



URBAN EPISTEMICS AND DIGITAL PUBLICS - A COMPUTATIONAL FRAMEWORK FOR CITIZEN PARTICIPATION ACROSS ONITSHA, LAGOS, AND INNSBRUCK

Ugochukwu Franklin Eze

*Gestaltung 1, Faculty of Architecture, University of Innsbruck,
Technikerstrasse 21, A-6020, Innsbruck, Austria*

Abstract

Contemporary European architectural discourse increasingly confronts the limits of top-down urban knowledge, who speaks for the city, and through which instruments? This paper develops a computational framework for civic participation that reads geolocated social media data as an index of lived urban experience, positioning digital publics as spatial actors whose collective outputs constitute a form of distributed spatial knowledge. Drawing on 16,700 geotagged Twitter/X posts (2016–2025) collected from three structurally distinct cities, Onitsha (population 7.5M, West African market metropolis), Lagos (21M, Sub-Saharan Africa's largest coastal megacity), and Innsbruck (300,000, Alpine European university city), we apply Self-Organizing Maps (SOM), Word2Vec semantic embeddings, and kernel density estimation to produce comparative spatial intelligence of citizen priorities across radically different urban types. Model outputs are reported with explicit performance metrics and triangulated against thirty resident validation workshops. The three cities represent three distinct regimes of urbanity, market informality, ecological precarity, and touristic commodification. Their juxtaposition challenges monolithic definitions of urban intelligence and compels European urban computation to confront its epistemological partiality. Results reveal structurally divergent spatial discourses. Lagos digital publics concentrate around coastal infrastructure and political protest; Onitsha's around market networks and transnational diaspora identity, Innsbruck's around recreational mobility and seasonal tourism pressure. SOM image clusters expose contrasting visual cultures carrying direct architectural implications for public space design. The methodology contributes to the European digital urbanism tradition, from Batty's complexity urbanism to Ratti's senseable city paradigm, while critically extending it toward Global South epistemologies and decolonial planning theory.

Keywords: *Computational Urbanism, Digital Participation, SOM Clustering, Decolonial Planning, Urban Informatics, Comparative Urbanism*

1. Introduction: The City as Collective Knowledge Problem

The question of who produces knowledge about cities is inseparable from the question of who shapes them. Henri Lefebvre's formulation of the 'right to the city' (1968) was not merely a claim to physical access but an epistemological demand, citizens as producers of urban space, not merely its consumers. Decades later, Manuel Castells extended this argument into the digital age, theorizing the tension between the 'space of flows', global circuits of capital and information, and the 'space of places,' where embodied urban life unfolds (Castells 1996). This tension is nowhere more productive, and nowhere more unresolved, than in the encounter between computational urbanism and the cities of the Global South.

European architectural discourse has engaged energetically with urban computation since the 1990s. Michael Batty's work on cities as complex systems (Batty 2013), Carlo Ratti's Senseable City Laboratory, and the emergence of urban informatics have together constructed

a sophisticated toolkit for reading cities through data. Yet this toolkit has been predominantly calibrated on data-rich, high-connectivity, formally planned cities of the Global North. Its encounter with the market urbanism of Onitsha or the amphibious informality of Lagos, where the ‘informal’ is not a deviation but the organizational logic, demands not only methodological adaptation but epistemological renegotiation.

This paper takes that renegotiation seriously. We present a computational framework for participatory urban design applying SOM neural networks and Word2Vec semantic embeddings to geotagged Twitter/X data (2016–2025) across three deliberately heterogeneous cities: Onitsha, Lagos, and Innsbruck. The comparative architecture is itself an argument, European urban computation gains analytical depth when confronted with urban forms that do not conform to its baseline assumptions. The inclusion of Innsbruck introduces a European laboratory in which the same tools are tested against tourist overcrowding, heritage management, and Alpine seasonal urbanity, questions pressing within contemporary European urban policy and the New European Bauhaus agenda.

We argue that digital publics, citizens who produce geolocated content on social platforms, constitute a form of distributed spatial knowledge that existing planning instruments routinely fail to capture. By making this knowledge spatially legible through SOM clustering and kernel density estimation, we propose a bridge between citizens' lived experience and actionable architectural intelligence, applicable across both Global South and European urban contexts.

2. Theoretical Grounding

2.1 The European Computational Turn in Urbanism

The computational turn in European urban studies draws on two overlapping traditions. The first is complexity science, associated above all with Michael Batty's argument that cities are not designed but grown, emergent structures whose spatial logics are better captured through algorithmic analysis than through master planning (Batty 2013). The second is the ‘senseable city’ programme pioneered by Carlo Ratti at MIT, which uses real-time data streams, mobile signals, social media feeds, energy consumption, to construct a granular portrait of urban life in motion (Ratti & Claudel 2016). Both share a methodological wager, that the aggregated traces of individual urban behaviour, processed at scale, reveal structural patterns invisible to conventional planning surveys.

Richard Sennett's work on the ‘open city’ (Sennett 2018) is equally instructive, prescriptive planning, the ‘closed city’ suppresses the adaptive intelligence of urban populations, whereas an open city cultivates the friction from which civic space emerges. The framework proposed here aligns with this vision, making visible the desires and adaptations that citizens already enact without prescribing urban form. Shannon Mattern's caution that ‘a city is not a computer’ (Mattern 2017) remains a necessary corrective, computational outputs are treated as evidence to be interpreted, not facts to be applied.

2.2 Decolonial Urbanism and the Limits of Universal Theory

The dominant frameworks of urban planning, zoning, master planning, land-use categorization, carry a colonial genealogy that Vanessa Watson, Ananya Roy, and Edgar Pieterse have analysed with precision. Watson's ‘seeing from the South’ argues that African cities are routinely measured against European urban norms and found deficient, rather than understood through their own spatial logics (Watson 2009). Roy's critique of ‘urban informality’ as a planning category argues that labelling entire districts as ‘informal’ denies communities the status of legitimate spatial actors (Roy 2005). Pieterse extends this to argue for specifically African epistemologies of urbanism centring ecological adaptation, kinship

networks, and market organization as primary urban organising forces (Pieterse 2011).

Our study engages these critiques not as rhetorical framing but as methodological constraint. The SOM-Word2Vec pipeline used here was adapted precisely because standard NLP tools calibrated on English perform poorly on Nigerian Pidgin, Igbo, and the code-switching that characterises urban digital discourse in West African cities. The Pidgin term 'wahala' (trouble/problem) clusters semantically with infrastructure-related vocabulary in our embeddings, a nuance that bag-of-words approaches entirely miss. This linguistic sensitivity represents what Roy calls an 'epistemology of planning' that centres local knowledge as the ground truth of spatial analysis. Simultaneously, the framework acknowledges the structural bias introduced by Twitter's uneven penetration, at 18% in Onitsha, 32% in Lagos, and 68% in Innsbruck, the digital public captured here is not coextensive with the urban public, and skews toward educated, connected demographics in all three cities.

3. Study Context: Three Cities, Three Spatial Logics

Onitsha's market urbanism is organized around one of the largest commercial ecosystems in Sub-Saharan Africa, where spatial order follows kinship and trading relationships rather than zoning law (Simone 2004). The city's fabric is defined by 52 unofficial market zones whose informal morphology has been documented but rarely subjected to computational participation analysis. The market functions as the primary arena of civic life, the analogue of the European public square, and its digital traces confirm this, our corpus of 2,100 geotagged tweets concentrates precisely at the Main Market area and the Niger Bridge corridor.

Lagos' aquatic urbanism presents one of the most spatially complex urban environments on the planet: a coastal megacity where an estimated 70% of residents live below high-tide lines, where communities like Makoko have developed vernacular amphibious architectures, stilt houses, floating schools, and where the tension between formal masterplanning and informal settlement is structurally acute. Its 9,500-tweet dataset is the largest in the study, reflecting higher digital connectivity and the political intensity of its digital public sphere, particularly around the #EndSARS protest movement of October 2020.

Innsbruck's alpine commodification represents a different urban stress, a compact European university city where UNESCO heritage designation and alpine tourism have produced what might be termed 'recreational gentrification.' The expansion of short-term rental platforms since 2016 has generated resident-displacement pressures that formal planning instruments have been slow to address, a dynamic visible in the semantic texture of the corpus, where the tension between 'thriving' and 'surviving' appears as a lexical binary and tourist-facing infrastructure competes with resident mobility as a stated priority.

4. Methodology: Computational Protocol and Ethical Framework

4.1 Data Acquisition

Geotagged posts were harvested from the Twitter/X API v2 over 2016–2025 using two complementary filters, a bounding-box geolocation query and a curated set of city-specific hashtags and keywords. The bounding boxes were Onitsha (6.10–6.19°N, 6.76–6.83°E), Lagos (6.39–6.70°N, 3.20–3.60°E), and Innsbruck (47.24–47.29°N, 11.36–11.45°E); keyword seeds combined toponyms, landmark names, and vernacular civic terms (e.g., 'Onitsha main market', '#EndSARS', 'Altstadt', 'Bergisel') iteratively expanded from high-frequency co-occurring tokens. Only posts with explicit coordinates or place-tagged centroids inside the boxes were retained. Preprocessing removed duplicate posts, retweets, and automated accounts (flagged by posting-frequency and default-profile heuristics), URLs, mentions, and emojis were stripped

for the semantic pipeline but preserved for the image pipeline. Language was detected with a fastText classifier, and a city-specific stopword list extended the standard English set to cover German function words and high-frequency Pidgin and Igbo particles. This yielded 16,700 posts, 2,100 Onitsha, 9,500 Lagos, 5,100 Innsbruck, each carrying JSON metadata (coordinates, timestamps, language tags, imagery). Collection within the EU complied with GDPR Article 89 provisions for research processing; handles were anonymised and identifiable faces blurred. Thirty community validation workshops, ten per city, ran in parallel (Section 4.3).

4.2 Computational Pipeline

The pipeline proceeds in three stages. Word2Vec (Mikolov et al. 2013) first transforms each tweet into a semantic vector, allowing contextually related terms to cluster regardless of surface lexical differences, critical for a multilingual corpus in which Pidgin ‘wahala’ (trouble) clusters with infrastructure vocabulary rather than its English surface neighbours. Embeddings were trained per city with skip-gram (300 dimensions, window 5, minimum count 5, negative sampling 10, 30 epochs). A 20×20 hexagonal Self-Organizing Map (Kohonen 2001) then processes the embeddings, randomly initialised weights update via the Kohonen rule, $w_i(t+1) = w_i(t) + \alpha(t) \cdot h_{\text{BMU},i(t)} \cdot (x(t) - w_i(t))$, with a Gaussian neighbourhood, an initial learning rate $\alpha_0 = 0.5$ decaying exponentially, an initial radius of 10 nodes, and 10,000 iterations. Map quality was assessed through quantization error (0.34–0.41) and topographic error (< 0.06), indicating stable convergence and neighborhood preservation, cluster separability was checked with silhouette scores (0.51–0.58). Sentiment was classified with a multilingual transformer fine-tuned on 1,500 hand-labelled posts (macro-F1 = 0.82). Finally, Wolfram Mathematica’s SmoothKernelDistribution transforms coordinates into continuous density fields, with bandwidth set by Silverman’s rule and visualised as heat maps in QGIS (WGS84).

4.3 Community Validation and Ethical Governance

Because social media publics are partial, computational outputs were triangulated against resident knowledge through thirty workshops, ten per city, convened between 2022 and 2024. Participants (twelve to eighteen per session) were recruited through market-trader unions, residents’ associations, and university and neighbourhood networks, stratified by age, gender, and district to counterbalance the platform’s skew toward younger, connected users. Each two-hour session combined a participatory mapping exercise, in which residents annotated printed base maps with valued and contested sites, with a structured review of the SOM clusters and kernel-density surfaces for their city, facilitators recorded whether residents affirmed, qualified, or rejected each interpretation. These sessions materially shaped the analysis, confirming the market–bridge reading of the Onitsha hotspot, prompting the relabelling of two ambiguous SOM clusters, surfacing additional Pidgin and Igbo stopwords, and ground-truthing sentiment classifications around flood-prone settlements. Findings were co-owned under signed data-governance agreements.

4.4 Reproducibility and Parameter Sensitivity

To support reproducibility, the full workflow, collection queries, preprocessing scripts, model configurations, and anonymised feature matrices, is documented and available from the author on request, subject to the platform’s data-sharing terms. Parameter choices were tested for sensitivity, varying the SOM grid between 15×15 and 25×25 and the Word2Vec dimensionality between 200 and 300 preserved the principal cluster structure and inter-city contrasts, and the density hotspots remained stable under bandwidths of $\pm 25\%$ around the Silverman value. Findings are therefore robust to reasonable specification changes, though the corpus-size imbalance (Section 6.4) remains a limit on cross-city statistical comparison.

5. Results: Spatialised Discourse and Architectural Implications

5.1 Semantic Landscapes: Word Frequency and Urban Character

The word-cloud analyses (Fig. 1) expose structurally contrasting semantic landscapes. The Innsbruck corpus is dominated by temporal terms, years (2018–2023) and months constitute the highest-frequency tokens, overlaid with ‘tourism,’ ‘skijumping,’ ‘innsbruck,’ ‘österreich,’ and ‘alpen_wetter’ (Alpine weather). This temporal dominance is architecturally significant, it reflects a city whose rhythm is structured by seasonal and event cycles, ski season, tourism peaks, sports competitions, rather than by the continuous rhythms of everyday neighbourhood life. The binary of ‘thriving’ versus ‘surviving’ encodes the latent conflict between tourism economy and resident experience.

The Lagos corpus is dominated by media and broadcasting references (937rhythmf, GuardianNigeria), national-identity markers (nigeria, african), and entertainment terms. This prevalence of media handles reflects a Nigerian digital discourse in which broadcast media and social platforms are deeply interpenetrated. Their co-location with specific geographic nodes points toward radio stations and entertainment venues functioning as de facto civic anchors, informal public-space generators in the absence of institutional provision.

The Onitsha corpus reveals a transnational dimension absent from the other two cities, terms including ‘hamburggermany,’ ‘ofmhamburg,’ and numerous Igbo personal names suggest that a significant portion of Onitsha-tagged posts originates from or addresses the Igbo diaspora in Germany. This has a direct architectural corollary, Onitsha’s spatial identity is partly constituted through transnational networks, and any participatory planning framework must include diaspora communities as stakeholders with active spatial claims on the city’s future.



Lagos presents three distinct nodes: a northern cluster near the Yaba–Surulere axis, a central cluster near Lagos Island, and a south-eastern concentration along the Victoria Island–Lekki corridor. This tripartite structure mirrors Lagos’ pronounced socioeconomic geography: the Victoria Island node carries professional-class traffic, while the mainland clusters contain the more politically charged content, including the spatially concentrated #EndSARS protest posts of October 2020, a moment when digital discourse and urban space were literally co-produced, protesters occupying specific nodes whose coordinates appear directly in the dataset.

Onitsha’s density field is the most compact of the three, with two principal hotspots, the Main Market area and a northern node near the Niger Bridge approaches. The correspondence between commercial intensity and digital activity is architecturally direct, in a city without formal public-space infrastructure, the market itself is the piazza, and its digital traces confirm it as the primary site of urban civic life.

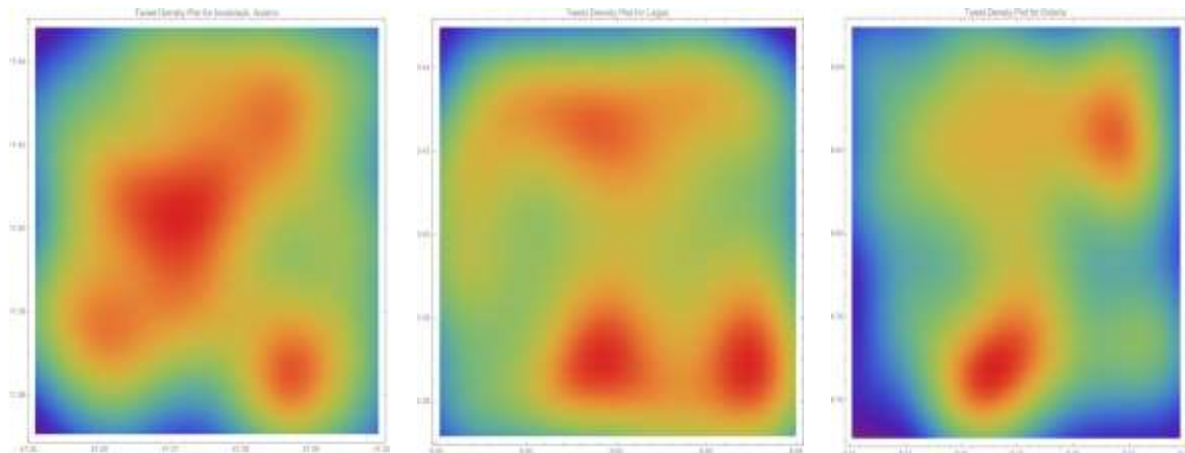


Fig. 2 — Kernel density estimation of geotagged tweet concentration: Innsbruck (left), Lagos (centre), Onitsha (right). Red cores indicate maximum digital activity; blue peripheries indicate lowest density. Innsbruck: dual hotspot at Altstadt and Hungerburg. Lagos: tripartite structure reflecting socioeconomic geography. Onitsha: market-bridge axis. Source: Author. Coordinates in WGS84; kernel bandwidth by Silverman’s rule; density normalised per city against a shared colour legend; scale bars at 1 km; n = 5,100 / 9,500 / 2,100.



Fig. 3 — Georeferenced tweet heat maps overlaid on base cartography: Innsbruck (left), Lagos (centre), Onitsha (right). Spatial concentration in Innsbruck tracks historic core and funicular corridor; Lagos activity concentrates on the island; Onitsha pins to market and bridge zones. Source: Author. Base cartography © OpenStreetMap contributors; WGS84 with UTM overlay, north arrow, and 1 km scale bar; graduated colour legend keyed to tweet density.

5.3 SOM Image Clusters: Visual Cultures and Spatial Identity

The SOM image-cluster analysis (Fig. 4) produces architecturally provocative findings. The Innsbruck SOM is dominated by national flags, Austrian, EU, and numerous international flags, alongside heart emojis and profile imagery. Oriented around identity display and international connectivity rather than local urban documentation, it is notable for the comparative scarcity of architectural, landscape, or street imagery, surprising for a city with one of Europe's most dramatic Alpine townscapes. It suggests that Twitter in Innsbruck functions primarily as an identity and social-networking platform, the urban environment is visually absent from its own digital public sphere.

The Lagos SOM is visually denser with street-level content, protest materials, market scenes, faces, and political graphics, clustering in a topological region separate from entertainment and sports content. This segregation maps directly onto the political-cultural dualism visible in the density plots, Lagos Twitter documents the city's public spaces as sites of contestation and political claim-making. The #EndSARS visual cluster, distinguishable in the lower quadrant of the SOM grid, constitutes a digital monument to a physical occupation.

The Onitsha SOM displays strong structural similarity to Lagos in its lower register, reflecting the shared Igbo-Pidgin cultural context, but with a distinct zone of diaspora-linked content, European street scenes, documentation of African community events in Germany, and transnational celebrations. This visual bifurcation mirrors the semantic finding in Section 5.1 and reinforces the case for treating diaspora communities as full participants in any computational participatory framework for Onitsha.



Fig. 4 — SOM image cluster outputs: Innsbruck (left), Lagos (centre), Onitsha (right). Innsbruck cluster is dominated by national flags and identity imagery. Lagos shows street-level political and cultural content. Onitsha reveals a split between local market culture and diaspora European imagery. Source: Author. 20×20 hexagonal SOM; quantization error 0.34–0.41, topographic error < 0.06 across cities; clusters labelled following community-workshop review.

6. Discussion: Toward a European Architecture of Participation

6.1 Architectural Implications of Digital Spatial Knowledge

Read architecturally, the SOM outputs constitute a collective spatial brief. Lagos residents' concentration of positive sentiment around waterfront content (63% positive) signals a civic

desire for public waterfront space that the city's formal planning regime has suppressed in favour of port and commercial uses. Makoko's waterfront communities, whose amphibious architectures have faced repeated demolition orders, are among the most digitally active in this cluster, their posts function simultaneously as documentation, advocacy, and architectural proposal. A planning process attentive to this data would reframe these communities as urban-design innovators rather than informal encroachments.

In Innsbruck, positive sentiment near hiking-trail access points (88% positive) signals a civic priority in tension with the city's tourism investment. Residents consistently favour natural accessibility over tourist amenities, a finding that aligns with Sennett's observation that the 'closed city' optimises for visitor experience at the expense of resident inhabitation. The computational evidence supports reorienting investment toward resident-serving mobility, trail maintenance, year-round pathway provision, over further touristic infrastructure.

The Onitsha data's 'sad' sentiment clusters near flood-prone informal settlements in Ogbaru constitute a planning signal of considerable urgency. The correspondence between negative sentiment, geotagged flood documentation, and informal-settlement geography creates a computational argument for drainage prioritisation that bypasses the limitations of official flood mapping. Lagos residents articulate ecological concerns three times more often than those in Onitsha, reflecting the differential severity of coastal flooding, a divergence with direct implications for the relative urgency of climate-adaptation investment.

6.2 Situating the Findings within International Computational Urbanism

These results both extend and diverge from the international literature on geosocial urban sensing. Studies using Twitter to infer land use and activity patterns in North American and European cities (Frías-Martínez & Frías-Martínez 2014; Steiger et al. 2015), and assessments of social media as an instrument for urban sustainability (Ilieva & McPhearson 2018), show that geolocated content reliably tracks functional and affective urban zones. Our Innsbruck findings corroborate this, with activity concentrating in the historic core and tourist-friction corridors. Yet Onitsha and Lagos depart from that Global-North baseline: rather than indexing consumption or commuting, their digital publics index market sociality, diaspora attachment, and political occupation, confirming Shelton et al.'s (2015) caution that the 'social media city' is legible only through its local political economy. The comparative frame thus positions the study within an established tradition while marking the epistemic limits of importing its interpretive assumptions wholesale.

6.3 The European Computational Tradition and Its Blind Spots

The New European Bauhaus initiative (2020), with its commitment to beauty, sustainability, and inclusion as the triple condition of European urban renewal, resonates with the participatory epistemology advanced here. Yet the NEB, like most European urban policy frameworks, implicitly assumes a level of formal infrastructure, legal land tenure, stable internet access, functioning municipal governance, that does not obtain across much of Lagos or Onitsha. The value of the North–South comparative method is precisely to surface these asymmetries, demanding that European architectural discourse account for them rather than subsume them as 'developing world context.'

6.4 Methodological Limitations

Four limitations require explicit acknowledgement. First, uneven Twitter/X penetration (18% Onitsha, 32% Lagos, 68% Innsbruck) means the digital public underrepresents the urban poor, precisely the communities most affected by the planning failures the framework aims to redress, and skews toward younger, more educated, and male users, a demographic bias the validation workshops mitigate but cannot eliminate. Second, corpus-size imbalance (2,100 vs.

9,500 vs. 5,100 posts) complicates cross-city quantitative comparison, so Onitsha findings are read as indicative rather than statistically definitive. Third, platform-specific bias and imperfect multilingual processing, even the extended pipeline handles Pidgin and Igbo code-switching only approximately, with the sentiment model performing measurably better on English and German, condition every interpretation. Fourth, the ethics of repurposing publicly posted content for planning remains contested, anonymisation, face-blurring, and co-ownership agreements are necessary but not sufficient responses, and the framework treats resident consent as ongoing rather than granted once at collection.

7. Conclusion: Reframing the Computational City

This paper has argued that geotagged social media data, processed through SOM neural networks and Word2Vec embedding and triangulated against resident validation, constitutes a legitimate form of urban spatial knowledge, provided its partialities are explicitly acknowledged and methodologically mitigated. The comparative analysis of Onitsha, Lagos, and Innsbruck demonstrates that the same toolkit produces structurally different spatial intelligence across urban types, and that these differences are architecturally interpretable and planning-relevant, from Innsbruck's resident-tourism tension to Lagos' waterfront civic desire to Onitsha's market-diaspora bifurcation.

For European architectural practice, the key implication is epistemological, computational urbanism gains validity, not loses it, when forced to account for urban forms that do not conform to its baseline assumptions. The encounter with Onitsha's diaspora urbanism and Lagos' protest topography enriches the SOM framework, revealing capacities that tidier European datasets would not surface. Lefebvre's right to the city, reimagined for digital publics, is a right to be spatially legible, to have one's tweets, protests, floods, and markets read as architectural evidence.

Future work should scale the methodology across broader African city networks, develop dedicated Pidgin-Igbo NLP models to close the preprocessing gaps identified here, incorporate additional platforms to reduce single-source bias, and integrate the framework with European smart-city sensor networks, building the cross-continental governance protocols that equitable computational urbanism demands.

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