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Case Report

Urban tech ecosystems: A framework for assessing the impact of development policies on startup clusters

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A B S T R A C T

Startup clusters exert a significant influence on territorial dynamics and local urban development by attracting job opportunities, talent, and shaping market interest, supported by effective land use policies. This study examines the impact of Urban Development Policies (UDP) on technology startup clusters' sustainability, focused on the city of São Paulo, in Brazil. It recognizes a gap in understanding UDP's influence on cluster growth, which motivates the research. The study employs a four-phase method: technology mapping, territorial differentiation, metric configuration, and decentralized district aggregation, utilizing QGIS and Python. The results reveal a trend of cluster formation in UDP areas due to infrastructure, academic proximity, and commercial growth, highlighting the interplay between urban policies, infrastructure development, and economic opportunities. The findings provide insights to strategic urban development policies, emphasizing holistic strategies for employment enhancement, sustainable urban evolution, and effective talent and real estate management. These implications advance knowledge in urban issues, policy implementation, urban design, and urban services provision, pertinent to the global development context. Results show actionable solutions to address urban challenges, build innovative urban solutions and support local sustainable development with technology startup clusters.

1. Introduction

Since 2011, discussions on smart cities and the role of technology in reshaping urban landscapes have become increasingly prominent, emphasizing digital innovation's potential to enhance infrastructure, resilience, and inclusivity in cities worldwide (Townsend, 2014; Albino, Berardi, & Dangelico, 2015; Wang, Peng, & Du, 2024). Initial conversations around smart city development were largely technocentric, focusing on the benefits of connectivity and infrastructure. However, recent perspectives emphasize human-centered, context-specific approaches that recognize each city's unique social, economic, and cultural fabric (Aina, 2017; Montero, Mejía-Dorantes, & Barceló, 2024; Vanolo, 2015). This shift is especially relevant in rapidly urbanizing environments, where the emergence of technology startups has catalyzed innovation-driven clusters, fostered localized economic growth and stimulated significant changes in land use (Esmaeilpoorarabi, Yigitcanlar, & Guaralda, 2018; Shi, Yang, Mu, & Yang, 2024).

Innovation clusters—anchored by supportive infrastructure, efficient mobility systems, talent attraction, and mixed land uses—stimulate economic and spatial transformation by attracting members of the "creative class," a skilled demographic that fuels demand for enhanced amenities and services (Blanutsa, 2022; Florida, 2002; Kosfeld & Mitze, 2023). Comparative studies underscore how cities

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like Helsinki, Brisbane, São Paulo, and Buenos Aires have developed synergies between startups, academic institutions, and urban policies to encourage clustering. For instance, Helsinki's Knowledge-Based Urban Development (KBUD) model and Buenos Aires' Parque Patricios showcase how policy-driven interventions can support innovation and urban regeneration, reinforcing the vital role of carefully structured policies in urban growth (Lerena & Orozco, 2020; Pelkonen, 2005; Subedi, McDougall, & Paudyal, 2024; Yigitcanlar & Lönnqvist, 2013).

Despite these developments, existing research often treats the elements of technology clusters—such as infrastructure, mobility, and talent attraction—as discrete factors, neglecting their combined influence on cities' spatial and economic landscapes (Alnaim & Noaime, 2024; Ng, Shabrina, Sarkar, Han, & Pettit, 2024; Shi et al., 2024). This segmented approach limits the development of comprehensive planning strategies that can fully leverage the potential of Urban Development Policies (UDPs) to sustain and expand technology clusters. Moreover, actionable methodologies for assessing the long-term impacts of UDPs on technology ecosystems remain scarce, particularly within rapidly evolving urban environments like São Paulo. Addressing this research gap, the present study offers an integrated framework to analyze the relationships between UDPs and technology cluster formation, contributing with a replicable model that supports holistic, policy-informed approaches to urban planning.

The study's novelty lies in its comprehensive method of examining UDP impacts on technology clusters. Unlike conventional analyses that narrowly focus on either economic or spatial dimensions, this research integrates land use data, employment patterns, and accessibility metrics to reveal the multifaceted factors that influence technology clusters. São Paulo, with its distinctive UDP framework, provides a valuable case study that highlights how targeted urban policies can drive sector-specific economic development, cluster formation, and urban renewal. This approach not only fulfills critical gaps in urban planning literature but also serves as a practical tool for other cities to replicate when fostering innovation ecosystems (Esmaeilpoorarabi et al., 2018; Shi et al., 2024; Tondro, Jahanbakht, Rabbani, & Zaber, 2022).

However, this study has certain limitations. The analysis emphasizes economic and policy factors but does not deeply explore socio-demographic variables, which could offer insights into how clusters impact affordability, social diversity, and equitable access to resources. Furthermore, focusing solely on São Paulo's regulatory and economic environment may restrict the generalizability of findings to cities with diverse planning frameworks and urban challenges (Sun & Lv, 2020).

Recommendations from this study suggest that cities aiming to foster technology clusters through UDPs should prioritize inclusivity to avoid gentrification and ensure that clusters remain accessible to a diverse range of startups. Future research could further examine the socio-demographic impacts within these clusters and adapt the framework to various urban contexts, supporting broader and more inclusive cluster growth. Cities like São Paulo, Helsinki, Brisbane, and Buenos Aires offer models for leveraging UDPs to shape innovation hubs, though ongoing policy assessments are essential to ensure that these developments remain equitable and resilient over time (Shi et al., 2024; Subedi et al., 2024; Yigitcanlar & Lönnqvist, 2013).

In sum, this study provides a structured method for evaluating the formation and sustainability of technology clusters in relation to urban policies. Findings underscore the value of flexible land use, targeted infrastructure investments, and continuous policy assessments, offering actionable insights for cities worldwide aiming to achieve inclusive, innovation-led urban growth.

2. Theoretical framework

The emergence and clustering of technology startups have become key drivers of urban transformation, influencing economic growth and spatial development across cities worldwide. This phenomenon is facilitated by factors such as innovation-supportive infrastructure, effective mobility systems, and enabling policy frameworks. Together, these elements create ecosystems that foster creativity, talent attraction, and knowledge exchange, which are essential for economic resilience and competitiveness (Gerolamo, Carpinetti, Fleschutz, & Seliger, 2008; Kosfeld & Mitze, 2023; Porter, 1998).

Urban centers like São Paulo, Barcelona, Helsinki, and the Yangtze River Delta in China serve as prominent examples of how innovation-driven businesses thrive near educational institutions, business incubators, and accelerators, which bolster the intellectual capital of these regions (Montero et al., 2024; Shi et al., 2024). For instance, Barcelona's diverse urban lifestyle attracts highly skilled professionals who reshape the city's spatial dynamics by driving demand for housing, retail, and cultural services (Montero et al., 2024; Moro Zamprogno; Esztergár-Kiss, 2024). Similarly, Shanghai has leveraged its high educational and scientific resources, attracted highly educated talents and created a robust innovation network that enhances regional development (Florida and Adler, 2016; Shi et al., 2024).

Technology clusters also lead to significant land-use changes, especially in underutilized industrial areas, as seen in Shanghai and the broader Yangtze River Delta, where innovation zones have transformed into high-value districts through public policy support and infrastructure investments (Shi et al., 2024). This pattern is mirrored in Buenos Aires' Parque Patricios District and Helsinki's Knowledge-Based Urban Development (KBUD) model, both of which demonstrate how public policies can drive both urban regeneration and technological growth (Lerena & Orozco, 2020; Pelkonen, 2005; Subedi et al., 2024).

However, while extensive research has highlighted individual elements of technology clusters, such as infrastructure and policy frameworks, a critical gap remains in understanding how these elements collectively shape urban economic dynamics. This study aims to address this gap by examining the integrated impacts of Urban Development Policies (UDPs) on technology clusters. By analyzing UDPs such as land use regulation, infrastructure, and incentives, this research offers a framework that links policy-driven urban renewal with sustainable technology-driven growth (Ng et al., 2024).

In addition, talent mobility is an essential component in urban competitiveness. Research on talent flow in regions like the Yangtze River Delta highlights the importance of urban policies in attracting high-skilled labor, which is crucial for maintaining a city's economic vitality and innovation capacity (Cunha and Makiya, 2008; Bao, Cui, & Yang, 2024). Through insights from cities in Australia, China, and Europe, this study builds a replicable framework for urban planners worldwide, providing tools to assess how technology clusters interact with urban policies to create resilient, inclusive, and economically vibrant urban spaces.

3. A method proposal to assess urban development & technology production clustering

This study proposes a systematic, integrated method for analyzing and monitoring the concentration of technology startups in urban areas and the associated Urban Development Policies (UDPs). The method is organized into four phases, each designed to assess the spatial and economic impact of technology clusters on urban development.

This method is structured in four key phases, each designed to systematically evaluate and monitor the impact of UDPs on technology clusters in urban areas. The phases are as follows in Fig. 1:

- **Phase 1** - The first phase involves mapping small and medium-sized active technology startups within the study area. Using Google Earth and QGIS (QGIS, 2023) with the WGS 84 coordinate system (EPSG 4326), geographic coordinates for each startup are collected and overlaid on the urban area's shapefile. This allows for a precise visualization of technology startup concentrations, establishing a foundational map for subsequent analysis.
- **Phase 2** - In the second phase, territories are categorized based on whether they are influenced by UDPs within the analyzed timeframe. The classification into UDP and non-UDP areas is mapped and organized by municipal district to enable a clear differentiation of urban regions affected by these policies. This setup allows for a comparative assessment of UDP and non-UDP zones over time.
- **Phase 3** - The third phase involves configuring and analyzing a comprehensive set of metrics to evaluate the impact of technology production in both UDP and non-UDP territories. The metrics, grouped into three categories, capture core aspects of urban dynamics as shown in Fig. 2.:
  A Land Use Metrics: This group assesses territorial transformation in UDP-covered districts compared to non-UDP areas. Metrics include total built-up area by land use (residential, commercial, mixed) (A1), number of building types (A2), average building height (A3), assessed property values (A4), floor-area ratio (A5), land coverage (A6), and startup concentration (A7).
  B Urban Mobility Metrics: This group evaluates movement patterns in UDP versus non-UDP areas. Metrics include total trip numbers (B1), mode of transport (B2), average distance to public transport (B3), and trip purposes (B4).
  C Urban Economy and Society Metrics: This group focuses on employment and socioeconomic conditions in the selected areas, using metrics like distance between tech hubs (C1), education levels (C2), employment concentration (C3), and average salary (C4).

These metrics provide a detailed assessment of how technology clusters influence urban land use, mobility, and economic factors, offering a comprehensive view of urban development trends in response to UDPs.

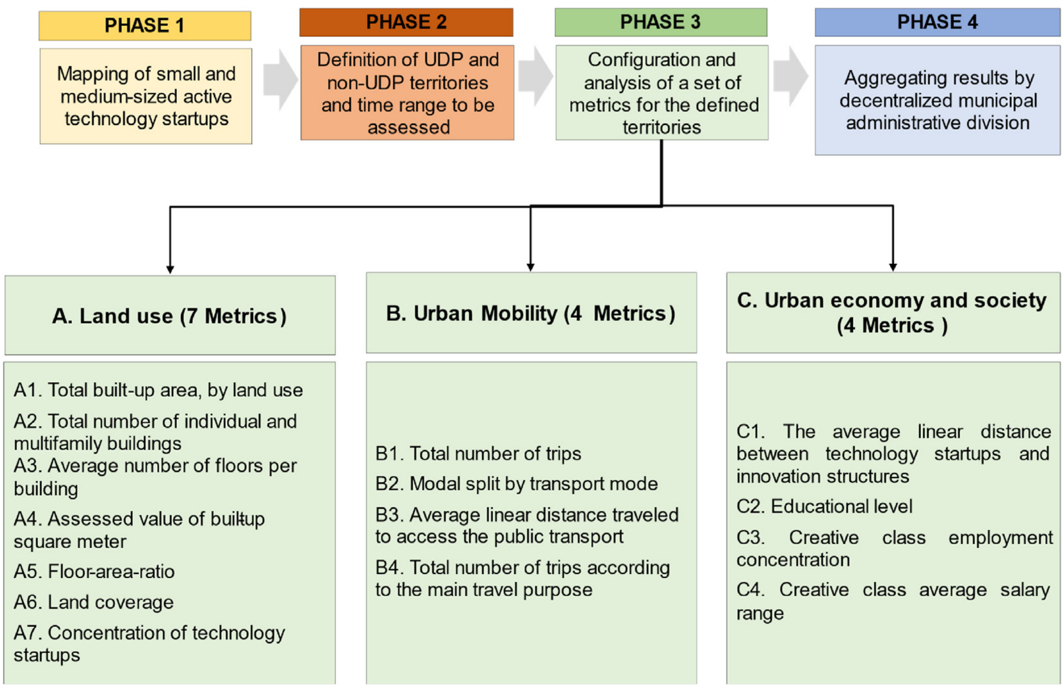

Fig. 1. Research method phase structure. Source: The authors (2024).

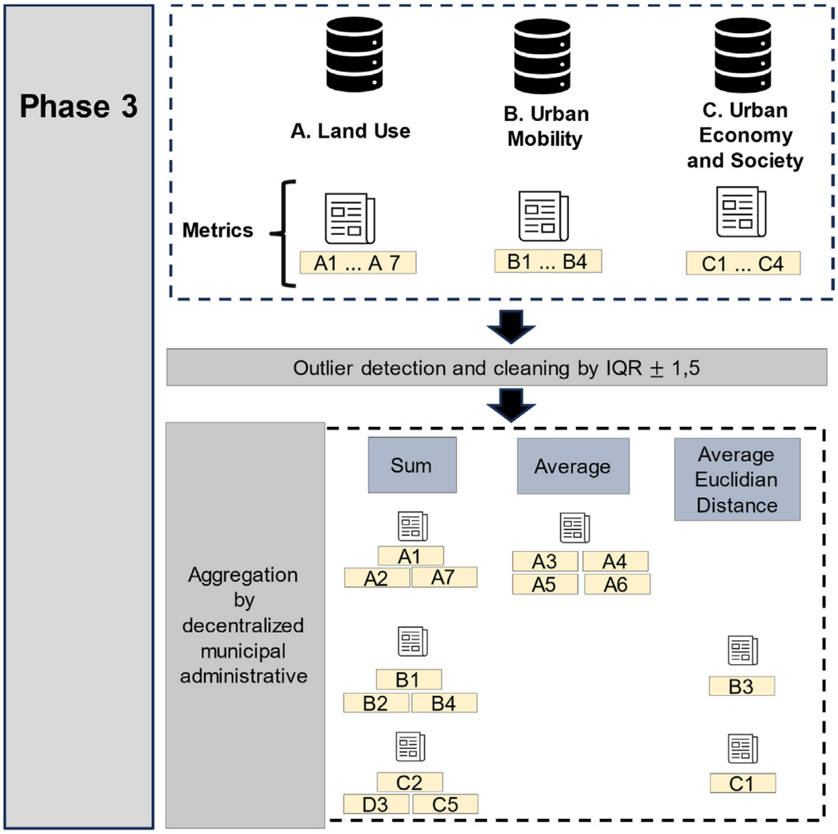

Fig. 2. Metrics proposed for the analysis of the impact of technology production in selected territories Source: The authors (2024).

- **Phase 4** - In the fourth phase, data is aggregated by municipal districts for standardization, facilitating the comparison of UDP impacts across different areas. Procedures include handling missing data (Group A), applying the "Travel Expansion Factor" for Group B metrics, and calculating Euclidean distances (Groups B and C) for spatial analyses using Equation (2):

$$d_{AB} = \sqrt{\left((X_A - X_B)^2 + (Y_A - Y_B)^2\right)} \quad \text{(Equation 2)}$$

where:

X = coordinate in x;

Y = coordinate in y.

This aggregation enables standardized comparisons across districts and allows the method to be adapted for other municipal or regional analyses, if necessary.

The proposed method serves as a structured approach for understanding technology cluster dynamics and the influence of UDPs at a localized scale. The mapping of startup concentrations in Phase 1 and the categorization of UDP versus non-UDP territories in **Phase 2** provide a spatial framework. Phases 3 and 4 offer a robust structure for metric-based analysis and cross-district aggregation, making this method a valuable tool for urban planners and policymakers. While demographic density could further enrich the analysis, it was omitted due to the lack of updated census data. Nonetheless, this method supports flexible, cross-city comparisons and can inform policy decisions to foster sustainable technology-driven urban growth.

4. The case study of the city of São Paulo, Brazil

To illustrate the application of this method, São Paulo, Brazil, serves as an ideal case study, as it has emerged as a significant center for technological innovation in Latin America. São Paulo hosts approximately 21.7% (4837) of Brazil's total registered technology startups, of which 3272 are active within the city itself, representing 67.6% of all startups in the State of São Paulo (ABStartups, 2023a, 2023b). The city is particularly strong in the "software as a service" (SaaS) and marketplace sectors, which together constitute 58% of the technology startups in the state. This concentration reflects São Paulo's strong appeal to talent, infrastructure, and investment, positioning it as a leader in the region's technology ecosystem (ABStartups, 2023a, 2023b).

São Paulo's attractiveness as a technological hub is further enhanced by comprehensive urban development initiatives implemented since the 1990s. These initiatives include the establishment of Urban Consortium Operations (UCOs) through legislation, starting with Law 11,732/1995, which launched the "Faria Lima" UCO. Additional UCOs, including "Água Branca," "Centro," and "Água Espraiada," were subsequently defined under laws passed in 1995, 1997, 2001, 2013, and 2016 (PMSP, 1995; 1997, 2001, 2013, 2016).

Further enhancing these efforts, the Strategic Master Plan of São Paulo (PDE) under Law 16,050/2014, and the Land Use Law (LPUOS) under Law 16,402/2016 introduced the "urban structuring axis" policy. This policy aims to promote urban densification and improve public spaces in areas close to high-capacity transportation. These combined efforts under the UDP framework have laid the foundation for São Paulo's emergence as a key technological hub, making it an exemplary case for evaluating how urban policies affect technology-driven clustering and urban transformation (PMSP, 2014; 2016).

Fig. 3 presents UDP territories in São Paulo, highlighting areas with flexible urban parameters that allow for increased construction potential, diversified land use, and social housing. These UDP territories, including the designated OUCs and structuring axes, have been instrumental in promoting urban densification near transportation hubs. Additionally, funds generated from Certificates of Additional Construction Potential (CEPACs) are directed towards municipal improvements, such as transportation infrastructure and public spaces, while fiscal incentives encourage development around high-capacity transport nodes (PMSP, 1995; 1997, 2001, 2013, 2016).

Data from 1995 to 2023 support the analysis of São Paulo's technology clusters. Using the Startup Map from ABStartups (2023a, 2023b) and Google Earth for precise mapping, active technology startups in São Paulo were geolocated. This information was then

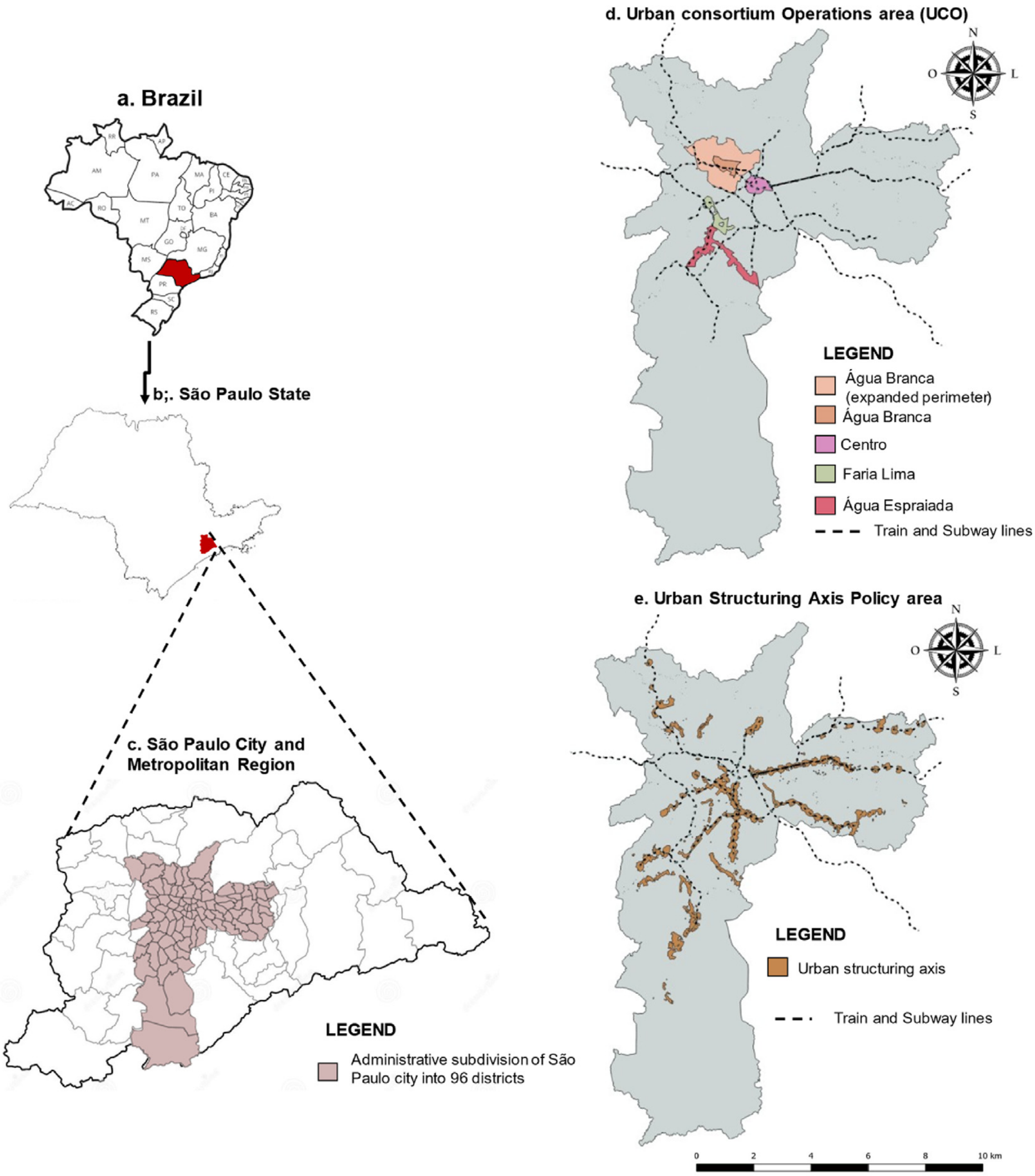

Fig. 3. UDP territories in the city of São Paulo. Source: The authors (2024). Geosampa database and São Paulo City Hall (PMSP, 2023).

overlaid onto São Paulo's district map in QGIS (QGIS, 2023), allowing for a detailed assessment of technology cluster concentrations. In addition to startup data, metrics were grouped into three categories for analysis, as seen in Table 1:

Land Use (Group A): Derived from urban and property tax records, this group includes metrics such as total built-up area by land use type and floor-area ratio, covering data from 1995 to 2023 (PMSP, 2021).

Urban Mobility (Group B): Based on data from the Origin-Destination Survey, metrics in this group track travel patterns, modes of transport, and travel distances, with data spanning from 1997 to 2017 (São Paulo, 1999, 2019).

Urban Economy and Society (Group C): This group includes metrics on education levels, employment concentration, and income, obtained from the Annual Social Information Report (RAIS) from 1995 to 2022 (Ministry of Labor and Employment, Brazil).

This method was applied across São Paulo's 96 districts, distinguishing those with UDP coverage from those without. By analyzing data across these categories and mapping technology startups within QGIS, this study effectively identifies technology clusters and evaluates their correlation with UDP territories, offering insights into the impact of urban policies on technology cluster formation.

The city's success as a technological and economic hub is further supported by policies promoting innovation and tech-driven entrepreneurship, making it an ideal region to apply the proposed method for evaluating urban policies' impact on startup clusters. With data available from sources such as the GeoSampa database, ABStartups, and other governmental entities, the case study aims to assess the spatial dynamics of technology startups across 96 districts in São Paulo, categorized into those with and without UDP coverage.

5. Results

Applying the proposed method to São Paulo's case study generated comprehensive insights into the relationship between technology startup clustering and Urban Development Policies (UDPs). Each phase of the method provided unique perspectives on the city's urban landscape, revealing critical connections between urban policy interventions and the spatial distribution of technology-driven activities.

Phase 1 involved mapping 1077 technology startups operating in São Paulo between 1995 and 2023. This mapping highlighted the growth and geographic distribution of startups over nearly three decades, reflecting shifts in the local technology landscape. Geolocating these startups allowed for a granular analysis of their clustering patterns, particularly in areas where policy interventions and infrastructural support were concentrated. By establishing the spatial foundation, Phase 1 enabled a historical view of startup growth, key for understanding how different urban areas contribute to or hinder innovation.

In **Phase 2**, UDP and non-UDP zones were defined based on São Paulo's urban planning data available on the GeoSampa platform (PMSP, 2023). This phase categorized districts by the presence of UDP initiatives, such as Urban Consortium Operations (UCOs) and the Urban Structuring Axis, providing a framework for assessing the influence of targeted policies on innovation as seen in Fig. 4. This classification revealed patterns in urban development driven by policies like the "Faria Lima" UCO and the "Água Espraiada" Axis, which serve as focal points for commercial growth and infrastructure enhancement. Distinguishing between UDP and non-UDP zones facilitated comparative analysis, enabling the study to isolate policy-driven impacts on the clustering and growth of technology startups.

The results of **Phase 3**, where selected metrics were applied to territories with and without UDP (Urban Development Plans), are discussed below. These results contribute to understanding how land use and infrastructure policies impact the formation, distribution, and sustainability of technology startup clusters.

According to Table 2 total built area by land use (**Metric A1**), The analysis of the total built area by land use reveals a clear distinction between districts with UDP and those without. Despite a stable percentage of land allocated to housing in both types of districts (Territorial Delineation 1 and 2), a notable trend emerged in districts with UDP: prioritization of commercial and service uses. In 1995, commercial and service land uses accounted for 19% of the total built area; by 2023, this figure had increased to 27%. This shift is largely attributed to a reduction in the area previously allocated to mixed-use developments, parking lots, public buildings, and hospitals. These changes suggest a concerted effort to facilitate the growth of commercial and service sectors, which is typical in areas aiming to foster innovation and business activity.

Table 2 shows that the analysis of the total number of individual and multifamily buildings shows how urban planning flexibility in UDP areas has influenced the city's verticalization. In districts with UDP, there was a significant increase in the construction of multifamily vertical buildings (condominiums), which grew from 3% of the total built area in 1995 to 16% in 2023. This trend indicates that UDPs have effectively promoted vertical development, absorbing much of the land previously allocated to individual and horizontal

Table 1
Source of research metrics for the case study of São Paulo.

Group	Number of Metrics	Source	Period
Startup concentration	1 Metric	Startup Map (ABStartups, 2023a, 2023b) Google Earth, (Google, 2009)	From 1995 to 2023
A. Land Use	7 Metrics	Urban and Property Tax (IPTU) (PMSP, 2021);	From 1995 to 2023
B. Urban Mobility	4 Metrics	Origin - Destination Survey (OD) (São Paulo, 1999, 2019)	From 1997 to 2017
C. Urban Economy and Society	4 Metrics	Annual Social Information Report - RAIS (Brazil. Ministry of Labor and Employment, 1995; 2022) ; Brazilian Occupation Classification (CBO), (Brazil, 2002)	From 1995 to 2022

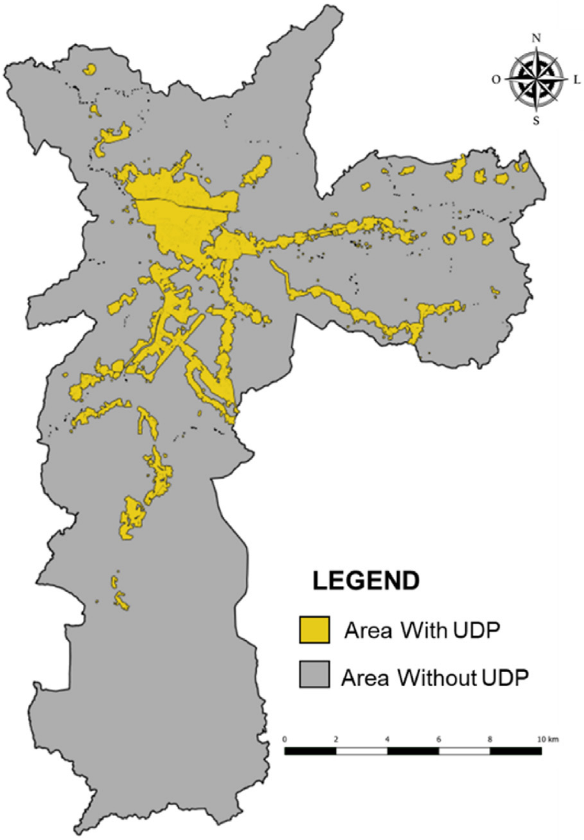

Fig. 4. Territorial relation between areas with and without UDP. Source: The authors (2024). Geosampa database and São Paulo City Hall (PMSP, 2023).

Table 2
Distribution of land use and the total number of individual and multifamily buildings (Metrics A1 and A2).

Year	Districts	A1. Total built area, by land use				A2. Total of individual and multifamily buildings	
		Residential	Commercial and services	Mixed uses	Other uses	Horizontal and individual-use buildings	Vertical and multifamily-use buildings
1995	**With UDP areas**	56%	19%	13%	12%	13%	3%
	Without UDP areas	64%	9%	10%	17%	48%	35%
2023	**With UDP areas**	57%	27%	6%	11%	7%	16%
	Without UDP areas	65%	14%	10%	12%	43%	34%

Metrics A1 and **A2** reveal that UDP areas prioritize vertical, multifamily buildings and commercial spaces, increasing office availability while reducing residential options. This setup fosters a higher worker concentration, suggesting UDPs create environments that support technology startup clustering through commercial growth and increased density.

buildings. In contrast, districts without UDP saw a continued expansion of individual and horizontal buildings, with a steady increase in available square meters for this type of construction. The share of land dedicated to multifamily vertical buildings remained stable at 34% in 1995 and 35% in 2023 (Table 2). This demonstrates the more traditional approach to land use in non-UDP areas, where horizontal development continues to dominate.

The average building height in UDP districts rose from 3.95 floors in 1995 to 4.76 in 2023, while non-UDP areas remained at 2.5 floors. The percentages in Table 2 indicate that the verticalization aligns with UDP goals to intensify urban density, promoting economic activity and attracting technology startups.

The value of the built square meter increased significantly in UDP areas—up 971% from 1995 to 2020, compared to 861% in non-UDP zones. Adjusted for inflation, UDP areas saw an 85% rise above inflation, versus 64% in non-UDP areas. These gains reflect UDPs' impact on property demand by modifying land use parameters like floor area ratio, land coverage, and height limits, enhancing area appeal for business and innovation, those results are shown in Table 3.

The results show a clear trend of verticalization and commercial growth in districts with UDPs, evidenced by increased building heights and property values. This suggests that UDPs play a key role in shaping areas that foster technology and business clusters by promoting commercial and service uses. Such flexibility in land use encourages a mix of offices, amenities, and services, attracting professionals while potentially raising costs and limiting access for new residents and smaller startups (Blanutsa, 2022; Florida & Mellander, 2020; Ng et al., 2024; Shi et al., 2024).

Data on technology startup distribution further highlights this effect, with 46.1% of the city's 1077 startups located in UDP zones, which cover only 9% of São Paulo's municipal area in Fig. 5. This significant clustering aligns with findings from global studies, such as those on the Yangtze River Delta, where similar policies have successfully created concentrated innovation hubs by enhancing urban density and accessibility (Raco, 2003; Esmaeilpoorarabi et al., 2018; Shi et al., 2024).

Table 4 shows that between 1997 and 2017, total trips in São Paulo increased by 25%, yet UDP districts consistently accounted for only 18% of these trips, with non-UDP areas comprising 82. Although UDP zones did not attract a higher share of total trips, there was a notable shift in transport modes within these areas. Public transport usage rose from 34% to 39%, while car trips declined from 32% to 27%, suggesting that UDP areas benefitted from expanded mass transit options, likely supporting a more accessible environment for tech clusters and skilled professionals (Florida, 2002; Florida & Mellander, 2020; Ng et al., 2024).

These findings highlight the importance of integrating robust urban mobility infrastructure in UDPs to enhance connectivity and attract talent, as seen in similar studies of tech-focused urban areas like the Yangtze River Delta, where efficient transit access supports cluster formation and economic growth (Esmaeilpoorarabi et al., 2018; Kosfeld & Mitze, 2023; Shi et al., 2024).

The average distance to public transport (**Metric B3**) shows that technology startups are typically located within 150 m of subway or bus corridors, while regions with fewer startups are over 450 m away. This proximity in UDP areas highlights the role of high-capacity urban transport in fostering tech clusters by improving accessibility and supporting talent retention (Markusen, 2006; Kosfeld & Mitze, 2023; Ng et al., 2024).

According to Table 5, from 1995 to 2023, UDP zones gained 19 new subway stations and five bus corridors, strengthening the attraction of startups to these areas. This expanded infrastructure not only supports startup concentration but also drives real estate demand and commercial activity, as observed in other urban tech hubs where transit access fuels local economic dynamics (Shi et al., 2024; Smętkowski, 2022).

In UDP districts, the total trips for service and education purposes increased, while trips for commercial and residential purposes declined (**Metric B4**). This shift suggests that technology clusters may be creating job opportunities for the creative class, attracting specialized professionals who rely on efficient mobility. However, trips for residential purposes decreased, likely due to a reduced residential area as seen in Table 6, which may indicate rising living costs and limited housing supply, potentially deterring new residents (Closs, 2017, pp. 349–363; Credit, 2019; Shi et al., 2024).

These shifts in travel purposes highlight changes in living patterns within UDP areas, with possible implications for residential accessibility and commuting distances. Further insights into these patterns could be gained by examining social and economic **metrics** from **Category C**.

In urban areas with established technology clusters, educational and research institutions are critical in developing specialized talent and supporting innovation. In São Paulo's UDP districts, the proximity of startups to such institutions, averaging 250 m, contrasts with the 750-m average in non-UDP districts. This spatial relationship aligns with findings that emphasize the role of educational and research bodies in enhancing local innovation ecosystems, attracting skilled labor, and reinforcing cluster dynamics (Kosfeld & Mitze, 2023; Qian & Liu, 2018).

Further analysis shows that 86% of technology workers in UDP areas had attained at least an undergraduate degree by 2022, a marked increase from 56% in 1995, those data are comprised in Table 7. This trend suggests that the rise of clusters fosters a specialized workforce, corroborating literature that links workforce education with innovation and cluster strength (Antonelli, 2013; Qian & Liu, 2018). This specialization also appears in the sharp decline of primary and secondary education-level occupations in these regions, reflecting an urban labor shift toward high-skill roles required by technology-driven environments (Kosfeld & Mitze, 2023).

The rise in highly educated professionals within São Paulo's technology sector correlates with increased educational trips (**Metric B4**), aligning with literature that underscores the importance of advanced training for sustaining tech clusters (Esmaeilpoorarabi et al., 2018). Additionally, the concentration of business travel for service-related purposes in UDP-covered areas highlights these zones as

Table 3
Metrics of land use and property value.

Years	Districts	Average - number of floors per building (Metric A3)	Average – assessed value of built-up square meter (R$) (Metric A4)	Average – Floor area ratio (Metric A5)	Average – Land coverage (Metric A6)
1995	**with UDP areas**	3,95	182,50	1,75	0,42
	without UDP areas	1,68	127,82	0,5	0,25
2023	**with UDP areas**	4,76	1.772,64	2,47	0,47
	without UDP areas	2,5	1.101,11	0,89	0,34

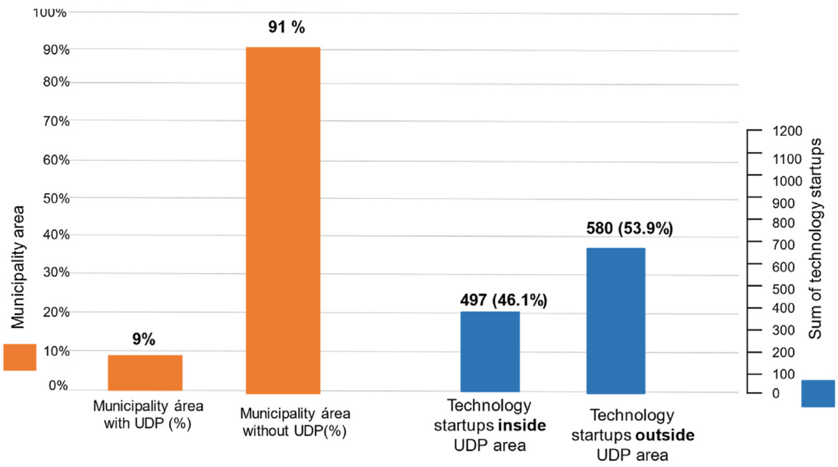

Fig. 5. Percentage of the territory of the city of São Paulo with and without UDP areas and the number of technology startups in and out UDP areas.

Table 4
Modal split by transport mode (Metric B2).

Years	Districts	Individual	Public	Bike	Walk
1997	**with UDP**	32%	34%	0%	34%
	without UDP	32%	35%	0%	33%
2017	**with UDP**	27%	39%	1%	33%
	without UDP	29%	39%	1%	31%

Table 5
Public transport modes in UDP areas.

UDP - OUC	Active transportation modes until 1995			Active transportation modes after 1995		
	Train	subway	Bus corridors	Train	Subway	Bus corridors
“Faria Lima"	1	0	1	4	4	3
“Água Espraiada"	1	0	1	4	4	3
“Água Branca” and expanded perimeter	4	3	1	4	6	2
City center	3	7	2	3	7	5

Table 6
Total number of trips according to the main travel purpose (Metric B4).

Years	Districts	Industrial employment	Commercial employment	Service employment	Education	Residence
1997	**with UDP**	12%	29%	26%	5%	33%
	without UDP	9%	25%	33%	4%	34%
2017	**with UDP**	6%	9%	34%	27%	30%
	without UDP	7%	8%	30%	34%	29%

Table 7
Distribution of professionals by the educational level (Metric C2).

Years	Districts	Elementary	High School	Higher education	Master's degree	Doctorate
1995	**with UDP**	15%	28%	56%	0%	0%
	without UDP	14%	29%	55%	1%	0%
2022	**with UDP**	1%	13%	81%	3%	2%
	without UDP	0%	11%	83%	3%	2%

hubs for job creation within technology sectors.

In 2022, out of 214,885 technology jobs in São Paulo, 55,364 (24%) were concentrated within UDPs, covering only 9% of the municipal area, while the remaining 91% hosted 76% of tech jobs. Fig. 6 shows a significant clustering in UDP zones indicates that these policies effectively foster technology-focused employment and attract creative class professionals, a pattern consistent with technology districts in Helsinki, Brisbane, and Buenos Aires (Adler, Florida, King, & Mellander, 2019; Florida, 2002; Kosfeld & Mitze, 2023; Lerena & Orozco, 2020; Pelkonen, 2005).

UDP policies demonstrate strong potential for replication in other cities aiming to stimulate tech-driven economies. Strategic urban design within these zones attracts investment, but managing rising living costs is crucial to prevent job dispersion and maintain cluster cohesion (Sun & Lv, 2020). Although São Paulo's UDP areas have seen increased tech employment from 1995 to 2022, there is also notable growth in technology jobs outside UDP zones, driven by emerging, small startups seeking more affordable spaces (Tondro et al., 2022).

The implementation of Urban Development Policies (UDPs) in São Paulo has significantly influenced the technology sector's labor market by intensifying demand for specialized talent within technology clusters. Studies by Huck, Liedtke, and Witte (2018) reveal that such clusters, when supported by targeted policies, create environments that foster knowledge transfer and stimulate job creation in technology sectors (Wang et al., 2024). Additionally, the spatial concentration of technology firms within UDP districts in São Paulo has resulted in increased wages, particularly among highly specialized professionals in technology, like observations in Europe where technology clusters drive regional economic competitiveness through high remuneration and skilled labor retention (Kosfeld & Mitze, 2023; Subedi et al., 2024).

The high level of professional qualification among technology workers in UDP areas further underscores the strategic role of educational and research institutions in supporting these clusters. Studies of the Yangtze River Delta highlight those cities with substantial educational infrastructure, including colleges and universities, are more likely to attract highly skilled talents, creating a feedback loop that reinforces the technological ecosystem (s41598-024-60436-5). Similarly, in São Paulo, the proximity between technology firms and academic institutions, with an average distance of 250 m in UDP areas, has bolstered the local talent pool, attracting and retaining individuals with advanced degrees who are essential to sustaining innovation-driven economies.

For sustainable urban development, it is critical to balance these economic gains with measures to mitigate potential gentrification. As highlighted by Closs (2017, pp. 349–363), unchecked real estate appreciation in tech-centric districts could impose financial barriers for residents and smaller startups, potentially limiting the socioeconomic diversity within these areas (Shi et al., 2024).

6. Discussion

This study investigates the impact of urban development policies (UDP) on the growth of startup clusters in São Paulo, offering insights applicable to other cities globally that aim to foster their tech sectors (Esmaeilpoorarabi et al., 2018; Wang et al., 2024). The proposed method identifies critical urban dynamics tied to technology cluster formation, capturing the spatial and economic factors driving territorial clustering and shifts in land use (Kosfeld & Mitze, 2023).

The findings reveal a clear correlation between UDP areas and the growth of technology jobs in São Paulo, generating demand for skilled labor and encouraging startup concentration. This clustering underscores the effectiveness of structured urban policies and provides valuable lessons for cities seeking to replicate similar ecosystems. However, high property costs in UDP zones present challenges for smaller startups, limiting access to these prime areas. This issue highlights the need for a development strategy that balances clustered growth with dispersed development to promote inclusivity and diversity (Subedi et al., 2024).

A core element of this study is the impact of São Paulo's Master Plan, which supports flexible planning and designates priority areas to foster local development. Through targeted land use regulations, the Master Plan facilitates real estate development, mobility infrastructure, and the creation of educational and research institutions, thus playing a significant role in generating technology jobs and supporting cluster formation (Lerena & Orozco, 2020; Shi et al., 2024). These policies have been pivotal in transforming São Paulo into a tech-driven hub, showcasing the role of urban planning in supporting economic growth through innovation.

The analysis also reveals a strong preference for commercial and service-oriented buildings within UDP zones, reflecting the potential of São Paulo's land use policies. However, rising property costs in these areas point to the need for inclusive strategies that ensure access for diverse actors, underscoring the importance of sustainable policies that balance growth and local diversity (Closs, 2017, pp. 349–363; Pelkonen, 2005). This aligns with findings from other cities, like Shanghai and the Yangtze River Delta, where UDP initiatives also drive-up property values and necessitate balanced approaches to inclusivity (Shi et al., 2024).

This research emphasizes the need for integrated policy planning and continuous reassessment to address evolving urban dynamics, fostering stability and adaptability in urban development (Markusen, 2006; Ng et al., 2024). Regular policy evaluation allows cities to adapt to local needs, supporting a dynamic environment that sustainably fosters technology innovation.

Beyond São Paulo, this model offers a replicable framework for other cities. In Helsinki, for instance, the Knowledge-Based Urban Development (KBUD) model integrates governance, sustainability, and innovation to support tech clusters, with an added dimension of cross-border collaboration with Tallinn, which further strengthens regional innovation (Yigitcanlar & Lönnqvist, 2013; Yigitcanlar, 2014). Similarly, Brisbane's Innovation District fosters a knowledge economy by balancing macroeconomic support with robust infrastructure, promoting sustainable growth while enhancing competitiveness in the global market (Yigitcanlar, 2014). In Buenos Aires, urban policies aim to create opportunities for technological diversification through proximity between established and emerging sectors, making it an emerging center for innovation (Harvard Growth Lab, 2020).

These international cases underscore the transformative potential of urban policies aligned with tech cluster development, showing how targeted urban policies can drive inclusive innovation ecosystems. However, São Paulo's UDP zones face challenges, including high property costs that may exclude smaller startups and reduce ecosystem diversity. Additionally, the study's focus on economic and spatial factors does not fully address socio-demographic elements, which could further inform equitable tech cluster distribution and impact on local communities (Sun & Lv, 2020).

By drawing on insights from cities like Helsinki, Shanghai, Brisbane, and Buenos Aires, this study contributes to a global

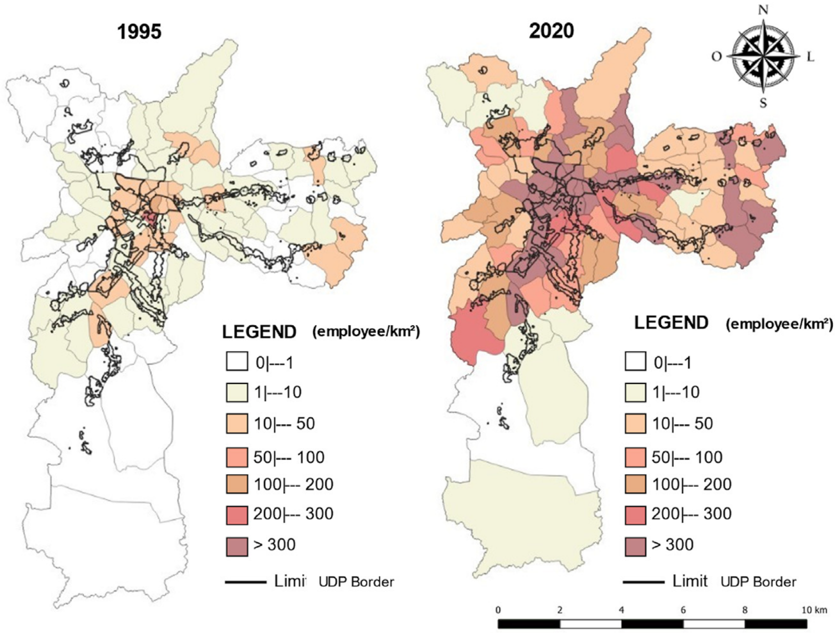

Fig. 6. Creative class employment concentration (C3) map. Source: The authors (2024). RAIS 1995; 2015 database (Brazil. Ministry of Labor and Employment, 1995; 2022).

understanding of how urban development policies can support technology clusters. It highlights the need for a balanced approach that promotes sustainable economic growth, while also addressing the risks associated with rising property values and the potential for gentrification within tech hubs.

7. Conclusions

The findings of this study emphasize the importance of a balanced and inclusive approach to urban development policies (UDPs) that supports sustainable technology cluster growth. For cities like São Paulo, the integration of affordable housing, diverse land use, and accessible infrastructure within UDP zones helps maintain equitable access to technology clusters. Strategic investments in mobility, education, and research institutions not only enhance knowledge-sharing but also drive the development of a specialized workforce essential for a thriving innovation ecosystem. São Paulo's experience highlights how carefully coordinated UDPs—such as efficient mobility systems, proximity to educational institutions, and infrastructure improvements—can attract talent, support startups, and encourage economic diversification, providing a model for other cities aiming to develop their technology sectors.

While the benefits of UDPs in fostering startup concentration and promoting real estate development are clear, the study underscores the need for ongoing monitoring to mitigate rising property prices that may hinder access for smaller startups. The proposed method for mapping and analyzing startup clusters provides urban planners with a valuable tool to support this balance, facilitating data-driven decisions for fostering inclusive growth. The study also shows that commercial and service sector growth within UDP zones, supported by high-capacity mobility infrastructure, enhances cluster sustainability but requires attention to potential gentrification impacts to retain diversity within these innovation hubs.

The recommendation for cities is to adopt inclusive UDP frameworks that ensure affordable housing, eco-friendly transportation, green spaces, and manage urban density to create livable, sustainable environments. By focusing on balanced land use and supporting education and research institutions near UDP areas, cities can foster dynamic technology clusters that attract talent and investment, ultimately enhancing their competitiveness in the global knowledge economy.

This study contributes a replicable framework for evaluating UDPs and technology cluster formation, which other cities can apply to achieve innovation-driven urban development. Future research should explore how demographic density and affordability metrics affect cluster accessibility, as well as investigate the socio-economic impacts of UDP-induced clustering. Additionally, examining the formation of diverse types of clusters under varying policy frameworks could refine strategies for sustainable, inclusive, and tech-centered urban growth.

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CRediT authorship contribution statement

Emílio Bertholdo: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Karin Regina de Castro Marins:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Conceptualization.

Data availability

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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