070) caused both trauma to people, due to the loss of family members, and impact to the health service system, which collapsed.

The effects on the territory were also striking and the expansion marks followed the rhythms of the social and economic dynamics in Ceara, defining centralities and displacements. Besides Fortaleza and its metropolitan region, the coastal regions (with greater tourist activity) and the urban centers of regional and local centralities were also affected, with emphasis on density of incidences in the northern region. On the other hand, as cartogram points out in Figure 03, the most distant areas from the main cities and the “deep” semi-arid region reveal a reduced number of contamination and deaths.

The social isolation is one of the most important measures to combat the virus proliferation. The isolation was imposed by Ceara State Government, which suspended the non-essential services operation and the intercity transport circulation, besides determining people confinement in their homes according to the State Decree number 33.510, published in the Official Gazette of Ceara State, in March 16, 2020, taking effect on April 20.

According to Figure 04, there is a considerable decrease in people’s circulation in cities and among the municipalities due to the measures imposed by the state government. The curve presents the evolution data of the Social Isolation Index, created and published by In Loco company⁶ on its platform. The curve also points out that the indexes mark a low social isolation, between 20% and 40%, before the date of the first cases of Covid-19 (March 15, 2020). After the decree was in effect by Ceara Government, from March 20 on, these rates quickly rose to values between 47% and 57%.

⁶ In Loco, a company from Pernambuco (active in Brazil and in the United States), works with localization technology development for private companies. During the Covid-19 pandemic, the company launched a geolocation data dissemination platform to determine a Social Isolation Index. They collect and use location data from mobile devices users, identifying the people presence, or not, in establishments. (Source: Privacy Policy of In Loco Company, 2020. Available at: <<https://public.inloco.ai/pt/privacy-policy>>).

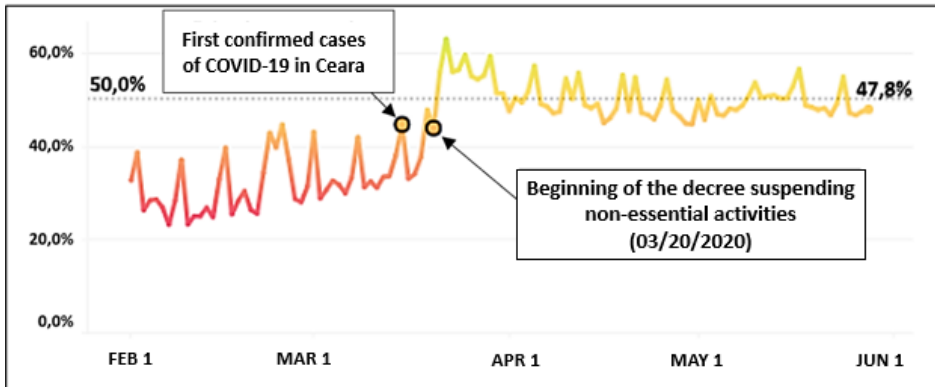


Figure 04: Social Isolation Index in Ceara (2020).

Source: In Loco, 2020. It does not represent the entire population.

During this period, although the decrease in people’s circulation, effected by the aforementioned decree, contamination and deaths cases still grew in the state. This fact happened due to the findings (already announced by some Imperial College London researches) related to the tendency of decrease in the number of infected and deaths caused by Covid-19 after the adoption of restrictive measures, although the effect is noted between two weeks and one month after the beginning of isolation (FERGUSON, LAYDON e NEDJATI-GILANI, 2020).

Thus, despite the delay, the containment measures revealed their effects. According to data from IntegraSUS, Ceara recorded a 39.4% reduction in the moving average of Covid-19 cases between the second half of June and the first half of July, indicating stability in the contamination average. In Fortaleza, the drop in death cases is 47.4% in the same period while there is a 16% reduction in confirmed, suspected and deaths cases in other state regions in spite of the different scenarios among the affected areas.

At a later stage, between the second half of July and the first half of October, when this article is finalized, both the number of new cases and the number of new deaths dropped considerably, making the state enter in a second phase, when the disease impacts had decelerated.

Covid-19 and the urban network fabric

Covid-19 produces a spatial configuration in Ceara state which can be related to its urban network interactions. In certain aspects, it reproduces the disjointed hierarchy of the relationship arrangement as well as the exacerbated centrality performed by Fortaleza and by some few centers. It also demonstrates a dispersion and concentration dynamics that subverts the network traditional patterns, sometimes showing tourist areas as areas of great contamination, and sometimes revealing subversion of the gravitational hierarchical models in the Sars-CoV-2 virus spread.

Figure 05 helps to analyze such configuration: it represents Ceara urban network hierarchy according to REGIG 2018; it highlights the highways that cross the state; and it shows the territorialization of the number of Covid-19 confirmed cases on June 15, the peak period of infections and deaths expansion.

On that day, Ceara presented 81.289 confirmed cases and 5.070 deaths by Covid-19. From this total amount, 31.149 infected people and 2.943 deaths were concentrated in Fortaleza, which means 38% and 58% from the total in the state. In the same date, the other municipalities in Fortaleza Metropolitan Region presented 14.938 infected people (18,3% of the state) and 857 deaths (16,9% of the state). The majority was reported in Caucaia, Maracanaú, São Gonçalo do Amarante, Maranguape and Eusebio, all of these cities with over a thousand confirmed cases.

The incident frequencies follow the urban network hierarchy pointed out by REGIG 2018. This way, we identified the role of the B and C regional capitals, which are the Population Arrangement of Juazeiro do Norte (Crato, Juazeiro and Barbalha/CRAJUBAR) and the Population Arrangement of Sobral (Sobral and Forquilha), where the numbers indicate a total amount of 5.273 infected people (6,5% of the state) and 222 deaths (4% of the state). In this centrality scale, there are some quite expressive indicators for Sobral, gathering alone 4.137 cases (5%) and 175 deaths (3,4%), being in the second position in the state and in the first position outside the Fortaleza Metropolitan Region.

Meanwhile, the sub-regional center A (Iguatu) and the sub-regional center B (Aracati, Baturite, Camocim, Crateus, Itapaje, Itapipoca, Limoeiro do Norte, Pacajus, Quixada, Russas, Tiangua) have 7.256 confirmed cases (8,9% of the state) and 323 deaths (6,3% of the state), having Itapipoca and Quixada the most significant numbers respectively: 1.369 (1,68%) and 1.319 (1,62%) of confirmed cases; 69 (1,3%) and 32 (0,6%) of deaths.

As shown in Figure 05, completing the network arrangement, there are the Centers of Zone A (Brejo Santo, Horizonte, Ico, Quixeramobim, Sao Benedito and Sao Gonçalo Amarante), comprising 2.970 confirmed cases (3,6%) and 92 deaths (1,8%); and the Centers of Zone B (Acopiara, Caninde, Guaraciaba do Norte, Ipu, Mauriti, Mombaça, Santa Quiteria and Taua), which together make up 2.235 confirmed cases (2,7%) and 85 deaths (1,6%).

We reiterate what has been said about the disease territorial dispersion in Ceara, that is, the first cases were identified in the capital city, being later diagnosed in greater numbers in other Ceara regions. According to data from the Ceara Health Department, until May 2020, Fortaleza had about 90% of the total infected people and death in the state. A month later, in June, around 30% of the contaminated people and 20% of the deaths were concentrated in municipalities outside the Fortaleza Metropolitan Region.

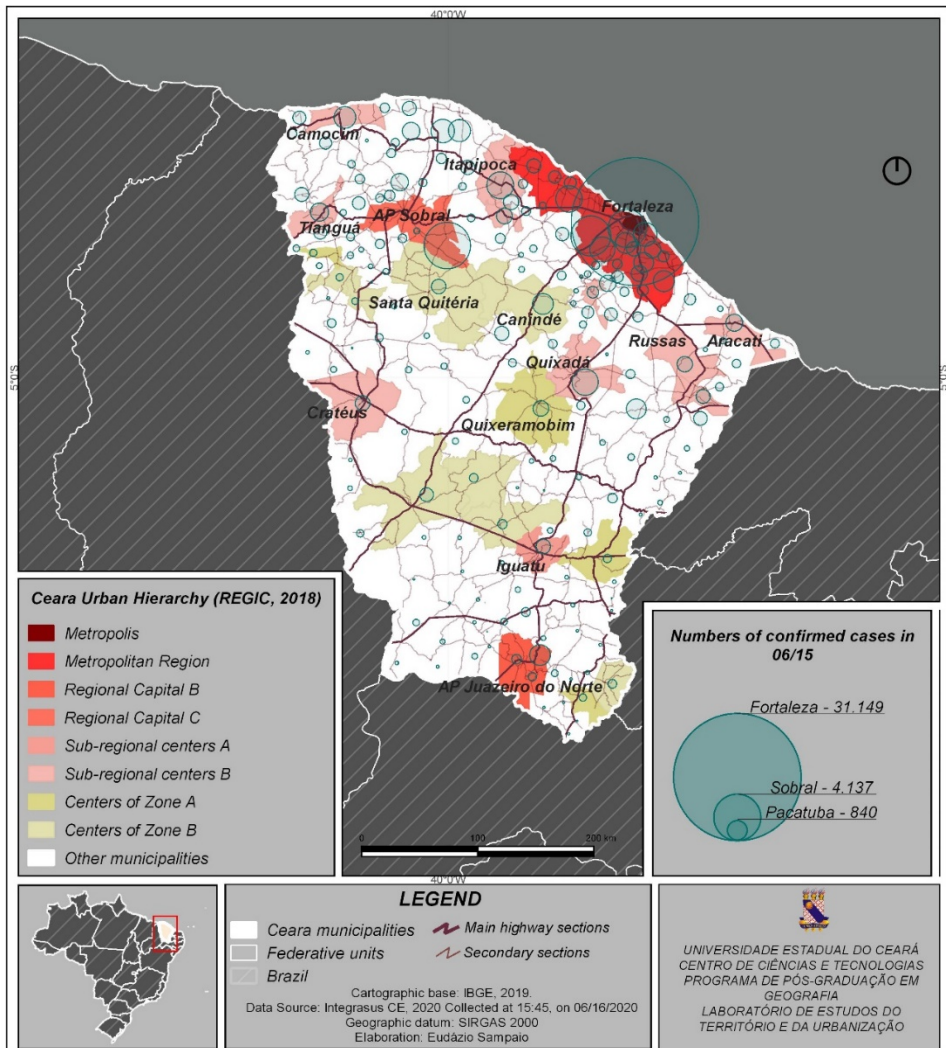


Figure 05: Spatial distribution of COVID-19 (SARS-CoV-2) confirmed cases in relation to the highways and the urban hierarchy.

Fonte: Source: REGIG 2018 (IBGE, 2020a); Source of information on highways: DNIT, 2020; Ceara State Health Department (Ministry of Health, 2020). Map base: IBGE, 2019; Geographic datum: SIRGAS 2000; Elaboration: Eudázio Sampaio.

It is possible to say that the new coronavirus entered in Ceara state through the capital city and was disseminated to the countryside, assuming a double movement with regard to its urban network arrangement:

1) On the one hand, the virus respects the hierarchy and centralities of conventional urban interactions. As diffusion vectors of the mentioned configuration are: a) the road network through which the absolute majority of people and goods flows pass; b) the asymmetrical distribution of product and service offers in urban centers which selectively guides the displacements and the relationship intensity, potentiating Covid-19 diffusion in some area while delay it in others.

2) On the other hand, it demonstrates the existence of a diffusion system that breaks with the traditional network pattern, subverting its influence hierarchy by revealing that smaller or distant urban centers have numbers of infected people and deaths greater than their immediate polarizing center.

Regarding the first case, as a concrete structure, the conventional urban network reveals the tangle of highways that articulate the relationships between people who consume goods, various services, consultancy, communications, higher education, hospitalizations and consultations, among others. All of these relationships have a collaboration potential in the disease spreading until the restrictive circulation measures are put in place.

In this configuration, it is possible to identify an “epicenter” in Covid-19 diffusion escalation throughout Ceara territory. The majority of infected people and death are concentrated in Fortaleza, where the new contamination comes from due to Fortaleza’s influence on the urban relation network as well as due to its demographic relevance and economic importance for the state. We should not forget that, in Fortaleza Metropolitan Region, there are the most dynamic modes of transport in the state, with their axes and traffic nodes that establish constant relations at the most diverse scales (regional, national and global), such as the Pecem port and the Mucuripe port, the Pinto Martins International Airport, bus stations, and duplicated highways.

On a lower scale, there are the urban centers with great regional importance, concentrating people and goods flows and spreading the disease to smaller cities. These urban centers bring together the best product and service offers outside Fortaleza Metropolitan Region, mainly in relation to commerce, health and education, even though it also develops agglomeration and daily people flow in meso and micro-regional space. By respecting the hierarchy scale already announced and their people attraction indexes, in a foreground Sobral and CRAJUBAR, and then Iguatu, Crateus and Quixada, reveal their ability to spread the new coronavirus.

Regarding to the second case, when the diffusion system breaks with the traditional hierarchical pattern of the network, the urban centers with unique geographical characteristics appear. Observing Figure 05, it is possible to identify three different situations in the hierarchy subversion, namely:

a) The urban centers and their respective municipalities that gather a people flow interested on tourism services: they correspond to spots of dissemination distributed along the coast (beach tourism) and inland (mountain tourism), highlighting the numbers presents by Camocim, Acarau, Itarema, Beberibe and Aracati, in the coastal environment;

Tiangua and Viçosa do Ceara, in the case of mountains. Generally, people who consume these services come from different places, not always respecting the hierarchy of the urban network but seeking these centers exactly for the different experiences they can offer to them. They become propagation vectors difficult to map, but with a high degree of efficiency in the discontinuous spatial disease spread.

b) small and medium scale traffic nodes within the scope of the urban network: they materialize themselves in urban centers with some demographic importance in relation to the regional environment, but they stand out for being a support for the meso micro regions in Ceara. As shown in Figure 05, it is worth mentioning Itapipoca, Caninde, Quixeramobim, Morada Nova, Russas and Taua for concentrating a higher incidence of cases due to presenting themselves as articulation points among different circuits (important bus stations), becoming passage places among different cities, spreading, therefore, the Sars-CoV-2 virus in a more comprehensive way than in other cities that are at higher level in the urban network.

c) the nuclei that establish interactions independently of the conventional urban network: they correspond to the small centers that articulate themselves with other centers through productive, business or migratory circuits alternative to the traditional urban network arrangement. In Ceara, some urban centers such as Santa Quitéria, Itatira, Mombaça, Ipueiras, Uruburetama, Pentecoste, Tabuleiro do Norte, among others, represent a small regional centrality despite presenting a common fact: they participate in migratory, service and industrial production circuits that articulate them to other centers of great Covid-19 spread, such as Sao Paulo, Rio de Janeiro and Porto Alegre. In this articulation configuration, traditional networks are reframed due to the productive spatial circuit (as the case of the relationship between Santa Quitéria and Franca - SP) or due to the return migration performed by workers dismissed from the companies where they worked in Sao Paulo city, as stated in an interview by Nilson Diniz⁷ who is the president of the Association of Ceara State Municipalities (APRECE). These nuclei have a substantial contamination rate in spite of revealing a small number of cases in the micro-region to which they belong, generally marked by a deficient infrastructure in health service provision.

Thus, the urban network is an important reference to investigate the direction and intensity of the new coronavirus contamination and death flows in Ceara territory. It is an observation angle in the intersection of possibilities for reading the disease spread. In addition, it can also capture numerous aspects of the scalar mobility, which represents one of the most representative data of the virus territorialization.

⁷ In an interview to the *Diário do Nordeste* newspaper, APRECE president informs that “the disease advance in cities like São Paulo and Rio de Janeiro is sending back to hinterland cities dozens of workers who lost their job in industries, restaurants, stores etc.”. According to him, this return “[...] occurs mainly through clandestine routes that enter in Ceara, Pernambuco and Paraíba, in addition to a route through Piauí” (COSTA; BARBOSA..., 2020).

Considerations

Covid-19 produces a spatial configuration in Ceara state which can be related to its urban network interactions, indicating that the SARS-CoV-2 virus spread in Ceara is linked to the circulation and connectivity among its different cities, reproducing the disjointed hierarchy of the relationship arrangement and the exacerbated centrality exercised by Fortaleza and by some few urban centers.

So, it is possible to say that the new coronavirus entered in the state through the capital city, respecting the hierarchy and centralities of conventional urban interactions, whose diffusion vectors are the road networks through which the absolute majority of people and goods flow as well as the asymmetric distribution of the products and services offer in the urban centers. Thus, the displacements and relation intensities are oriented in a selective way, potentiating the Covid-19 diffusion in some areas while delaying in others.

On the other hand, due to the way in which the disease is territorialized, there is also a virus diffusion system that breaks with the traditional pattern of the urban network, revealing that urban centers with singular geographical characteristics, smaller or distant from the main centers, present numbers of infected people and deaths greater than their immediate polarizing centers. Three situations stand out for this experience: a) when the urban centers and their respective municipalities gather a people flow interested in tourism services; b) when the small and medium scale traffic nodes have more striking indexes than their superior centers; and c) when small urban centers bring together many cases and deaths by Covid-19 for participating in productive, business or alternative migratory circuits to the arrangement of the traditional urban network.

Thus, by interpreting the spatial discontinuities and by indicating an observation plan that skips scales and articulates points aligned to their interactions, the urban network approach contributes greatly to the vision which captures the density, the connectivity and the people circulation in relation to the Covid-19 dissemination in Ceara. As these are the factors that are responsible for the greater disease spread, its investigation is increasingly necessary to inhibit the perverse effects of its proliferation.

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