THE DIGITAL TECHNOLOGIES COMMAND: A THIRD DIMENSION OF THE CENTRAL FLOWS IN THE REGIC?

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Abstract

The study on the Areas of Influence of Cities (REGIC) primarily measures central flows based on the public management and business management of the territory. The aim of this article is to propose a third dimension for the operationalization of these long distance relations, considered from the perspective of digital command. This involves a theoretical-methodological framework, which considers the centrality and influence of the territory coupled with the flows of information, knowledge, and wealth, typical of a digital era. The methodology has been based on the development of an indicator to measure the digital command, which may be analyzed either individually or in conjunction with existing data on public and business managements. The article discusses the interplay between innovation and urban networks, which, while corroborating REGIC's findings, reveals centralities that may not be duly identified by the current methodology.

Keywords

Urban Centrality; Digital Era; REGIC.

O COMANDO NAS TECNOLOGIAS DIGITAIS: UMA TERCEIRA DIMENSÃO DOS FLUXOS CENTRAIS NA REGIC?

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Resumo

Os fluxos centrais na pesquisa Regiões de Influência das Cidades (Regic) são mensurados a partir da gestão pública e empresarial do território. O objetivo deste artigo é discutir uma terceira dimensão para a operacionalização dessas relações de longa distância pensadas a partir do comando digital. Trata-se de uma proposição teórico-metodológica que pensa a centralidade e a influência do território atrelada aos fluxos de informação, conhecimento e riqueza próprios de uma era digital. A metodologia está pautada na formulação de um indicador que pode ser analisado tanto de forma individual (para medir o comando digital) quanto de forma combinada aos dados de gestão pública e empresarial. O artigo coloca em discussão uma articulação entre inovação e rede urbana que reforça os resultados da Regic e indica centralidades que podem não estar sendo devidamente evidenciadas com a metodologia em vigor.

Palavras-chave

Centralidade Urbana; Era Digital; Regic.

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1. Introduction

The 2018 study Areas of Influence of Cities (REGIC)[1], conducted by the Brazilian Institute of Geography and Statistics (IBGE), incorporated the central flow theory into its theoretical framework to analyze the Brazilian urban network, and to classify the hierarchy of urban centers (IBGE, 2020). This approach acknowledges that the urban system consists of a combination of close and long-distance relationships. Close relationships, as described in Christaller's (1966) central place theory, involve the exchange of goods and services between urban centers and their hinterlands. In contrast, long-distance relationships, intensified by globalization, connect urban centers through intangible flows, fostering economic growth and the emergence of knowledge-intensive activities, referred to as "new work" (Taylor; Hoyler; Verbruggen, 2010).

In the REGIC, the close relationships are calculated from primary sources derived from questionnaires that measure the distances that populations need to travel in order to acquire goods and services. The hierarchy emerges from the intensity and level of complexity of these goods and services within urban centers. Long-distance relationships are determined in two ways: through public management, gauged by the hierarchy of government institutions (ranging from local to federal), and through business management, measured by the number of business headquarters and branches located in the urban centers (IBGE, 2020).

1. REGIC is the Portuguese acronym for *Regiões de Influência das Cidades*, which has been maintained and used throughout this article.

Our primary objective is to discuss a third dimension for the operationalization of the central flow theory, viewed from the perspective of what we term 'digital command'. This proposal aims to complement, rather than replace, the existing public and business management flows. The idea is to recognize a new type of flow that affects urban centrality, which, despite the substantial advancements of the digital era (Pochmann, 2022), has been overlooked in the operationalization of the REGIC framework based on public and business management indicators.

Digital command is not a focused emphasis on a particular sector of the headquarters-branch relationship as calculated within business management. Instead, it is a theoretical-methodological framework that considers the centrality and influence of the territory. It recognizes that the flows of information, knowledge, and wealth are shaped not only by the decisions of public and private managers but also by the supply of goods and services that underpin the emergence of new business models, and the profound transformation of management driven by new digital technologies (Fernandes; Sabino; Pimentel, 2021).

The theoretical reflection aligns with the formulation of the central flow theory (Taylor; Hoyler; Verbruggen, 2010) in the context of the digital era (Pochmann, 2022) and employs principles from the geography of innovation (Boschma, 2005; Storper, 1997) to consider command centers with the diffusion of the technical-scientific-informational medium (Santos, 2008, 2014). The methodology hinges on the development of an indicator to measure the presence of a digital command, which may be analyzed both individually and in conjunction with the flows of public and business managements that comprise the Territory Management Centrality (CGT)[2] index in the REGIC (IBGE, 2020).

It is certainly not the intention of this article to reclassify the urban hierarchy of the REGIC. Such a task would require significant institutional work and effort and would be beyond the scope of the authors. Our study is justified as a reflection, based on a brief exercise that reinforces the findings of the REGIC, while highlighting certain centralities that may have been overlooked with the IBGE methodology, which has relied solely on the flows associated with business management and public management.

This article is divided into four parts in addition to this introduction. In the following section, we discuss the methodology employed by REGIC to calculate the central flows, and our proposal for operationalizing the digital command. Next, we demonstrate what would change if the digital command were considered as

2. CGT is the Portuguese acronym for *Centralidade de Gestão do Território*, which has been maintained and used throughout this article.

a dimension of the central flows. The ensuing results are then discussed from the perspective of potential implications for the disparate insertion of Brazilian urban centers into the digital era. Lastly, we conclude with a discussion on the salient points we propose to underscore.

2. The central flows: business management, public management, and the digital command

Since the 1960s, the IBGE has conducted the REGIC, a series of periodic studies on the urban hierarchy and areas of influence of Cities3 in Brazil. To date, five editions have been issued (in 1966, 1978, 1993, 2007, and 2018), providing valuable findings for the allocation of public and private resources across the territory. Guided by Christaller's central place theory (1966) since its 1978 edition, the REGIC has sought to identify centrality based on the degree of complexity of goods and services offered in urban centers and the distance that the population needs to ravel to acquire them. In the 2007 edition, the study expanded its scope to include public and business managements, aiming to identify the "relationships of control, decision, and command between urban centers, delimiting the nodes of the hierarchical networks that influence other centers"[4] (Moura; Nagamine; Ferreira, 2021, p. 20).

The 2018 REGIC incorporated the contributions of Taylor, Hoyler, and Verbruggen (2010), recognizing that "every urban system is composed simultaneously of two processes: on the one hand, the city continues to play the role of providing goods and services polarizing its surrounding region in a contiguous manner, and on the other, it is part of a network of long-distance connections, which selectively interconnect" (IBGE, 2020, p. 70). The connections of cities operate in both a "town-ness" sense, related to their hinterland, and in the "city-ness" sense, constituted by networks that connect them to other cities through long-distance flows (Taylor; Hoyler; Verbruggen, 2010).

In the 2018 REGIC, the operationalization of long-distance relationships, which is of direct interest to us, is undertaken through an analysis of public management and business management. The first is grounded in the notion that "the headquarters of state institutions are decision-making hubs that impact the territory as a whole" (IBGE, 2020, p. 73). These flows, resulting from decision-making power, support a hierarchical structure that measures everything from providing

3. As in the REGIC, we have also capitalized "Cities" when the term refers to classified territorial units, either as a population arrangement (PA) – a term used by IBGE, consisting of more than one municipality, or just one municipality, when not included in a PA.

4. This and all other non-English citations hereafter have been translated by the authors.

services to the population to a division of institutional labor. This concerns how the "State manages the territory, collecting dispersed information and issuing directives and parameters for its decentralized units" (IBGE, 2020, p. 74).

The REGIC selects seven institutions in order to analyze public management: the National Social Security Institute (INSS), the Ministry of Labor and Employment (MTE), the Special Secretariat of the Federal Revenue, the Federal Justice, the Regional Electoral Courts (TREs), the Regional Labor Courts (TRTs) and the IBGE itself (IBGE, 2020). Subsequently, the units of these federal departments are classified into five management levels: level 1 is the most elementary (IBGE agencies and INSS service units, for example), closer to meeting the immediate needs of the population; level 2 contains regional units with a wider scope, but limited to the federative unit; level 3 is composed of state departments; level 4 corresponds to the agency in the large regions; and level 5 is the most comprehensive, corresponding to the national headquarters of each of these institutions. Through this organization, REGIC adopts the following equation for classifying urban centers according to the public management coefficient:

$$CGP_j = IP1_j + (2 \times IP2_j) + (4 \times IP3_j) + (8 \times IP4_j) + (16 \times IP5_j)$$

whereby *CGPj* refers to the central management of City *j* and *IPX* is the number of public institutions of level X considered in City *j*.

Business management, in turn, is based on the urban network constituted by multi-located companies, that is to say, "those that have at least two local units in two different municipalities, one of which must necessarily be the headquarters" (IBGE, 2020, p. 75). Centrality is not only given by the location of the headquarters:

> equally important is its ability to attract branches with headquarters in other Cities, whose concentration also defines nodal importance, since the relationships between the local units of the same company and their respective Cities are intensified, consequently strengthening its position as a network node (IBGE, 2020).

Within these terms, an Intensity Coefficient (IC) is calculated based on the total sum of headquarters and branches defined by REGIC (IBGE, 2020) using the following formula:

$$CIA = \sum SFextA + \sum FextSA + \sum FatrA + \sum SFatrA$$

whereby CIA is the intensity coefficient of the relationships of City A; $\sum SFextA$, the total sum of the headquarters in City A with branches in other Cities; $\sum FextSA$ the

total sum of branches related to $SFextA$; $\sum FatrA$ the total sum of branches located in City A whose headquarters are not located there; and $\sum SFatrA$ the total of headquarters that control the branches of $\sum FatrA$.

Although significant long-distance flows are considered in the calculation of the urban network hierarchy, the coefficients of public management and business management do not fully account for the intensified knowledge flows facilitated by new digital technologies. To address this perspective, we propose to complete the REGIC procedure by introducing a new coefficient that we call 'digital command', as a third dimension of the central flows.

The proposal of the digital command brings our argument closer to Santos' (2014) conception regarding the distinction between a scale of realization of actions and the scale of command. As Santos stated, "this distinction has become fundamental in today's world: many of the actions that occur in a place are a product of the needs of others, of functions whose generation is distant and of which only the response is localized at that precise point on the Earth's surface" (ibid., p. 80). Santos differentiates a technical command, linked to production itself, from a political command, carried out through "directives, disposition of surplus value, control of movement, all of which guides circulation, distribution and regulation" (ibid., p. 273). It may be said that the REGIC methodology has been concerned with measuring the political command of central flows. What we propose is to include the centrality arising from the technique, thus aiming at a complementarity in the study of the urban network that seeks to recognize the inseparability between technique and politics as command functions (id., 2010; 2014).

The digital command is rooted in the understanding that technical command exists in diverse forms, one being the capacity to leverage digital technologies. This competence has become indispensable for capital accumulation since the microelectronics revolution, also termed by Perez (2010) as the 5th Technological Revolution. The significance of these technologies has intensified with the advent of the world wide web (www), recognized by Albuquerque (2021, p. 70) as a "potent candidate for the position of radical innovation", which has emerged from a sequence of preceding breakthroughs within the long wave, coupled with a "systematic concern and demand for connecting different computers and their users" (ibid., p. 71). The advent of this network has marked a new technological revolution, profoundly influencing all sectors of economic activities, generating new activities, devices, and connectivity solutions that accelerate the flow of information on the network, resulting in new demands that become translated into inventions, goods, and firms. As Castells (2007) noted, we now live in the information age, where

specialized skills in the development of information technologies are crucial for the current dynamics of capital accumulation. It is not a matter of reducing the importance of other skills but recognizing that their development now depends on the integration of digital technologies.

To operate the function of digital command, we adhere to Taylor's (2005) principle that in order to analyze the urban network it is necessary to identify the agents responsible for interconnecting the cities. With the emergence of a digital era, knowledge flows have been potentiated between higher education institutions (IESs)[5] offering postgraduate programs (PGP) and undergraduate programs in computer-related fields and in technology-intensive software development companies. The presence of these institutions and companies fosters the availability of scientific and technological expertise and the exchange of knowledge among them, essential for meeting the demands of the digital transformation of the economic landscape and the development of new products and processes driven by the digital era. These capacities have repositioned urban centers within the territorial division of labor, given the diverse functions involved in the production and application of knowledge specific to digital technologies and the required complementarities and spatial interactions in this process. Knowledge (and innovation) evolves in a collective, interactive, and cumulative manner.

Our exercise of measuring the digital command coefficient has been conducted in two phases. In the first, we developed an index based on IESs operating in the fields of computer science and engineering. Our proposed methodology is similar to the approach adopted by REGIC to measure public management, but with a key distinction: in our study of digital command, we adhere to a hierarchical framework rooted in the complexity of knowledge. This aligns with central place theory, where higher specificity leads to broader spatial reach. In our case, we suggest a hierarchy that shifts according to the growing specificity and complexity of knowledge in the digital age.

Postgraduate programs occupy a higher hierarchical position due to their high sectoral and territorial capillarity. Sectoral capillarity is evident in the widespread adoption of information and communication technology (ICT) applications across the economic landscape, a hallmark of technological paradigms, particularly pronounced in activities such as "healthcare, education, agricultural and agribusiness, finance, aerospace and automotive sectors, defense, construction and

5. IESs is the Portuguese acronym for *instituições de ensino superior*, which has been maintained and used throughout this article.

legal services" (Capes, 2019, p. 3). Territorial capillarity is evident in the disparity between the widespread demand for ICTs, essential for the competitiveness of globalization (Santos, 2008), and their localized production, which relies on infrastructure and human resources that are concentrated into specific regions. In this context, PGPs in computer science and engineering take on a pivotal role.

The highest hierarchical level of IESs is represented by the PGPs with a rating of 6 or 7 in the 2017-2021 quadrennium, as assessed in Brazil by the Coordination for the Improvement of Higher Education Personnel (Capes, 2021). These esteemed programs – created between the 1970s and 1990s, have attained excellence due to their international engagement. Key criteria for achieving this rating are based on aspects such as the international recognition of publications, collaborative research with foreign co-authors; attraction for international professors and postdoctoral researchers; the receipt of international awards; organization of international events; participation in international research networks and involvement in doctoral committees abroad, which collectively underscore the internationalization of programs (id., 2019). These attributes align with the theoretical framework of central flows, which posits a synergy between the generation of new work, which increasingly requires complex knowledge, and the insertion of cities into the global landscape.

The second hierarchical level is composed of the PGPs in the field of computer science and engineering with ratings 4 and 5. This group comprises programs established after the year 2000, reflecting the trend toward decentralized postgraduate studies in Brazil. While these PGPs may not be sufficient to elevate the City to a global standing, their presence significantly strengthens national flows (with the active participation of teachers and students at conferences and in publication networks) and regional knowledge flows (with the conferral of master's and doctoral degrees).

The third and fourth hierarchical levels are defined by the undergraduate courses in the area of computer science (bachelor's and licentiate degrees), information systems and computer engineering. These courses contribute to the training of higher-level professionals, but with a lower degree of complexity and with a more restricted scope to local and regional coverage. At the third level, courses with a rating of 4 and 5 in the National Student Performance Exam (ENADE) were considered, indicating where student learning is above average, thus serving as a proxy to hierarchize the degree of knowledge. The fourth hierarchical level refers to courses with a rating of 3, understood as courses that promote student development in the ability to absorb basic knowledge regarding

ICTs. The database source used at this hierarchical level is the ENADE/INEP[6]. Although more recent data is available, we have used the year 2017 as a basis for compatibility with the 2018 REGIC data (IBGE, 2020).

We constructed a IES index (IIES) that considers the presence[7] of organizations in the Cities at the four hierarchical levels and a weight that doubles as the level increases. Thus, we used the following equation (1):

$$IIES = IES1j + (2 \times IES2j) + (4 \times IES3j) + (8 \times IES4j) \quad (1)$$

whereby *IES1j* is the presence of undergraduate courses in the selected areas with a National Student Performance Exam (ENADE) rating of 3; *IES2j* is the presence of undergraduate courses with ENADE ratings of 4 and 5; *IES3j* is the presence of a PGP in computer science and engineering with ratings of 4 and 5; and *IES4j* is the presence of PGPs with ratings of 6 and 7, all in City *j*. The data were calculated at the municipal level and aggregated according to the composition of the PAs within the REGIC. This enabled a comparison between our findings and the existing public management and business management indices of the REGIC.

The second pillar for calculating the digital command corresponds to services related to the software sector. These companies have responsibilities such as coordinating and managing markets; commanding data flows; creating artificial intelligence-based models; and providing feedback on business models (Silva Neto; Chiarini; Ribeiro, 2024). Thus, the networks created with digitalization are hierarchical and function following the influences of companies that are constituted as "nodes." These relationships manifest geographically, to the extent that the software segment with the greatest complexity is concentrated in specific regions (Evans; Gawer, 2016). Moreover, the ease of long-distance communication facilitated by ICTs allows these nodes to expand their reach nationally and internationally. In addition, identifying and engaging potential customers emerges as a key strategy for company growth.

In the Brazilian context, although software exports represent a relatively small proportion of the total market – 1.6% of US$ 11.858 billion in 2022, according to the Associação Brasileira das Empresas de Software [Brazilian Association of Software Companies] (ABES, 2023) – it is important to recognize

6. ENADE/INEP is the Portuguese acronym for the *Exame Nacional de Desempenho de Estudantes* and the *Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira*

7. We did not calculate the number of PGPs and courses when constructing the index, but rather their presence, indicating that that type of knowledge is produced locally. Therefore, the values were either 0 or 1.

that the presence of international flows significantly influence the development of Cities where they are evident. These interactions with the external market often involve a higher level of complexity in the exchange of knowledge. On the other hand, the Informatics Law has fostered the development of ICTs in collaborative research and development (R&D) projects between research institutions and the beneficiary companies, the latter being largely multinational corporations. However, these initiatives have provided opportunities for the creation of startups and, consequently, clusters of ICT companies in Cities across the country where the main PGPs in computer science were created.

Recognizing that not all software companies exert command over the territory, we have adopted the taxonomy proposed by Roselino (2006), adapted by Fernandes and Lacerda (2023) to align with the current National Classification of Economic Activities 2.0 (CNAE 2.0), which identifies companies with the greatest potential to constitute themselves as "nodes" of the central flows. The taxonomy categorizes the activities of the information technology services sector into four types, based on the level of knowledge required to develop the products that characterize them. Types 3 and 4 of a higher technological intensity, encompass the following activities: Development of Customized Computer Programs (CNAE code 6201-5) and Information Technology Consulting (6204-0) make up type 3; and Development and Licensing of Customizable Computer Programs (6202-3) and Development and Licensing of Non-Customizable Computer Programs (6203-1) make up type 4. The data on the software sector were calculated based on the number of establishments in 2017, made available by the Relação Anual de Informações Sociais [Annual Report of Social Information] (RAIS)[8], from the Ministry of Labor and Employment (MTE).

Our conjecture is that the digital command is potentiated by the co-location of an IES specializing in computer science and companies that develop more knowledge-intensive software within the same City. It is certain that geographic proximity, considered in terms of physical distance, is not solely determinative of interaction. These ties depend on a much more complex set of factors, including a minimum level of shared knowledge among the agents so that communication, interests, and a certain degree of common values and mutual trust may be established between them (Boschma, 2005). While software development companies, even those that are knowledge-intensive, may not require high-level researchers on

8. The *Relação Anual de Informações Sociais* (RAIS) is a compulsory administrative document from the Brazilian government, which aims to collect information regarding companies and employment.

their staff, they are able to access cutting-edge expertise through collaborative projects in remote partnerships with renowned research institutions (CGEE, 2020). However, despite these factors, geographic proximity can still reduce transaction costs, foster cooperation, and facilitate the exchange of tacit knowledge, as noted by Storper and Venables (2004). Thus, to strengthen its position in the global marketplace, a company can leverage the synergy between its locally developed scientific and technological competences and the economic actors within its region, including customers and suppliers operating on both national and international levels (Storper, 1997).

Based on this principle, the digital command was calculated by the following equation:

$$CDj = IIESj \times ESTj \quad (2)$$

whereby *CDj* is the digital command of City *j*; *IIESj* is the index of higher education institutions in City *j*, calculated based on postgraduate and undergraduate programs in computer science, according to the ratings by Capes and Enade; and *ESTj* is the number of establishments working with knowledge-intensive information services in City *j*. The results obtained serve as a parameter of comparison with the hierarchy derived from the REGIC procedure, offering indicators of potential shifts or continuities arising from the integration of a new dimension of centrality in the central flow study.

3. The digital command as a third dimension of the central flows

An initial observation regarding the findings concerns the number of urban centers that act in the production of the different types of central flows. While public management in the REGIC identifies 1,896 Cities and business management identifies 1,288, in the digital command we identify only 191. Following the same procedure adopted by the IBGE to measure the levels of centrality of business management and public management, the digital command was divided into nine classes of centrality, applying the Jenks natural break method (IBGE, 2020). The result is presented in Figure 1.

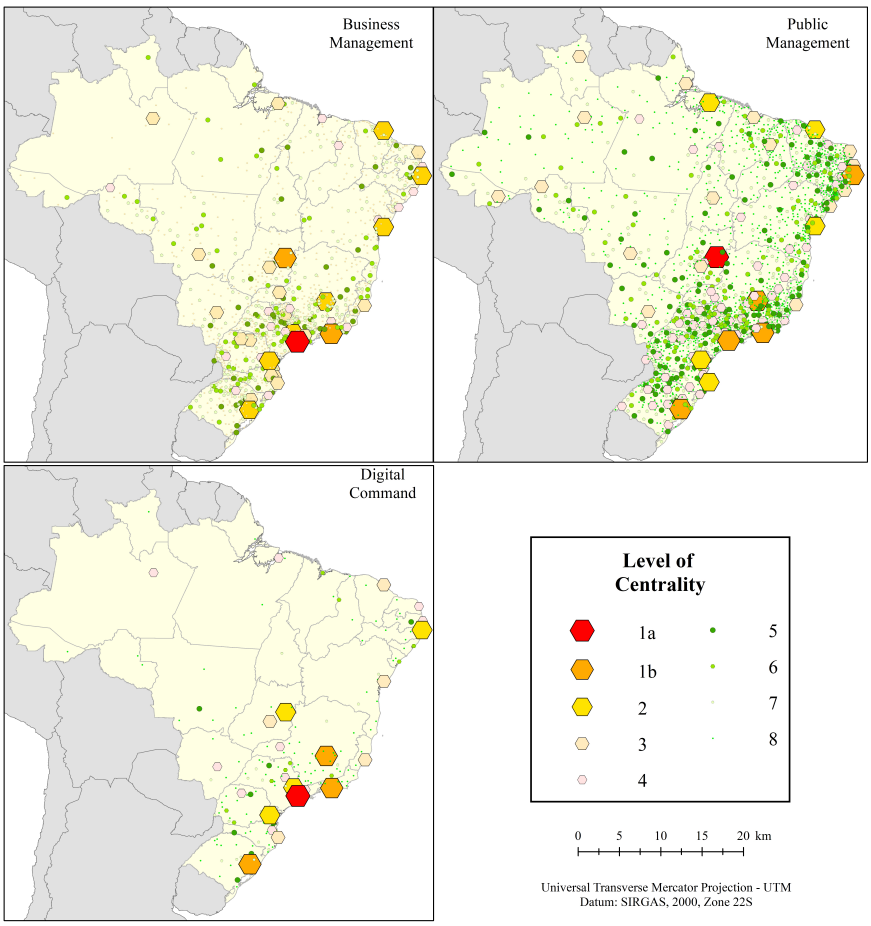

Figure 1. Brazil: centrality in the business management, public management and digital command
Source: IBGE, 2020 – business management and public management; own elaboration (digital command).

Following a hierarchical structure similar to that of the business management, the highest levels of centrality in digital command rely on the cumulative process that, over time, reiterates the prevailing trend of centripetal forces directed towards Cities with higher economic and population densities and position in the urban hierarchy. Within this context, this dimension accentuates the centrality of the São Paulo PA, with the maximum hierarchical level (1a), as would be expected, as well as the PAs of Rio de Janeiro, Belo Horizonte, and Porto Alegre, which appear with centrality 1b. The main difference is the decrease in Brasília, which appears with level 1a in public management, 1b in corporate management, and 2 in digital command. Table 1 presents the differences identified in the fifteen main centralities in digital command compared to public and business corporate managements.

Cities	Digital command		Public management		Business management	
	Index	Level	Index	Level	Index	Level
São Paulo (SP) PA	44,460	1A	58	1B	75,913	1A
Rio de Janeiro (RJ) PA	11,775	1B	66	1B	28,984	1B
Belo Horizonte (MG) PA	8,985	1B	50	1B	15,174	1B
Porto Alegre (RS) PA	7,605	1B	50	1B	16,707	1B
Recife (PE) PA	3,735	2	56	1B	9,583	2
Campinas (SP) PA	2,838	2	17	4	9,840	2
Curitiba (PR) PA	2,576	2	40	2	14,663	2
Brasília (DF) PA	2,366	2	154	1A	25,368	1B
Florianópolis (SC) PA	2,037	3	40	2	5,185	3
Fortaleza (CE) PA	1,400	3	42	2	8,638	2
Goiânia (GO) PA	1,288	3	32	3	7,155	3
Salvador (BA) PA	1,197	3	42	2	8,784	2
Vitória (ES) PA	1,001	3	32	3	7,313	3
São José dos Campos (SP) PA	784	4	14	4	4,296	3
Maringá (PR) PA	679	4	13	4	3,726	3

Table 1. Main centralities in the digital command: comparison with public and business managements

Source: IBGE, 2020 – business management and public management; own elaboration (digital command).

A second procedure to measure the impact of integrating the digital command as a third dimension of central flows involves its links with the Territory Management Centrality (CGT) index. This provides a comprehensive approach to identifying how the State and the market go about structuring the territory based on their organizational and operational scales (IBGE, 2020). As the REGIC states, "on the one hand, public bodies, foundations, and institutes manage and implement public policies and services for the population, and on the other, companies act as the economic backbone of the territory producing goods and services and generating jobs (ibid., p. 75).

To consider the Centrality of the Territory Management and Innovation (CGTI) index, including the digital command indicator in the CGT, we used a similar procedure to that of the REGIC, as expressed in the equation (3):

$$CGTlj = \log CGPj + \log (CIj) + \log (CDj) \quad (3)$$

In this case, *CGTlj* refers to the centrality of territory management and innovation; *CGPj*, to the centrality of public management; *CIj*, to the intensity coefficient of business management; and CDj, to the digital command, all in City *j*. Adopting this procedure, we calculated the centrality levels using the classification of equal intervals, arriving at the result in Figure 2, which compares the *CGT* and the *CGTI*.

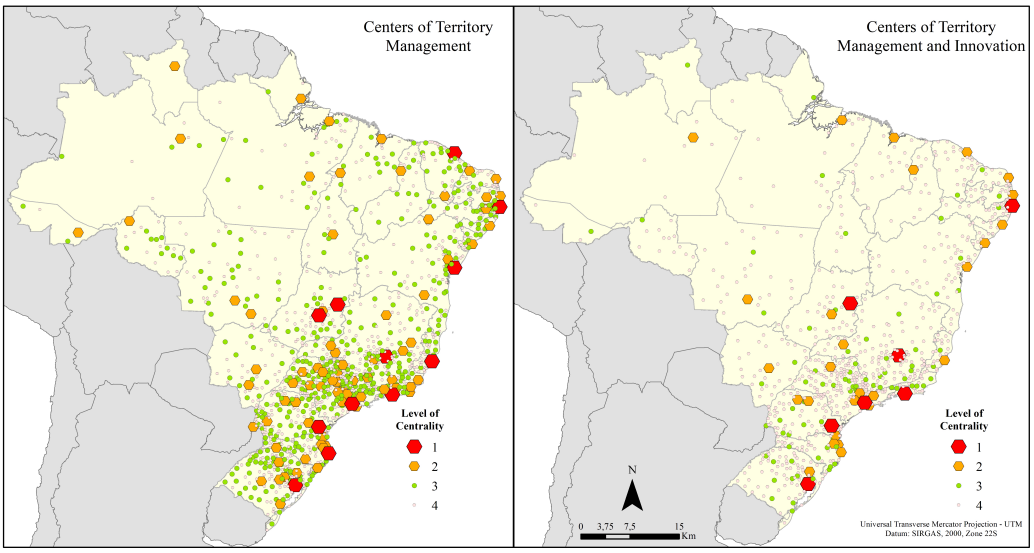

Figure 2. Central Flows: Centralities of the Territory Management and Centralities of the Territory Management and Innovation

Source: IBGE, 2020 – business management and public management; own elaboration (digital command).

The inclusion of a third dimension, with high territorial selectivity, ultimately reduces the number of centers with a higher hierarchical level. In this new classification, the main central places would need to combine the capacity to generate business, public management, and knowledge flows aimed at command in a digital era economy. In effect, while the CGT considers a total of 12 Cities at Level 1 and 77 at Level 2, the CGTI reduces this number to seven Cities at Level 1 and 28 at Level 2. The seven Level 1 centers are the Metropolitan Regions of São Paulo, Rio de Janeiro, Brasília, Belo Horizonte, Porto Alegre, Recife, and Curitiba, in order of classification (Table 2).

There are parallels between the CGT and CGTI indices regarding Northern Brazil in terms of the absence of Level 1 centers in the central flows. However, including the digital command results in only the Manaus and Belém PAs retaining Level 2 centralities, while the other state capitals and the Marabá PA are relegated to Level 3. In the Northeast, the Salvador and Fortaleza PAs maintain their Level 2 status, while the Recife PA is the sole Level 1 center. The remaining state capitals in the region remain at Level 2, with no other centers in the interior achieving this hierarchy. In the Midwest, the Goiânia PA retains its Level 2 status, while Brasília is the only Level 1 center, and the Level 2 urban centers in the interior are repositioned to Level 3.

Cities	Territory Management[a]		Territory Management and Innovation[b]	
	Index	Position	Index	Position
São Paulo (SP) PA	6,6437	1	11,2917	1
Rio de Janeiro (RJ) PA	6,2817	3	10,3527	2
Brasília (DF) PA	6,5918	2	9,9658	3
Belo Horizonte (MG) PA	5,8801	5	9,8336	4
Porto Alegre (RS) PA	5,9219	4	9,8030	5
Recife (PE) PA	5,7297	7	9,3020	6
Curitiba (PR) PA	5,7683	6	9,1792	7
Florianópolis (SC) PA	5,3168	12		
Fortaleza (CE) PA	5,5597	9		
Goiânia (GO) PA	5,3597	11		
Salvador (BA) PA	5,5669	8		
Vitória (ES) PA	5,3692	10		

Table 2. Centrality of Territory Management and Centrality of Territory Management and Innovation at level 1

Source: IBGE, 2020 – business management and public management; own elaboration (digital command).

Note: a) The classification per level is distributed as follows: 77 Cities at level 2, 455 Cities at level 3, and 573 Cities at level 4, totaling 1,117 Territory Management Centers. Another 3,782 Cities were not considered management centers, since there are subordinate to the influence of other centers; b) The classification per level is distributed as follows: 28 Cities at level 2, 80 Cities at level 3 and 484 Cities at level 4. The other cities do not exert centrality in digital command alongside territory management.

In the case of the CGT, the Southern region has 18 Level 2 centralities, all comprised of urban centers within the states, and three Level 1 centralities, which correspond to the state capitals. In the CGTI, Florianópolis drops down to Level 2 and only six interior centralities retain their position: the PAs of Maringá (PR), which emerges as the main interior centrality of the Southern region in central flows, Blumenau (SC), Joinville (SC), Londrina (PR) and Itajaí-Balneária Camboriú (SC).

In the Southeast, the CGT identifies the four state capitals as being Level 1 centralities. However, when the digital command is included, some changes may be observed. Among the capitals, the Vitória (ES) PA moves up to Level 2. In relation to the interior of the states, the number of Level 2 Cities dwindles from 24 to just seven. Six are located in the interior of São Paulo – the PAs of Campinas, São José dos Campos, Baixada Santista, Jundiaí, Sorocaba and São José do Rio Preto – while one is situated in the interior of Minas Gerais – Uberlândia. It is plausible that the pioneering interiorization of state institutions of higher education and research, with units of excellence distributed throughout the state whose area of influence exceeds its political-administrative limits, provides support for sustaining the vitality of sub-regional São Paulo state economies in this digital era.

4. Urban Centrality in the Digital Era: what does the new dimension for measuring central flows demonstrate?

According to Pochmann (2022), post-colonial Brazil has undergone four major structural transformations: the first was the formation of the nation through independence in the 1820s; the second, starting in the 1880s, was entry into the capitalist economy; the third, the constitution of the modern State and the enabling of an urban-industrial society, from 1930; and the fourth, a transition to the digital era at the turn of the twenty-first century, coinciding with social and production disintegration. Each change, the author continues, "has reconfigured cultural symbols, behavioral models, social organizations, and value systems" (ibid., p. 12), leading to changes in the driving forces of urban centrality.

The fourth structural transformation, as identified by Pochmann (2022), is a direct consequence of the 5th Technological Revolution (Perez, 2010), the civilian application of technologies linked to the US military-industrial complex (Mazzucato, 2014), and the expansion of intangible flows related to ICTs. As Kenney and Zysman (2016) demonstrated, while the Industrial Revolution was organized in factories, contemporary changes in the economy, politics, and social interactions occur within the virtual realm enabled by digital technologies.

This is not a decentralized system, as was believed in the early days of internet dissemination, where technology users dictated the nature of their applications (Mansell; Steinmueller, 2020). The digital era is configured as a system in which infrastructure networks – providing an internet signal, such as base transceiver stations (BTS), submarine cables, satellites, copper wires, and fiber optic cables, as well as computers and smartphones – are disseminated, albeit unevenly (Bertollo, 2019). However, the command is centralized in places that capture, analyze, and process the extraordinary amount of data generated by the digitalization of economic and social life for value creation and improved control over businesses (Mansell; Steinmueller, 2020) and people (Zuboff, 2021). This command is not purely technical but is articulated with a normative basis grounded in contracts that guarantee large companies the capacity to regulate the system (Kenney; Bearson; Zysman, 2021).

It may therefore be understood that the geographic landscapes, which have become globalized on the periphery of capitalism, are transformed through the principles of rationality, fluidity, and competitiveness of a technical-scientific-informational environment that makes a large portion of the territory apt to receive the influence of digital technologies (Santos, 2008; 2013). However, few urban centers have the conditions to exert any kind of command over this system. Cities with substantial science and technology (S&T) infrastructure and

the ability to foster job growth (Jacobs, 1969) in areas such as computer science and engineering, are those that empower professionals to develop applications/components, consulting, and technical support in cutting-edge digital technologies. These technologies, such as big data processing and analysis, cloud computing, machine learning, the internet of things, computer vision, and speech recognition, are crucial for digital transformation and modernizing the entire economic base to meet today's competitive standards.

Given Brazil's subordinate insertion into the digital era, a significant portion of the command remains external to the territory. This dependency is emblematically translated by the digital platforms that create an ecosystem and are able to induce or inhibit the growth of the actors that articulate with them. Big techs, like Amazon, exert significant power over more than 2 million sellers worldwide, controlling prices and access to consumers. Google has the ability to rank and catalog more than 1 billion websites (Kenney; Bearson; Zysman, 2021). As the innovative dynamics inherent to the digital economy accelerate, the ever-increasing investment demands make it challenging for economies like Brazil to enter. Even though the country has built a robust university and business system in computer science and engineering, among other related areas of knowledge, internalizing a larger portion of the digital command remains elusive.

As is known, the second great transformation in Brazil, with the growth of the coffee economy, marked a significant shift in the nation's economic dynamic center toward the Southeast (Furtado, 2006). This process was reinforced by industrialization efforts as of the 1930s through to the 1970s (Cano, 2007), and even by subsequent industrial decentralization, which, while reducing the dominance of São Paulo and Rio de Janeiro, favored nearby regions in the Southeast and South of the country (Diniz; Mendes, 2021). As a result, inertial and centripetal forces ultimately reinforced the development of productive and innovative dynamics in regions consolidated with greater economic density and productive diversification (Brandão, 2019), thereby raising the potential of these regions to remain as centralities.

The São Paulo PA, despite being one of the epicenters of the deindustrialization process in Brazil (Diniz; Mendes, 2021), has not lost its centrality in the territory, reinforcing its role as a financial and business center (Diniz; Campolina, 2007), and as the main command center in the digital era. In 2017, of all the establishments classified nationwide as knowledge-intensive software companies, the São Paulo PA accounted for 30.7%. As Figure 2 illustrates, the CGTI expresses the outstanding command of the São Paulo macro-metropolis, encompassing the PAs of Campinas, São José dos Campos, Sorocaba, and Baixada Santista, which are also of relevance

in this indicator. In addition to the macro-metropolis, the PAs of São Carlos, Rio Claro, and São José do Rio Preto have also expanded their centrality in terms of the CGTI, expressing the differentiated condition of the state of São Paulo in relation to the other Brazilian states.

The second major digital command centrality, the Rio de Janeiro PA, is bolstered by its robust academic system, boasting PGPs of excellence, in fields such as systems and computer engineering at the Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa em Engenharia [the Alberto Luiz Coimbra Institute for Postgraduation and Research in Engineering], linked to the Universidade Federal de Rio de Janeiro (UFRJ), computer science at the Pontifícia Universidade Católica in Rio de Janeiro (PUC-Rio), and in computing at the Universidade Federal Fluminense (UFF). Additionally, in 2017, Rio de Janeiro had the country's second-largest concentration of knowledge-intensive software companies, accounting for 8.1% of the national total. Despite the national government's centralized decision-making in Brasilia, the innovative dynamics within the Rio de Janeiro PA reinforced its position as the second centrality when considering the CGTI, even though its economy has faced strong challenges over recent years due to the crises in the shipbuilding and Petrobras industries.

The Belo Horizonte PA is fourth in the CGTI index, reflecting the relevance of its economic base, reiterated by the presence of PGPs of excellence in computer science at the Universidade de Minas Gerais (UFMG) and Pontifícia Universidade Católica in Minas Gerais (PUC-MG). This reputation is further solidified by its established initiatives to create high-demand digital technology jobs within the mining-metallurgical and automotive sectors installed throughout the state. In addition, organizations associated with the Minas Gerais Innovation System (Simi) are also known in the state capital, in which excellent technological research centers such as the former CSEM Brazil (now Oninn) and Biominas are particularly outstanding, coupled with strong interactions between the Instituições Científicas, Tecnológicas e de Inovação [Scientific, Technological, and Innovation Institutions] (ICTs) in Belo Horizonte and the so-called Vale da Eletrônica, in Santa Rita do Sapucaí.

In the Northeast, Recife is particularly outstanding, where our index reflects a group of PGPs and knowledge-intensive software companies, which may be traced back to the 1980s, when the region's scientific and technological competencies began to take shape. During this decade, Brazil experienced a period of hyperinflation, with monthly rates exceeding 80% in the early 1990s. This prompted economic agents to seek strategies to reduce the damage of the inflationary process in their businesses. Among other initiatives, most notably, companies headquartered in the state capital

of Pernambuco, a bank (formerly Banorte) and a supermarket (Bompreço) invested significantly in internal software development structures. While these companies no longer exist under the control of local capital, the technological competencies created over this period of hyperinflation and later, with the incentives of the Informatics Policy, have constituted an important software cluster in the city. This has been expressed in the various PGPs (particularly at the Universidade Federal de Pernambuco (UFPE), Capes Level 7, and the Universidade de Pernambuco (UPE), Level 4), in the group of knowledge-intensive companies and in the Porto Digital, a technology park focused on software.

Our methodology has enabled us to identify centralities that REGIC may have overlooked. Among the sub-regional B centers, we highlight the cases of Viçosa and Santa Rita do Sapucaí, both located in the state of Minas Gerais. While they exhibit minimal centrality in public and business managements, they nonetheless demonstrate significant influence in digital command. With the inclusion of the parameters related to the digital economy in the CGT to calculate the CGTI, Viçosa gains 209 positions and Santa Rita do Sapucaí, 249. As Mesquita and Furtado (2023) demonstrated, Viçosa has become a national reference in the area of agricultural sciences, and has fostered interaction with the local PGP in computer science to develop software linked to Agriculture 4.0, and agribusiness as a whole. In Santa Rita do Sapucaí, on the other hand, there is a local production cluster of electro-electronic equipment, the growth of which is associated with endogenous factors related to the training of local actors (Garcia et al., 2015) and to public policy associated with the demands of the national telephony system, led by the then state-owned Empresa Brasileira de Telecomunicações (Embratel). There is also a computer science course offered by the Centro de Ensino Superior em Gestão, Tecnologia e Educação [Center for Higher Education in Management, Technology, and Education] (FAI-MG) and a small software production park.

In the Southern region, two sub-regional A centers, Francisco Beltrão and Pato Branco, both the state of Paraná, have exhibited remarkable growth, ascending 62 and 56 positions, respectively, when comparing the CGT and CGTI. This upward trajectory is indicative of emerging centralities rooted in the expansion of higher education and research during the 2000s. Both urban centers benefited from the establishment of computer science courses at local units of the Universidade Tecnológica Federal do Paraná. This exemplifies the catalytic role of educational institutions in fostering software development activities within the region.

On the other hand, some state capitals have lost their positions when the digital command is used to measure central flows. This is the case of the state capitals composed of the PAs of São Luís (MA), Maceió (AL), Teresina (PI) in the

Northeastern region, Palmas (TO) in the North, and Cuiabá (MT) in the Midwest. It may be assumed that the Northeastern capitals lack the robust economic, scientific, and technological bases needed to maintain their positions in public management, despite being state capitals. The capitals of the Cerrado regions polarize a more powerful economic base, focused on agribusiness. However, the mismatch between expansion of the agricultural frontier and the capacity for scientific knowledge production (Mesquita, 2022) generates a dependence on the knowledge accumulated from major urban centers, which ultimately manifests in the realm of digital technologies.

5. By way of conclusion

The exercise presented herein was constructed experimentally, adhering closely to the IBGE REGIC study, a cornerstone for understanding the urban-regional dynamics of the Brazil territory. Our aim has been to contribute to the ongoing discussion on how to integrate the dimension of innovation and offer a quantifiable metric for operationalizing the central flow theory within the REGIC. By introducing the concept of "digital command," we seek to complement the existing focus on public and business management flows. Given the substantial advancement of ICTs in social and economic interactions, penetrating diverse sectors and dimensions of society and the economy, we acknowledge the profound influence of intangible knowledge, information, and value flows on urban centrality. Therefore, incorporating a third dimension to measure central flows will enable the identification of urban centers that exhibit greater centrality in the digital era, while not overlooking the significance of the traditional public and business managements of the territory.

Assuming that knowledge and innovation competencies in computer science and engineering are an indispensable factor in the development of technologies (product and process) in this digital era, places with the highest concentration of such competencies tend to become more advantageous for value creation in this phase of contemporary capitalism. On the other hand, as proposed by the central place theory, cities at the top of the urban network, particularly national metropolises, meet the demand for more complex and sophisticated goods and services in distant areas, thus exerting influence over regions of wide territorial scope. Updating this rationale for the economic dynamics in the digital era certainly implies that the demand for complex ICT-associated services tends to concentrate in metropolises and cities with higher positions in the urban hierarchy.

In Brazil, it is in these cities that have been at the forefront of establishing universities and research groups which, over time, have achieved excellence, qualifying researchers and professionals sought after by leading competitive companies. Government incentives for science, technology, and innovation have also played a pivotal role in this process. As a result, these cities have accumulated significant knowledge, research infrastructure, and a diverse pool of highly qualified professionals. This has helped them to become ideal locations for complex IT service companies essential to the digital revolution. Targeting both domestic and even potential international markets, these companies attract top talent from across the country.

While direct indicators of knowledge flow remain a subject for future investigation, the concentration of prestigious PGPs in computer science and engineering, along with knowledge-intensive IT companies, can serve as proxies for assessing the centrality of cities in contemporary urban-regional dynamics. The validity of this approach is supported by the results, which reaffirm the prominent position of Brazil's major metropolitan areas, particularly São Paulo. Despite the profound impact of deindustrialization, São Paulo continues to assert its dominance as the country's primary territorial center, as measured by the CGTI. Other metropolises, including Rio de Janeiro, Belo Horizonte, Porto Alegre, Recife, and Curitiba, as well as intermediate cities like Maringá, Uberlândia, São Carlos, and Blumenau, also warrant significant attention, given the notable disparities observed between our CGTI index and the IBGE indices.

However, the effort to construct an indicator capable of effectively measuring the intensified knowledge flows in the digital age is far from over. On the contrary, this contribution requires continued reflection to improve the analysis procedure and to consider the REGIC as a support tool to foster innovation and technological development. Among the points that need improvement is the possibility that the choice of data from IT companies for calculating the CGTI may imply some double counting, accentuating the command of business management in the indicator. At the same time, the findings have demonstrated that the key to a consistent analysis involves a historical reconstruction that demonstrates how different urban and regional contexts adapt to the digital era, substantiating the validity of quali-quantitative analyses. Recognizing these and other challenges, we trust that this work will encourage new efforts toward developing a procedure that effectively corresponds to the theory of central flows.

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