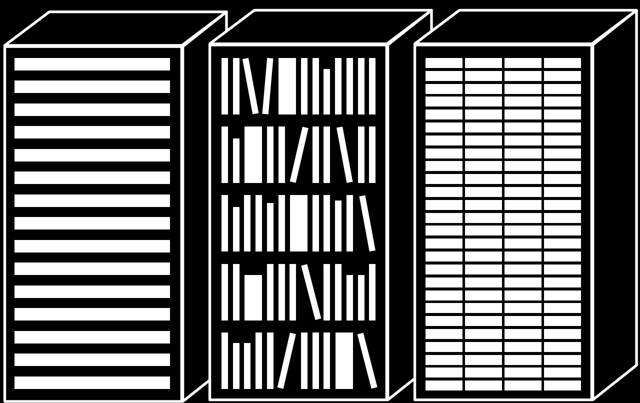
Thesis Research Paper

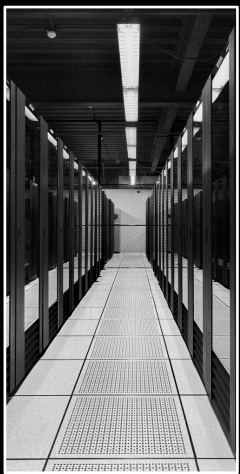
MSc Graduation Studio 2024-2025
Architectural Desgin Crossovers
Heterogenous City - Madrid
Tsz Kwan Kelvin Chan



BEYOND THE BLACK BOXES

Cultivating Knowledge Commons from Madrid's Digital Shadows

The Three Black Boxes



Data Center *Archive* *Digital Archive*

Abstract

From virtual to visible: Activating archives through digital infrastructure

Madrid's planned 80% increase in data center capacity by 2026 creates an opportunity to reimagine digital infrastructure as civic space. This research proposes transforming data centers—currently hidden in industrial peripheries despite consuming enormous resources—into integrated civic institutions at Plaza Colón, a site historically evolved from Royal Mint to National Library to public plaza.

The project addresses a triple crisis: infrastructure invisibility that conceals resource consumption; digital literacy gaps stemming from black-boxed interfaces; and archive digitalization that disrupts traditional memory institutions. By leveraging the concept of the "post-archival constellation," the architectural intervention makes visible both the physical infrastructure of digital archives and the knowledge they contain.

The design employs a cloud-fog-edge computing framework that reveals resource flows while integrating technical functions with public programs. Transparent server rooms, exposed cooling systems, and interactive displays of algorithmic processes transform technical infrastructure into educational features. Heat recovery systems repurpose server waste energy for public benefit, making environmental impacts tangible.

This hybrid typology creates spaces where citizens actively participate in producing and verifying digital memory rather than merely consuming it. The architecture materializes the shift from static containers to dynamic circuits in memory practices, establishing a new type of civic institution where cultural heritage is continuously activated through technological engagement and democratic participation.

Keywords:

Digital Infrastructure,
Archives,
Digital Literacy,
Collective Memory,
Madrid

◀ Figure 1 / **Mapping of energy and water flows relative to data center locations / Author, 2025**

Contents

01

INTRODUCTION

Figure 1 / **Mapping of energy and water flows relative to data center locations / Author, 2025**

Polígono Industrial Valportillo
1388.4m
Polígono Industrial Julián Camarillo
7657m
Plaza Mayor
Parque Eólico de Maranchón (Wind)
208 MW
Central Nuclear de Trillo (Nuclear)
1003 MW
Aceca Power Plant (Combustion)
759 MW
Planta Solar Fotovoltaica Solaria-Añover I
(Photovoltaic) 759 MW
Parque Eólico La Plata(Wind)
21.25 MW

Figure 2 / Merlin Data Center / Getafe / Madrid / Spain / MerlinProperties, 2015


MERLIN | edged

Problem Statement

1 “Thirsty Data Centres Are Making Europe’s Dry Summers Even Drier,” The Straitstimes, Jul 2023, https://www.straitstimes.com/world/europe/thirsty-data-centres-are-making-europe-s-dry-summers-even-dryer.

2 Marc Cervera, “Spain to Boost Data Centre Capacity 80% by 2026,” 4Imagazine, October 11, 2024, https://4imag.com/spain-to-boost-data-centre-capacity-80-by-2026/.

The Triple Crisis of Digital Knowledge

Madrid faces three interconnected architectural challenges in the relationship between digital infrastructure and civic life:

Infrastructure Invisibility manifests as deliberate spatial separation between citizens and data processing systems. Data centers hidden in peripheral industrial zones (8-12km from Madrid’s center) consume enormous resources (613 MW of power, 665 million liters of water yearly)[1] while remaining concealed from public view. This architectural arrangement creates both physical and cognitive distance between urban inhabitants and the technical systems increasingly governing their daily lives. As Madrid plans to increase data center capacity by 80% by 2026, this spatial disconnect becomes increasingly problematic for civic engagement with digital infrastructure.[2]

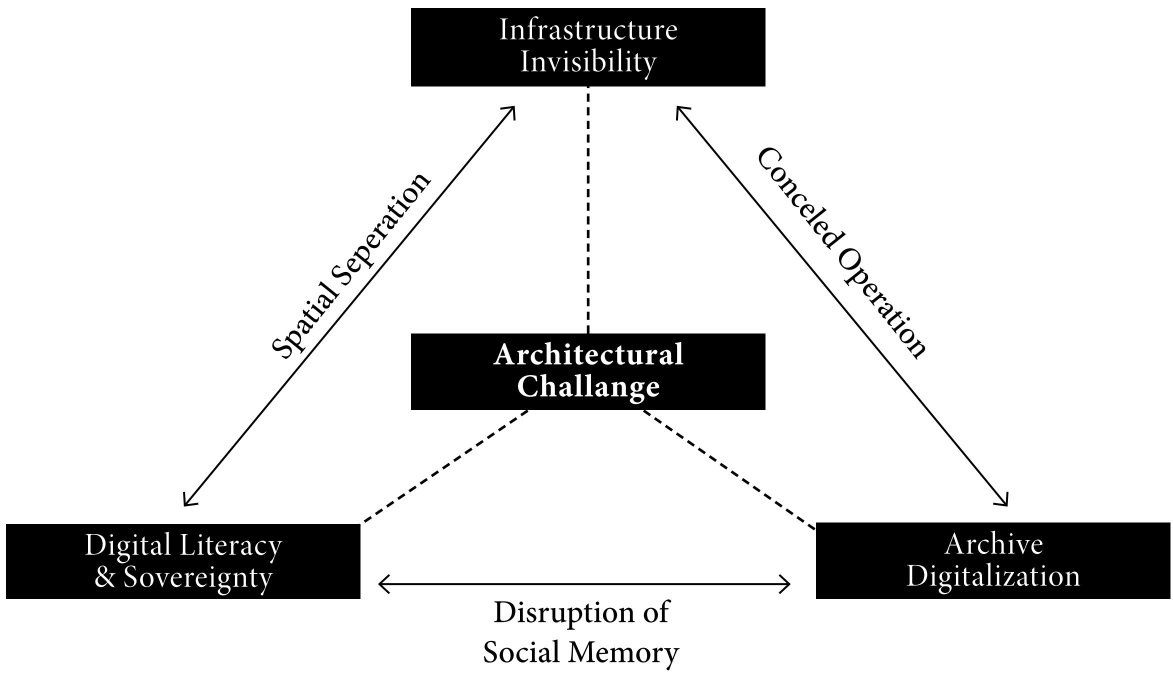


Figure 3 / The interrelationships among the three different aspects. / Author, 2025.

Digital Literacy & Sovereignty suffers from a lack of architectural spaces that make data flows comprehensible. Citizens encounter the digital realm primarily through black-boxed interfaces that obscure how information moves from creation through processing to application. The absence of dedicated environments where people can understand algorithmic systems and participate in data collection, organization, and utilization represents a critical spatial gap in Madrid's civic landscape. Without such spaces, the pathways between individual data contributions and collective applications remain abstract and inaccessible.

Archive Digitalization disrupts traditional spatial organization of memory institutions. As archives transform from stable repositories into dynamic systems requiring constant regeneration, their physical requirements fundamentally change. The characteristics of digital memory—what Chun calls "an enduring ephemeral"[3]—challenge conventional architectural frameworks for preserving and accessing cultural heritage, leaving communities without adequate spaces to engage with their evolving digital memory.

These challenges demand reconsideration of how architecture mediates between citizens, digital infrastructure, and digital knowledge systems.

3 Wendy Hui Kyong Chun, Programmed Visions: Software and Memory, First MIT Press paperback edition, Software Studies (Cambridge, Mass London: The MIT Press, 2013), 137-140

Research Question

“.....the architectures of the EXTERIORLESS act as expanded domains, whose extension and influence reach beyond their physical boundaries.”

Corbo, 2023

Main Question

WHAT IF archives and digital infrastructure were reimagined as accessible civic spaces that foster digital literacy and democratic participation through architectural intervention?

Operational Question

1. WHAT spatial strategies make invisible digital processes visible and comprehensible to citizens in public institutions?

2. WHERE should data processing facilities be positioned within knowledge institutions to maximize visitor engagement with digital literacy?

3. WHY does revealing the material resources of digital infrastructure (energy, water, heat) matter for civic benefit and environmental sustainability?

4. WHAT IF memory institutions evolved beyond repositories to become active producers of collective digital knowledge?

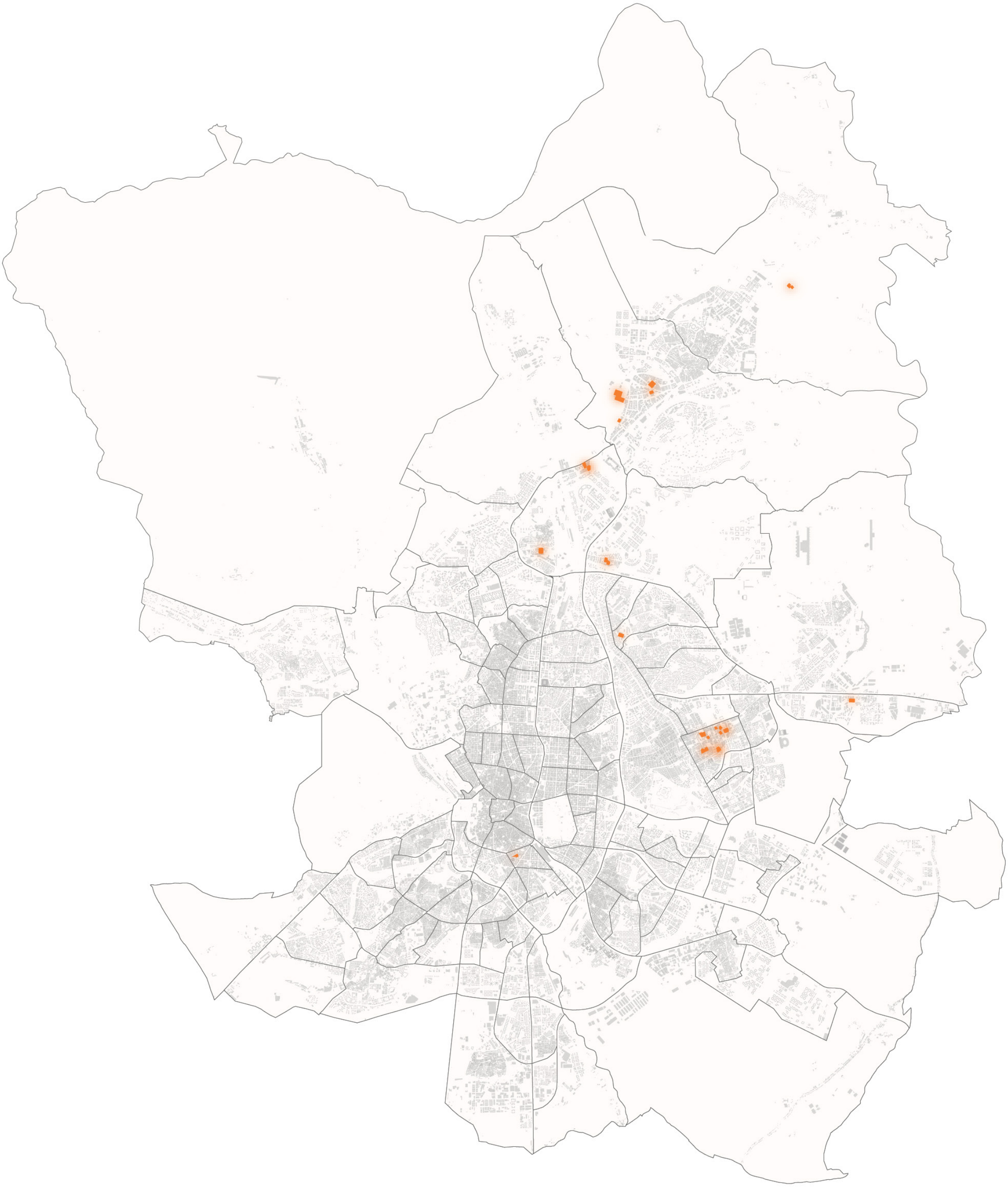


Figure 4 / Mapping of Data Center Location / Data Center that hidden in the City's Periphery. / Author, 2025.

Research Question

Relevance & Position

4 *Hernández Aja, "Energy Needs and Vulnerability Estimation at an Urban Scale for Residential Neighbourhoods Heating in Madrid (Spain)," (2016), 1415.*

5 **Madrid Data Center Power Consumption Equivalency Analysis**
Annual Energy
= 613 MW × 8,760 h
= 5,369,880 MWh/year
Apartment Need for Heat
= 121.2 kWh/m² × 97 m²
= 11,756.4 kWh/year
Equivalent Apartments
= 5,369,880,000 ÷ 11,756.4
= 456,760

This project emerges at a critical moment when two parallel transformations are converging: Madrid's aggressive data center expansion and the digitization of traditional archives. As the city plans to triple its data centers by 2026 - facilities consuming enough energy to heat 456,000 homes[45] - traditional memory institutions are simultaneously being transformed through digitization. This convergence creates a unique opportunity to reimagine both systems as a unified civic resource through architectural intervention.

The relevance of this work lies in addressing six critical concerns:

1. The Archive in Transition

Transforming static repositories into dynamic knowledge systems that actively engage citizens in the production and verification of digital memory.

2. Digital Infrastructure as Civic Platform

Reimagining technical facilities as public institutions where citizens can understand, interact with, and shape the systems processing their data.

3. Material Visibility

Making tangible the physical reality of digital systems through architectural interventions that reveal resource flows, energy consumption, and cooling processes.

4. Civic Knowledge Production

Creating environments where technical processing combines with public programs for digital literacy, fact-checking, and democratic deliberation.

5. Resource Integration

Repurposing the byproducts of digital infrastructure (heat, water) for civic benefit while making these flows visible and comprehensible.

6. Democratic Memory

Ensuring citizens maintain active participation in shaping digital archives and infrastructure through transparent interfaces and participatory spaces.

This research proposes that architectural intervention can transform traditionally separate systems - hidden data centers and digitizing archives - into integrated civic institutions. By reimagining these converging infrastructures as places that combine technical processing with public understanding capabilities, we can create new types of public space that serve both knowledge preservation and democratic resilience.

02

LITERATURE REVIEW & THEORETICAL FRAMEWORK

Literature Review

The Post-Archival Constellation: The Archive under the Technical Conditions of Computational Media

In term of digital archive, The "post-archival constellation" concept introduced by David M. Berry offers a framework for understanding digital-age archives.[6] In the contemporary era, "the archive is no longer hidden away in national libraries, museums, and darkened rooms, restricted in access and guarded by the modern-day equivalents of Jacques Derrida's archons – the guardians of the archive".[7] This shift represents a fundamental change in knowledge management as archives transmit social elements piece by piece, transforming them technologically and driving evolution.

Digital archives operate through dual processes: de-archiving undermines traditional memory institutions while re-archiving creates new forms leveraging digital capabilities. This challenges traditional memory paradigms where memory consists of stable stored objects. As Blom explains, "with digital technologies, nothing is stored but code: the mere potential for generating an image of a certain material composite again and again by means of numerical constellations".[8] This fundamentally alters how we understand the organization and operation of archives.

Berry's framework identifies six interconnected layers of computational archives (image 3) - from physical hardware foundations through logical networks and coding structures to social organizations, user psychology, and interfaces.[9] This multilayered approach shows digital archives as complex socio-technical assemblages operating simultaneously across material, informational, algorithmic, social, personal, and interactive dimensions, creating new accessibility possibilities while potentially reinforcing exclusion patterns.

6 David M. Berry, "The Post-Archival Constellation: The Archive under the Technical Conditions of Computational Media," in Memory in Motion, ed. Eivind Røssaak, Trond Lundemo, and Ina Blom (Amsterdam University Press, 2013), 103–26, https://doi.org/10.1515/9789048532063-006.

7 Berry, 105.

8 Ina Blom, "Rethinking Social Memory: Archives, Technology, and the Social," in Memory in Motion, ed. Eivind Røssaak, Trond Lundemo, and David M. Berry (Amsterdam University Press, 2013), 103–26, https://doi.org/10.1515/9789048532063-006, 8.

9 Berry, 112.

Individuational	Stratification of embodied personality (the psychology of actors, the user, etc.)
Logistical	Social and organizational structure (at the level of institutions, economies, culture, etc.)., social ontology, socialities, etc.
Interactional	Surface/interface level (between human beings and non-humans mediated through code)
Codal	Textual and coding logics (level of code, algorithms, software as text and/or process)
Logical	The logical, network and informational transactional level (level of software as diagram or platform)
Physical	Material and transactional level (of the hardware)

◀ Figure 5 / Berry framework illustrating how computational systems operate across interconnected technical and social layers / Berry, 2013

The Stack: On Software and Sovereignty

While Berry's essay examines the layered complexity of computational archives, Benjamin H. Bratton's "Stack" framework conceptualizes planetary-scale computation as a megastructure through four key layers essential for architectural integration.[10] The Earth Layer grounds digital infrastructure in tangible elements from raw materials to energy sources, connecting digital processes to material realities and ecological impacts.[11] The Cloud Layer encompasses distributed computing facilities, power infrastructure, and communication networks that remain largely invisible to users, creating democratic disconnection.[12]

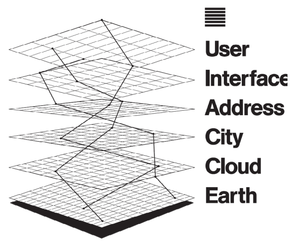
The City Layer represents urban spaces as segmented regions linked through complex networks where physical and virtual habitation coexist, revealing how digital systems reshape physical spaces.[13] At the User Layer, distinctions between people and machines blur as both function as interlinked nodes creating and analyzing data, challenging traditional human-technology interaction concepts.[14]

10 Benjamin H. Bratton, The Stack: On Software and Sovereignty (Cambridge, Massachusetts: The MIT Press, 2016).

11 Benjamin, 75-105.

12 Benjamin, 111-141.

13 Benjamin, 149-183.



▲ Image 6 / The Stack's six-layer structure visualized by Metahaven / Benjamin, 2016

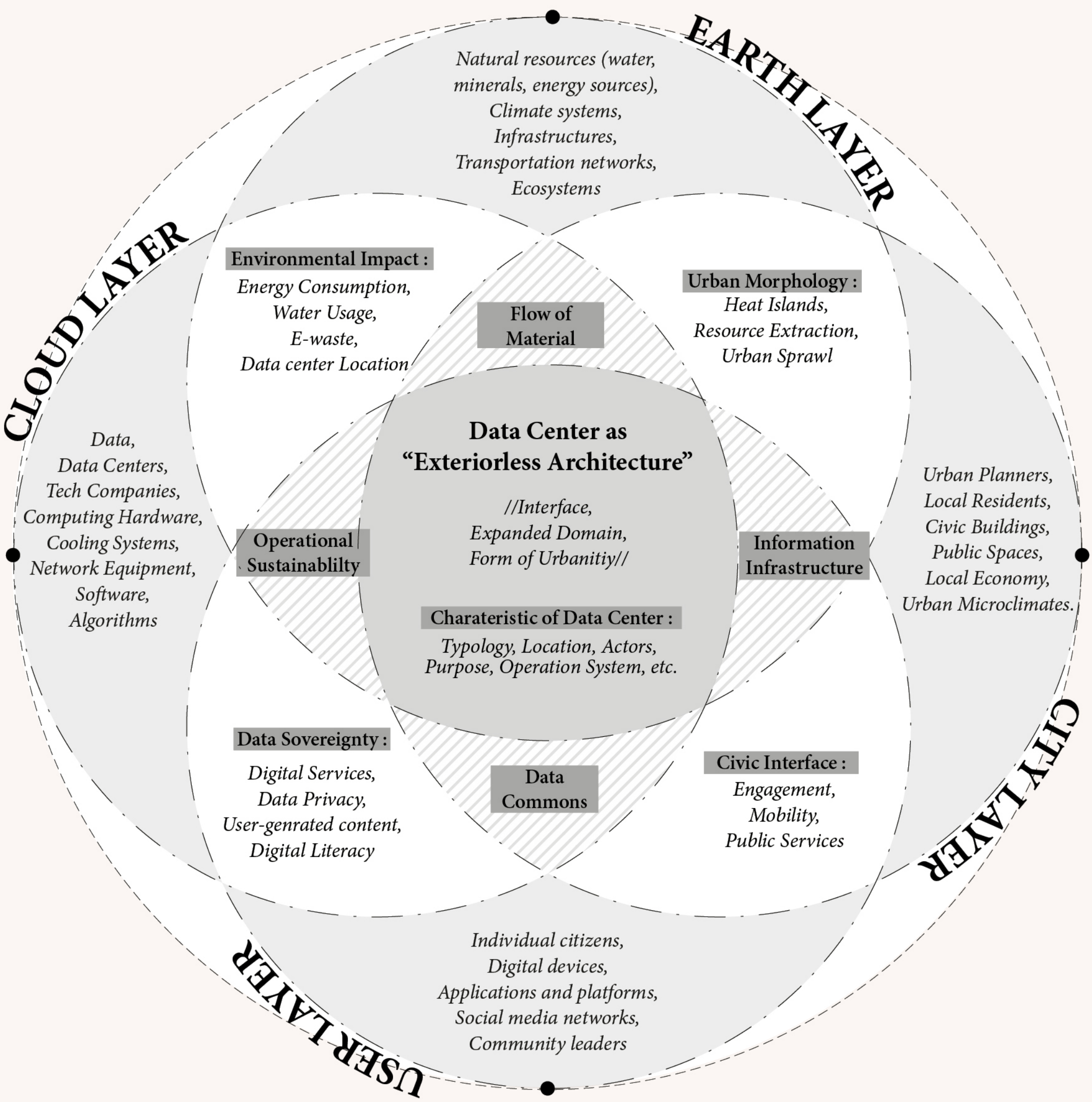


Figure 7 / Venn Diagram show the relationship between Earth, Cloud, City & User layer. / Author, 2025

Together, these Stack layers reveal computation as an accidental megastructure reorganizing sovereignty and transforming social relations. This vertical framework helps understand how technical systems at different levels interact, creating new power and knowledge forms transcending traditional boundaries.

Deep Time of Media Infrastructure & Hybrid Morphologies

While Berry's and Bratton's frameworks provides a vertical framework, Klingmann and Angelil's "Hybrid Morphologies" offers insights into how "architecture is declared as landscape, infrastructure as architecture, and landscapeas infrastructure."[15] However, this spatial framework alone lacks the temporal dimension needed to understand how digital systems transform these relationships.

This research therefore integrates Shannon Mattern's "Deep Time" perspective adds crucial temporal dimensions to understanding digital infrastructure, showing how information systems historically shape cities beyond current technical manifestations. This approach reveals modern digital infrastructure not as a break from previous systems but as continuing and transforming longstanding socio-technical arrangements.[16]

Three key perspectives illuminate infrastructure's historical dimensions: Techno-Socio-Spatio-Material Entanglements show infrastructure systems deeply interwoven with social practices throughout history;[17] Path Dependency demonstrates how infrastructure follows established patterns influencing contemporary possibilities;[18] and People as Infrastructure shows how communities create parallel networks through informal practices.[19] Together, these perspectives frame digital infrastructure as the latest manifestation of ongoing socio-technical processes with deep historical roots.

14 Benjamin, 254 - 284.

15 Marc Angelil and Anna Klingmann, "Hybrid Morphologies: Infrastructure, Architecture, Landscape" Daidalos: Architecture, Art, Culture, no. 73 (1999): 20.

16 Shannon Mattern, Deep Time of Media Infrastructure, The Geopolitics of Information 1 (University of Illinois Press, 2017), 102-108

17 Mattern, 103.

18 Mattern, 105.

19 Mattern, 106.

Theoretical Framework

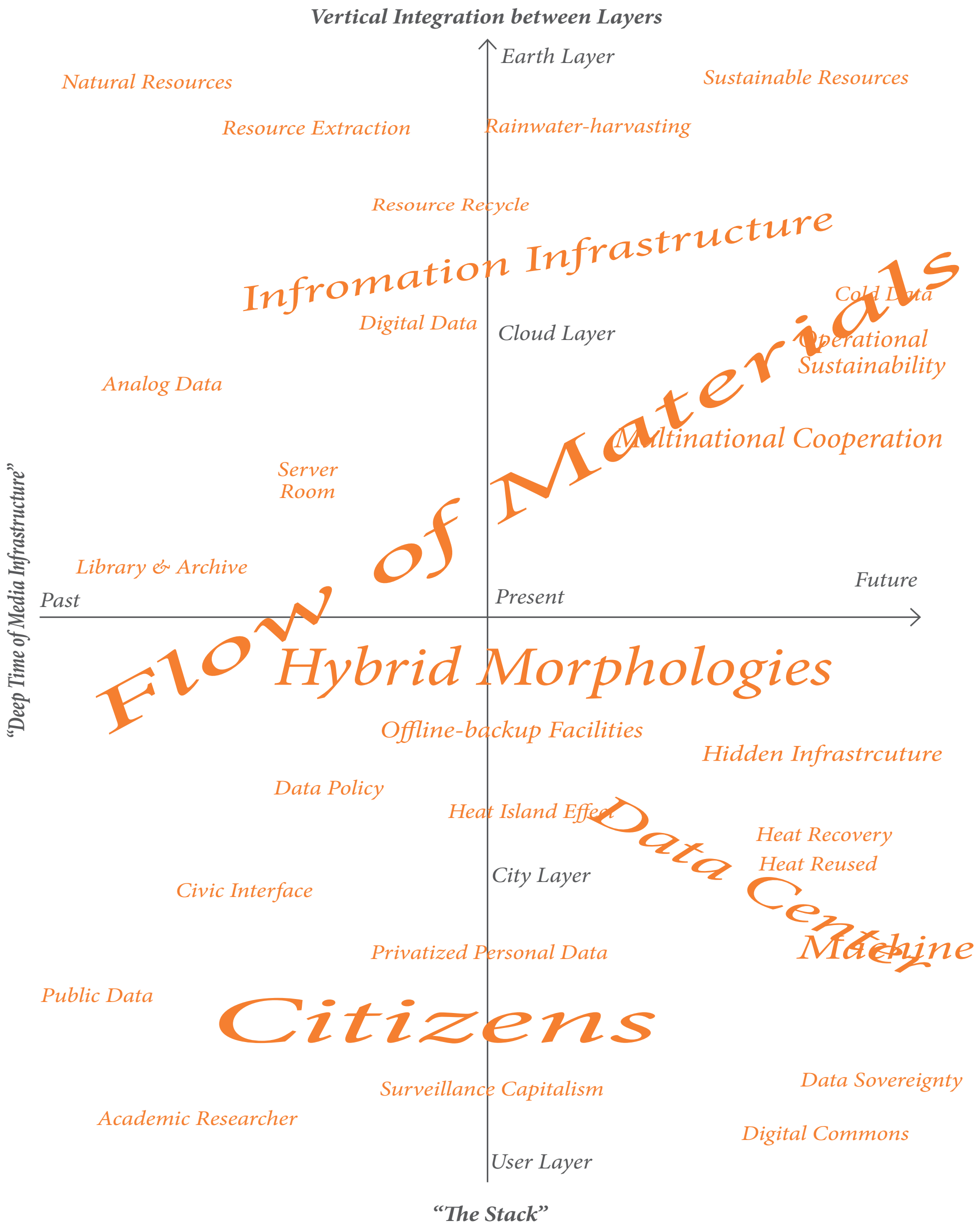
Figure 8 / Merging historical and spatial frameworks to analyze digital infrastructure development / Author, 2025. ▶

Intergration: A Comprehensive Framework

This research proposes a synthetic framework that bridges Berry's post-archival constellation, Bratton's Stack, and Mattern's deep time perspective into a new architectural approach for digital infrastructure. Berry's layered understanding of computational archives shows how digital systems operate across multiple dimensions, while Bratton's Stack maps vertical hierarchies from Earth to User layers. When combined with Mattern's temporal perspective, these frameworks enable understanding digital archives as simultaneously layered, interconnected, historically embedded, and spatially transformative systems.

This synthesis addresses gaps in each individual framework: Berry's post-archival constellation lacks explicit consideration of architectural implications; Bratton's Stack insufficiently addresses historical continuities; Mattern's temporal perspective requires clearer connection to spatial design. Together, however, these approaches create a comprehensive framework for reimagining digital infrastructure as civic space.

The integrated framework suggests new architectural possibilities where data infrastructure becomes legible across multiple dimensions. By revealing the physical materiality, network connections, algorithmic processes, social organization, user experience, and historical evolution of archive storages, architecture can transform isolated technical systems into civic spaces fostering digital literacy and democratic participation. As Blom suggests, A point of departure for elucidating this question may perhaps be found at the intersection of media archaeology, archive theory, and a social



philosophy informed by (among other things) process ontology and new materialist perspectives.[20] This framework provides the theoretical foundation for reimagining Plaza Colón as a site where Madrid's digital infrastructure becomes accessible and meaningful to citizens, bridging the current disconnect between technical systems and democratic life.

20 Blom, "Rethinking Social Memory", 18.

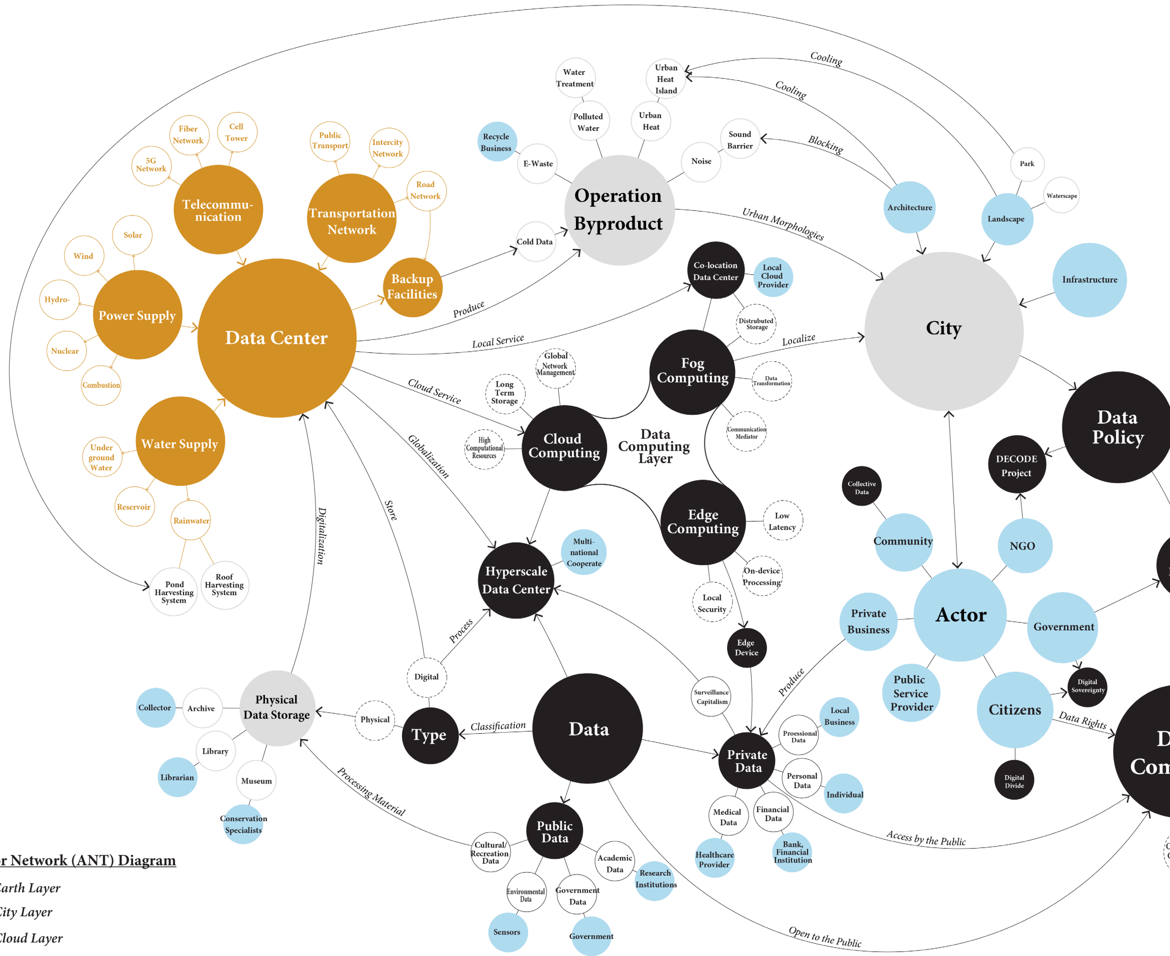
04

METHODOLOGIES

Methodologies

This research employs a multi-layered methodological approach anchored in **Actor Network Theory** (**ANT**) to bridge the divide between Madrid's digital infrastructure and its citizens. ANT enables tracing associations between human and non-human actors across different layers of The Stack framework, revealing how various elements interact and influence each other through their network relationships. As Latour emphasizes, this approach

Figure 9 / Actor Network Theory diagram mapping relationships and flows between Madrid's infrastructural layers - from data centers to water systems, green spaces to power grids - revealing interdependencies and potential integration points between technical, environmental, and social actors. / Author, 2025.



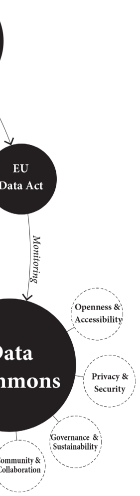
Actor Network (ANT) Diagram
- Earth Layer
- City Layer
- Cloud Layer
- User Layer

moves beyond traditional social explanations to understand how different actors assemble and reassemble into new configurations.[21]

21 *Bruno Latour, "Introduction: How to Resume the Task of Tracing Associations*," in Reassembling the Social, by Bruno Latour (Oxford University PressOxford, 2005), 1–2, https://doi.org/10.1093/oso/9780199256044.003.0001.*

The methodology combines four key techniques: S**patial Mapping** using GIS software traces connections between physical infrastructure networks, from data centers to green spaces, water systems, and energy networks. This multi-layer analysis reveals how actors at different levels influence and shape each other's behaviors and relationships. **Actor Network Mapping** and **Systemic Diagrams** explore relationships between human actors (citizens, operators, policymakers), non-human actors (data centers, infrastructure networks, environmental systems), and intermediaries (policies, technologies, spatial practices) to identify potential synergies and intervention points.

Quantitative and Comparative Analysis examines Madrid's data storage evolution by comparing traditional archives with modern data centers through their spatial organization, operational efficiency, and building scale. This analysis reveals how data centers' massive computing capacity and energy demands contrast with traditional archives, informing strategies for civic integration. **Field Observation** and **Site Survey** document physical facilities and neighborhood relationships to identify potential zones for infrastructure integration.



This comprehensive framework, anchored by ANT's emphasis on tracing associations, reveals both vertical causation through infrastructure layers and horizontal relationships within layers. The resulting analysis will inform strategies that consider both technical requirements and community needs while acknowledging the complex interplay between different infrastructural layers and their various actors.

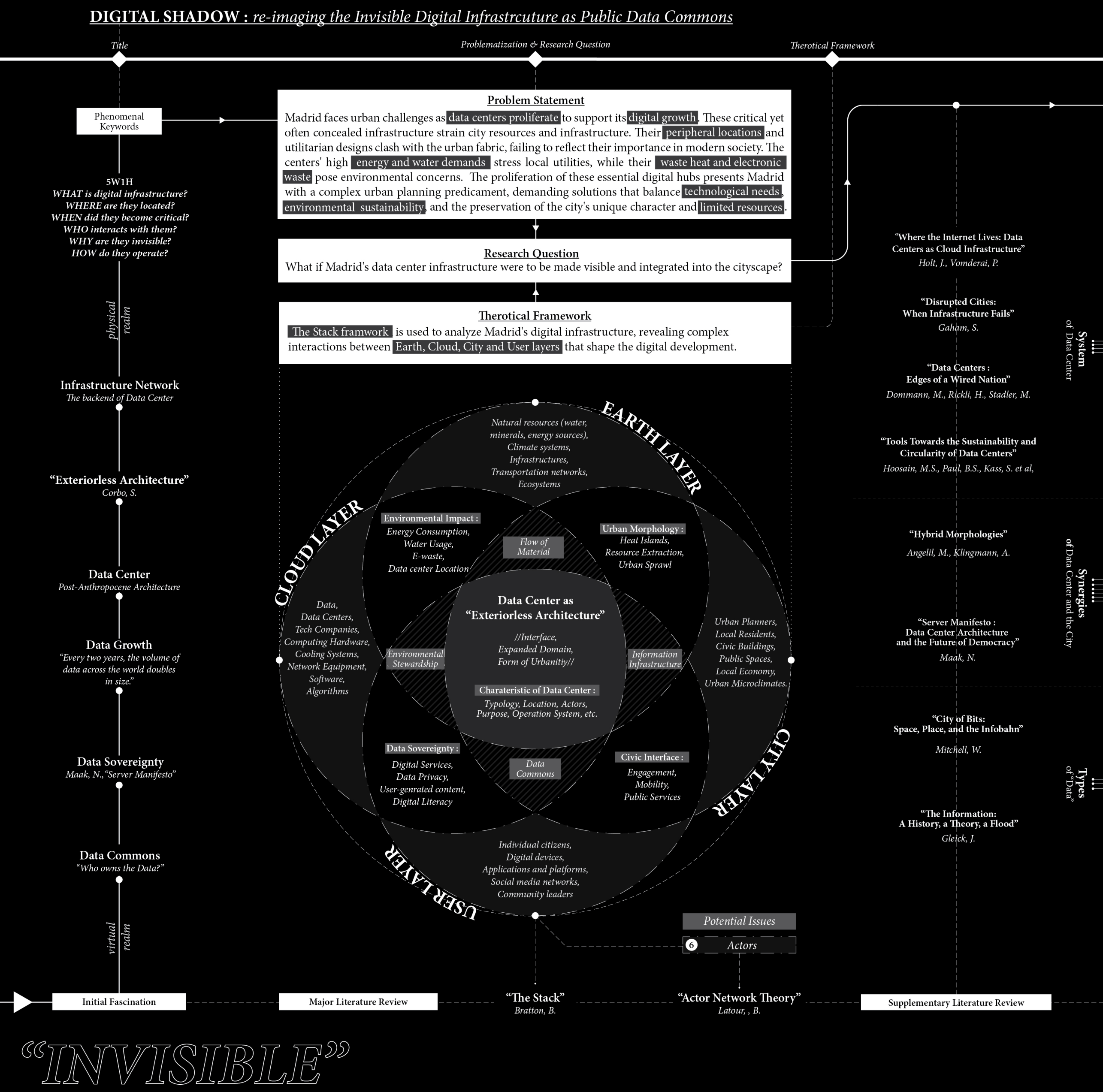
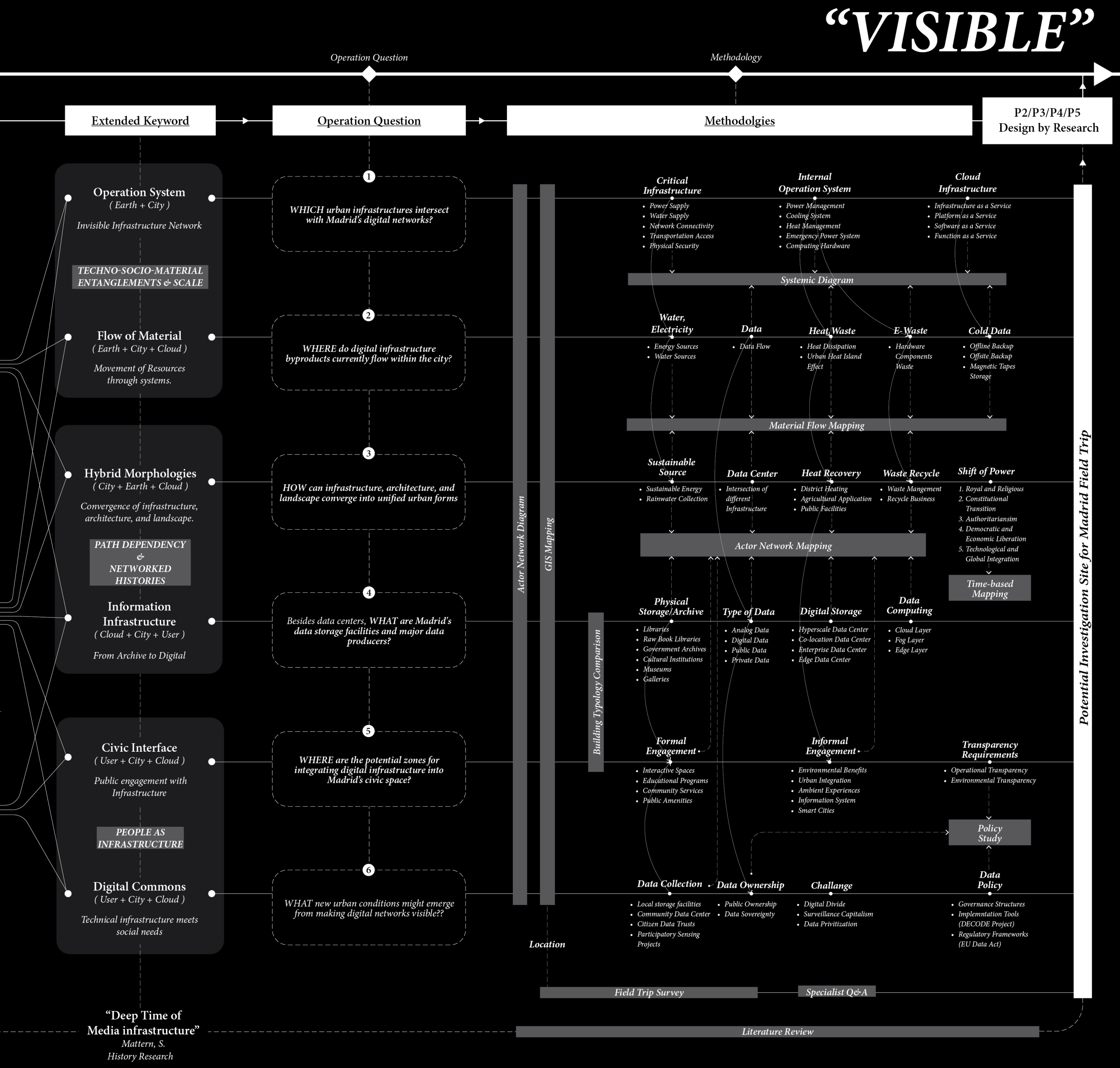
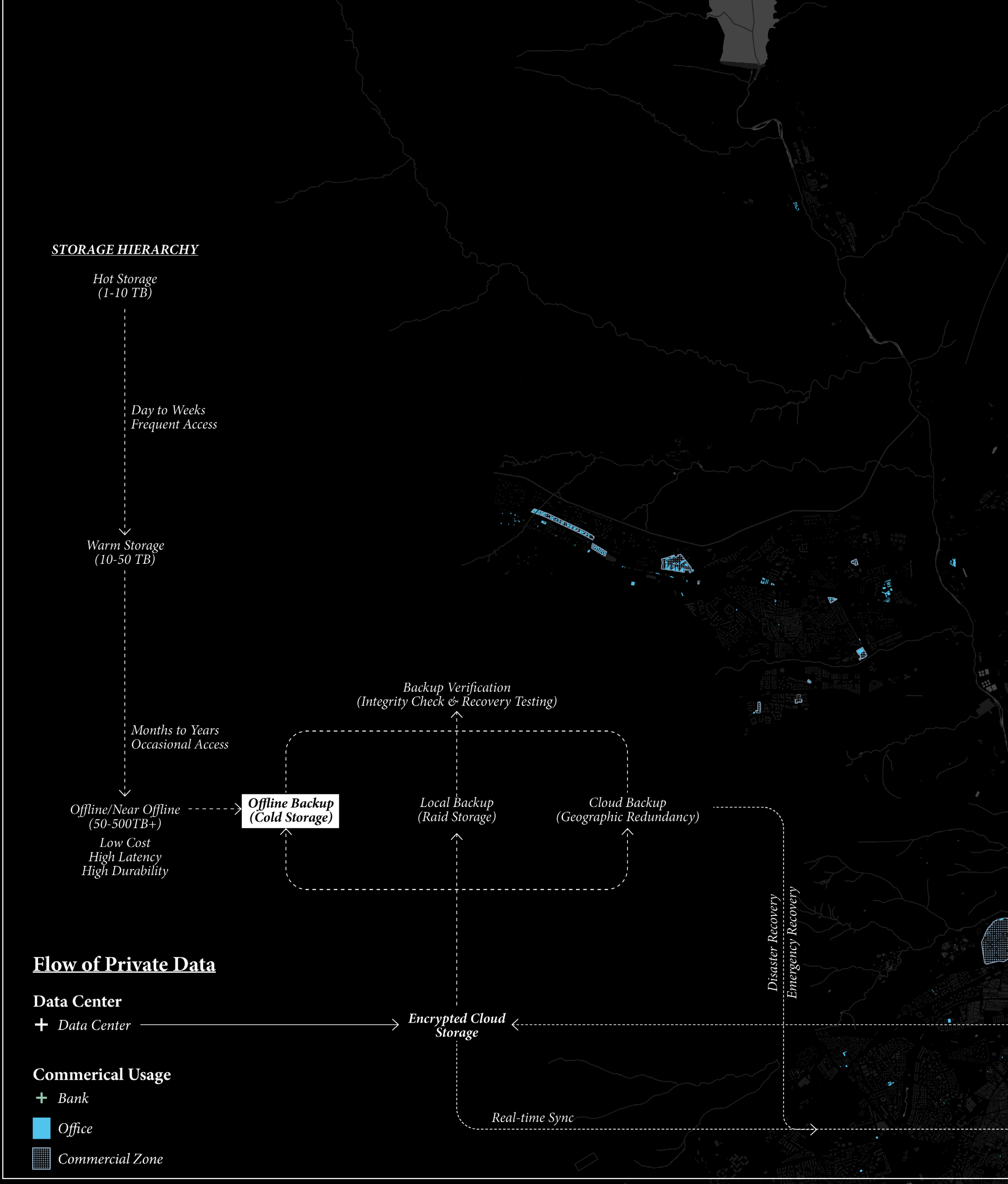


Figure 10 / Sequential research roadmap showing progression from inital fascinations to methodolgy. / Author, 2025.



Research Diagram

Figure 11 / A Hierarchical Network Analysis illustrating data storage architecture for confidential and protected information, highlighting regions necessitating robust private data facilities. The network diagram examines storage stratification based on data retrieval patterns and access intensity levels. / Author, 2025



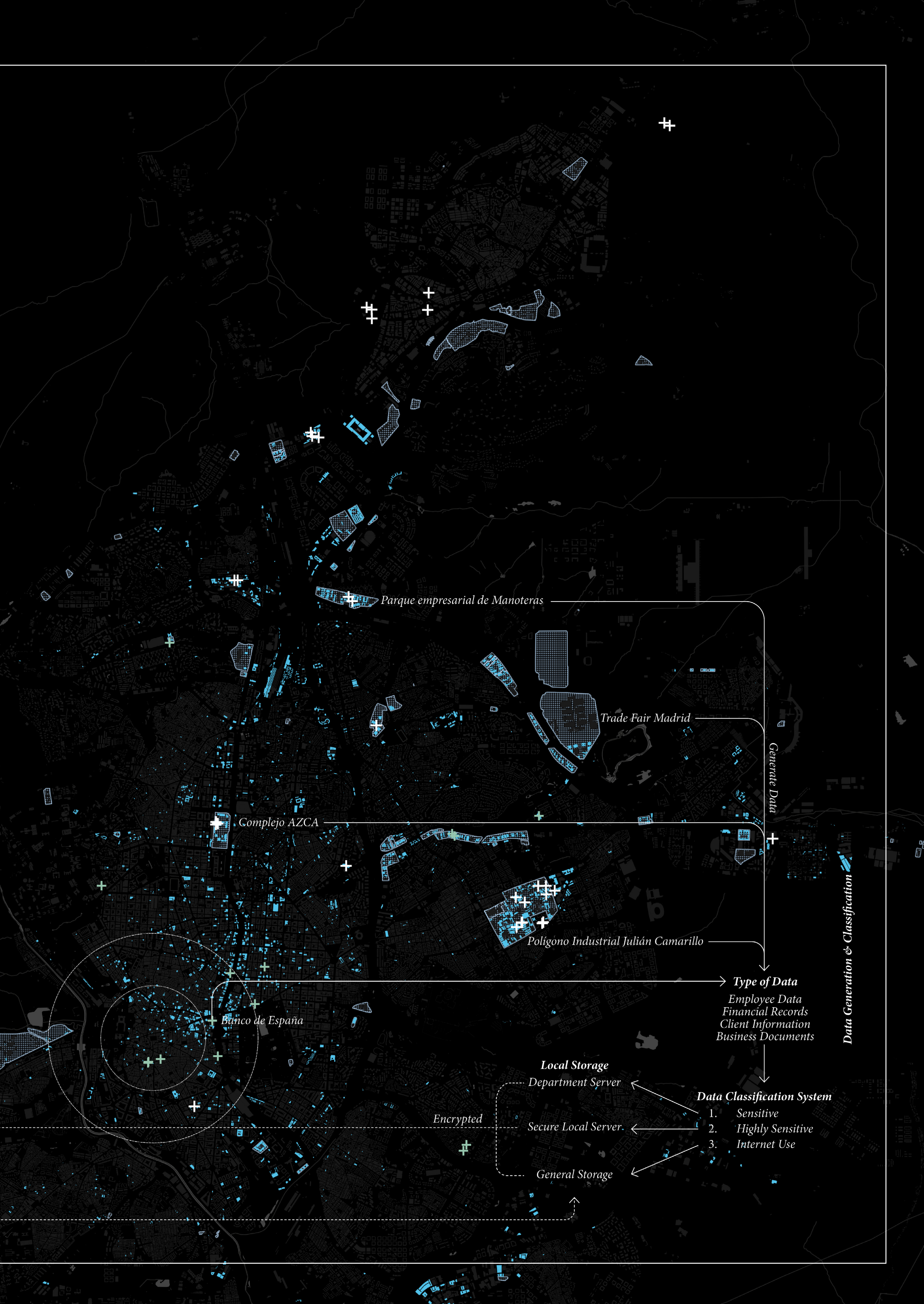
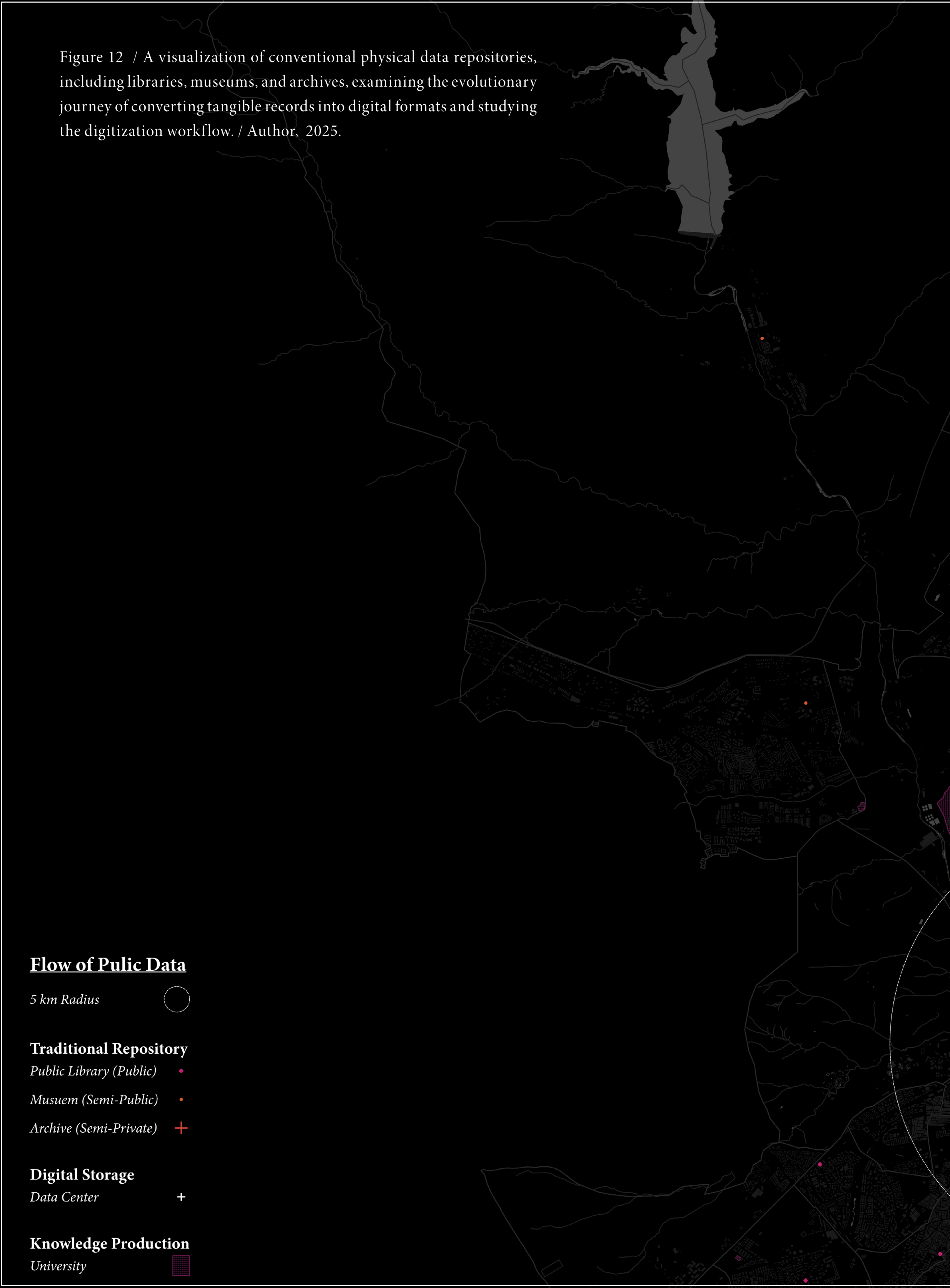

Parque empresarial de Manoteras
Trade Fair Madrid
Generate Data
Complejo AZCA
Polígono Industrial Julián Camarillo
Type of Data
Employee Data
Financial Records
Client Information
Business Documents
Data Generation & Classification
Banco de España
Local Storage
Department Server
Data Classification System
1. Sensitive
2. Highly Sensitive
3. Internet Use
Encrypted
Secure Local Server
General Storage

Figure 12 / A visualization of conventional physical data repositories, including libraries, museums, and archives, examining the evolutionary journey of converting tangible records into digital formats and studying the digitization workflow. / Author, 2025.



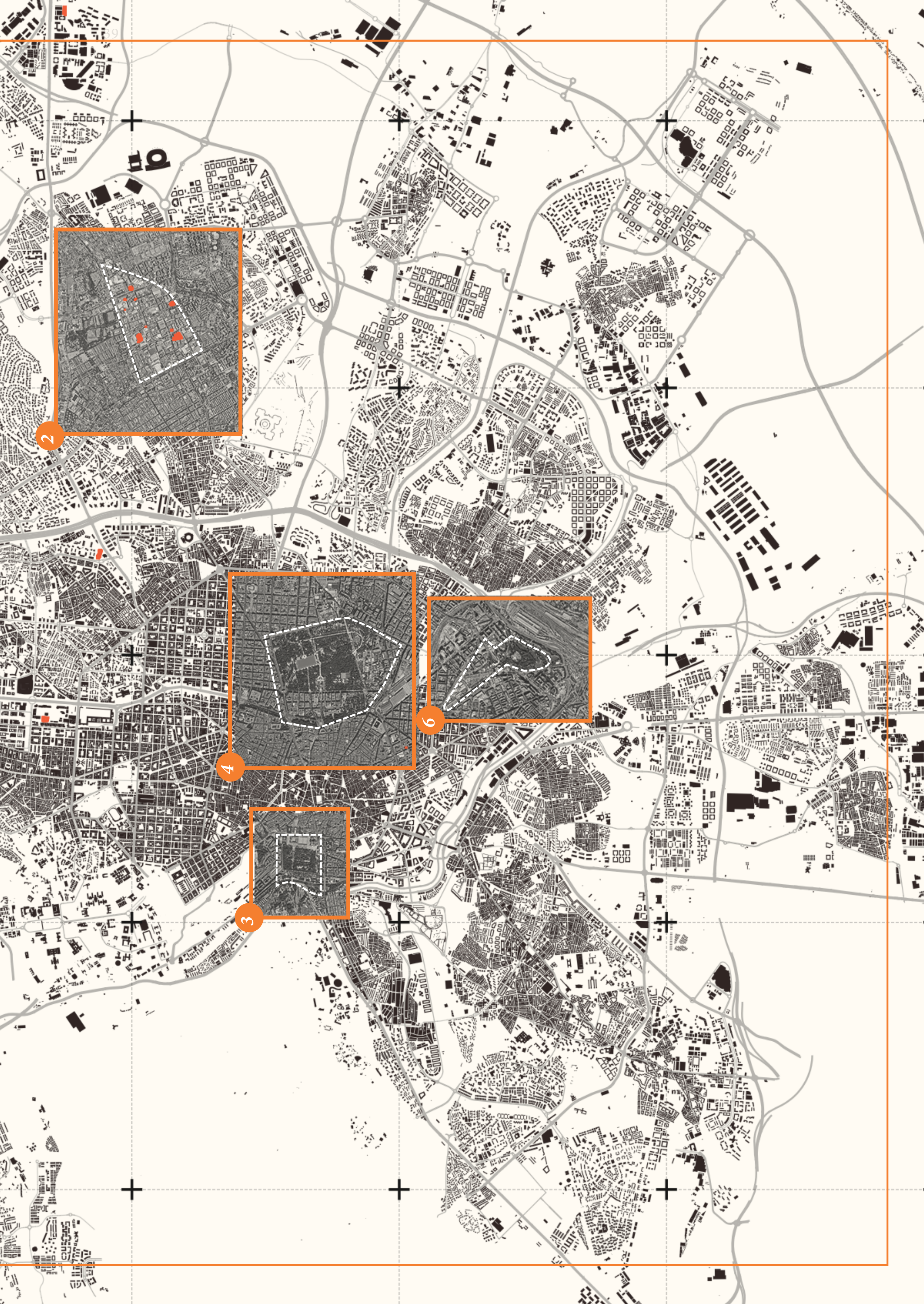
Offsite Backup
Metadata Mangement
Emergency & Disaster Recovery
Digital Presearvation
Autonomous University of Madrid
Post-Processing
Public Access Interface
Quality Control
DIGITALIZATION PROCESS
1. Academic Research
2. Government Agencies
3. Legal Professionals
4. Genealogists
5. Cultural Institutions
Scanning/Photography
Equipment Setup & Calibration
Pre-Digitization Prep
Selection for Digitization
Universidad Politécnica de Madrid
Storage in Climate-Controlled Environment
Archivo Histórico Nacional
Physical Organization
PHYSICAL ARCHIVE MANAGEMENT
Conservation Treatment
Good Condition
Archivo General de Palacio
Conservation Check
Initial Assessment
Archivo Regional de la Comunidad de Madrid
Receive Materials

04

SITE & CONTEXT

Figure 13 / 4/11 - 15/11 Madrid Field Trip Focus Area

1. Polígono Industrial de Alcobendas
2. Polígono Industrial Julián Camarillo
3. Royal Palace of Madrid
4. Parque de El Retiro
5. Parque Norte-Carmen Tagle
6. Parque Enrique Tierno Galván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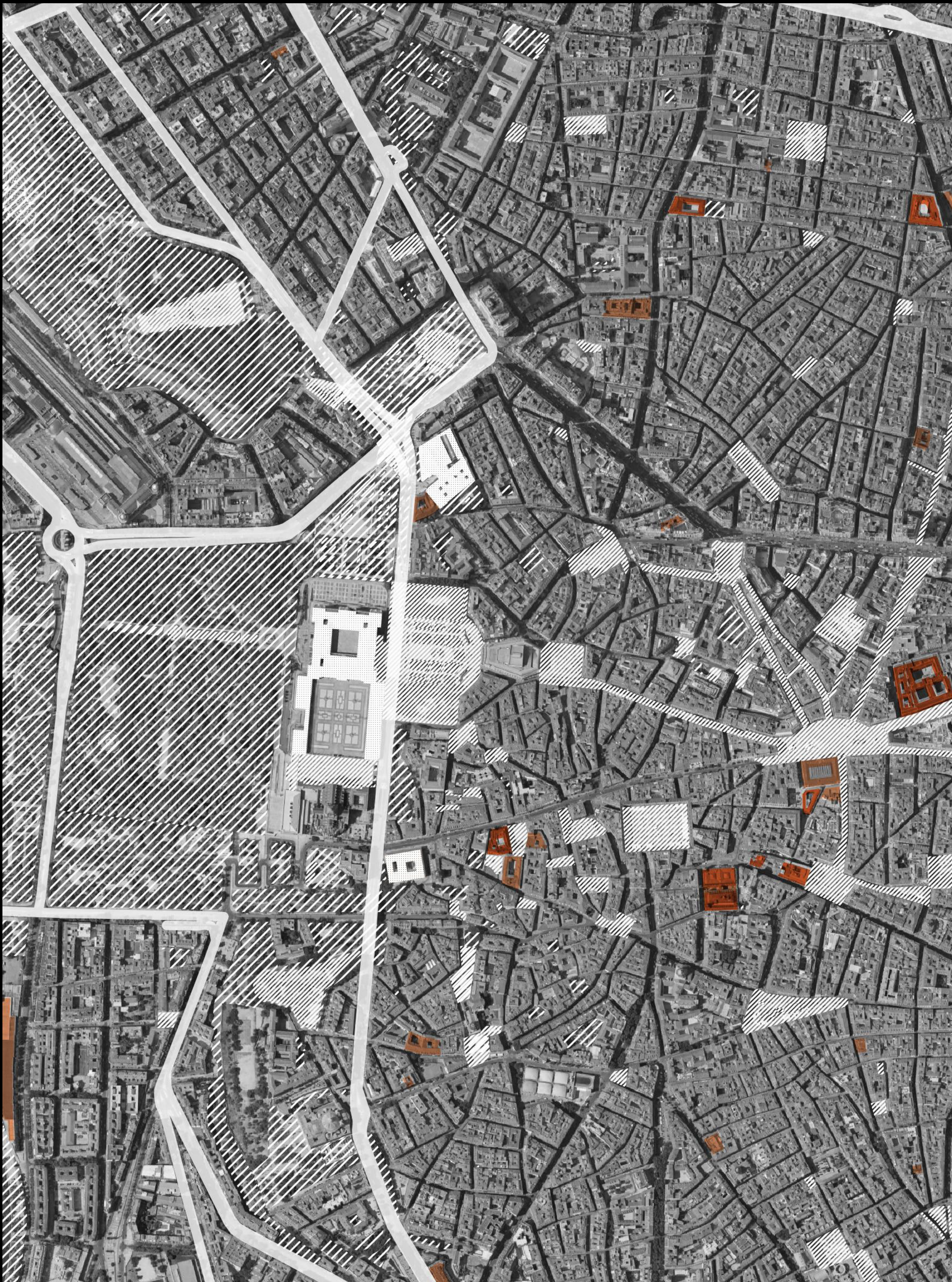


Figure 15 / Field survey map of democratic sites such as public spaces, government buildings and public parks. / Author, 2025.

Paseo de la Castellana
Plaza de Colón
Paseo de Recoletos
Paseo del Prado

Madrid's Digital Infrastructure

Current State: Invisible Infrastructure

The resaerch start from the facination of invisible digital infrastructure in Madrid. Madrid's digital infrastructure embodies a critical paradox in urban democracy, now intensified by severe drought conditions. While these facilities remain deliberately hidden in three peripheral industrial zones (Polígono Industrial Julián Camarillo, Getafe, and Alcobendas), their resource consumption significantly impacts the city. Current data centers consume 613 MW of power as mentioned - and require approximately 665 million liters of water yearly for cooling, with peak usage reaching 195 liters per second.[22] This massive water consumption occurs as Madrid faces a water crisis, with reservoir levels below historical averages forcing residents to accept nighttime supply cuts and irrigation restrictions. While local farmers expect to lose 80-90% of their 2023 harvest due to water scarcity, data centers continue their intensive water usage without public oversight or benefit.[23]

The crisis extends beyond resource consumption. These facilities, averaging 8-12 kilometers from historic civic centers, create both physical and democratic distance between citizens and the infrastructure processing their data. With no public oversight mechanisms, citizens have little control over their personal data while misinformation spreads six times faster than truth across these networks. This spatial and democratic disconnect reflects a broader pattern where technical efficiency is prioritized over civic engagement and environmental responsibility.

22 "Thirsty Data Centres Are Making Europe's Dry Summers Even Drier," The Straitstimes, NJul 2023, https://www.straitstimes.com/world/europe/thirsty-data-centres-are-making-europe-s-dry-summers-even-dryer.

23 "Thirsty Data Centres Are Making Europe's Dry Summers Even Drier."

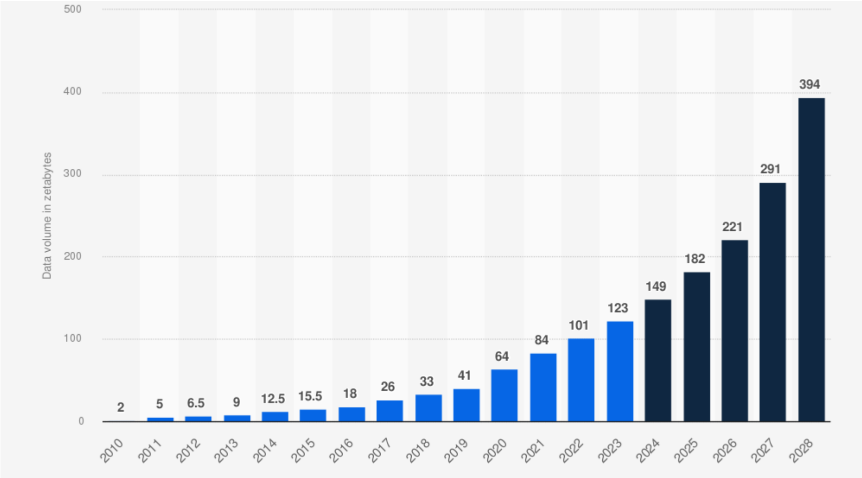


Figure 16 / A chart show the exponential grow of data usage annually. / Statista, 2025.

Growth Projections

Madrid's digital infrastructure faces unprecedented expansion, driven by explosive global data growth projected to surge from 149 zettabytes in 2024 to over 394 zettabytes by 2028 - a staggering 164% increase in just four years.[24] This dramatic rise in data production, accelerated by AI, autonomous systems, and our increasingly digital lives, has direct consequences for Madrid's infrastructure. While only 2% of this data is currently retained long-term, storage requirements continue to grow rapidly, with global capacity increasing at 19.2% annually from its 6.7 zettabyte baseline.[25]

For Madrid, this translates to a nearly fivefold increase in data center capacity by 2030, with installed capacity growing from 164 MW to approximately 792 MW.[26] The city's three major data center markets - Madrid, Barcelona, and Aragón - which currently have a combined installed IT capacity of 314 MW, will gain an additional 249 MW by 2026 alone.[27] This expansion requires an estimated investment of 2.5 billion euros and poses a critical challenge for a city already grappling with drought and energy demands. Without intervention, this massive growth threatens to intensify existing environmental and democratic deficits, as technical infrastructure expands while remaining isolated from civic life and environmental responsibility. The question isn't whether Madrid needs this expanded capacity - global digitalization makes it inevitable - but how this growth can be shaped to serve rather than strain the city's democratic and environmental future.

24 Petroc Taylor, "Volume of Data/Information Created, Captured, Copied, and Consumed Worldwide from 2010 to 2023, with Forecasts from 2024 to 2028," Statista, November 21, 2024, https://www-statista-com.tudelft.idm.oclc.org/statistics/871513/worldwide-data-created/.

25 Taylor, "Volume of Data/Information Created."

26 Cervera, "Spain to Boost Data Centre Capacity 80% by 2026."

27 Cervera.

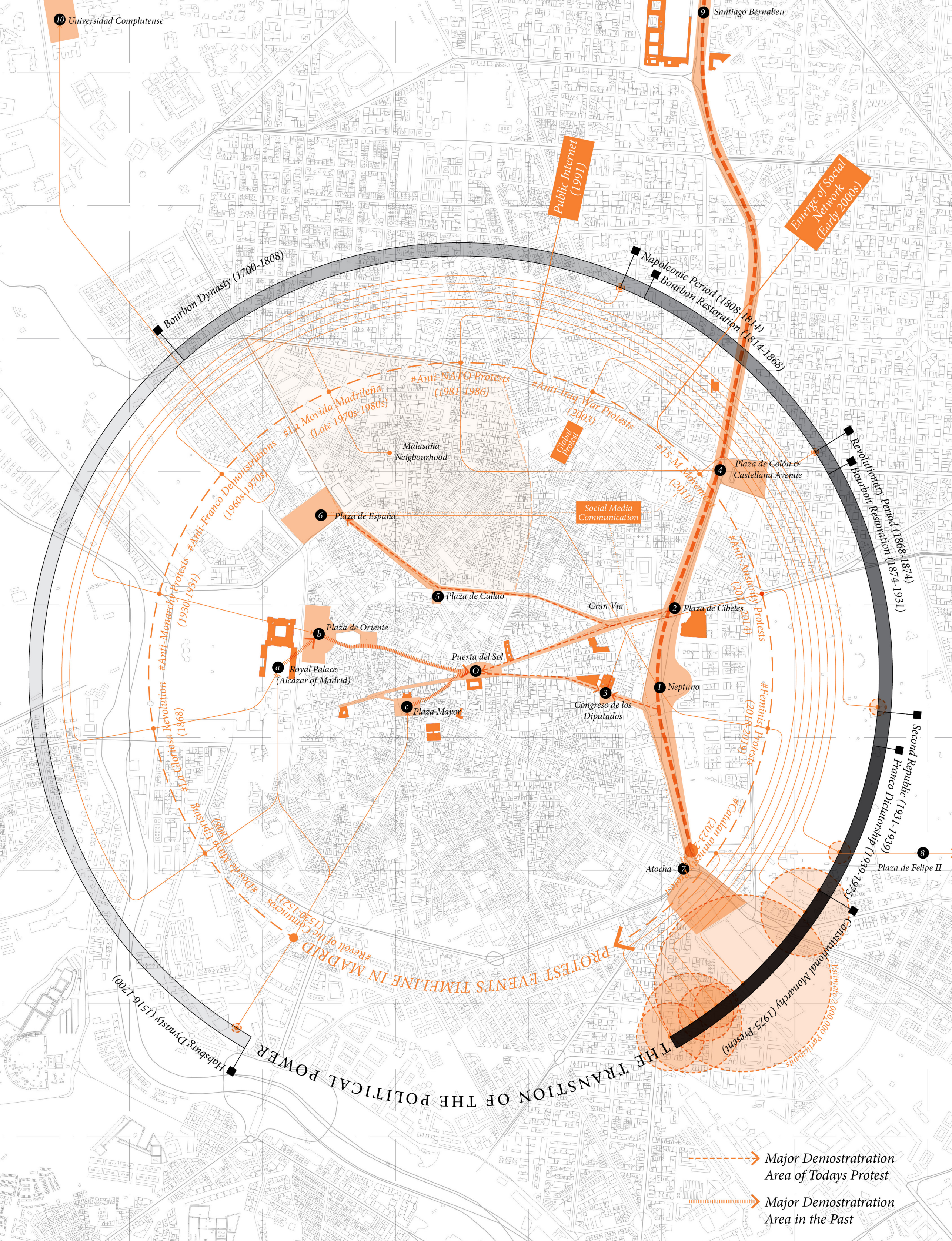


Figure 16 / Map of historical sites and timeline of events at the Madrid demonstration sites. / Author, 2025.

Site Selection: Plaza de Colón

A Space of Democratic Evolution

Plaza de Colón emerges as the ideal focal point for reimagining digital infrastructure as democratic commons through its unique intersection of civic engagement, historical evolution, and infrastructure readiness. The site's selection stems from a careful analysis of Madrid's democratic spaces, particularly those where citizens traditionally gather to exercise their right to public expression and demonstration. The plaza's rich historical transformation

Figure 17 / Existing condition of Plaza de Colón. / Wikipedia, 2007.

WHAT NEXT?

5. 1995 - Present
Technological and Global Integration

- Tech hub

- International Corporations

- Networked Insitutions

4. 1975-1995
Democratic and Economic liberation

- New Business District

- New Industrial District

3. 1939-1975
Centralized Authoritarianism

- Expansion of Government Ministries

- State Controlled Institutions

2. 1808-1939
Constitutional Transition

- Parliament

- Civic Institution

1. 1561-1808
Royal and Religious

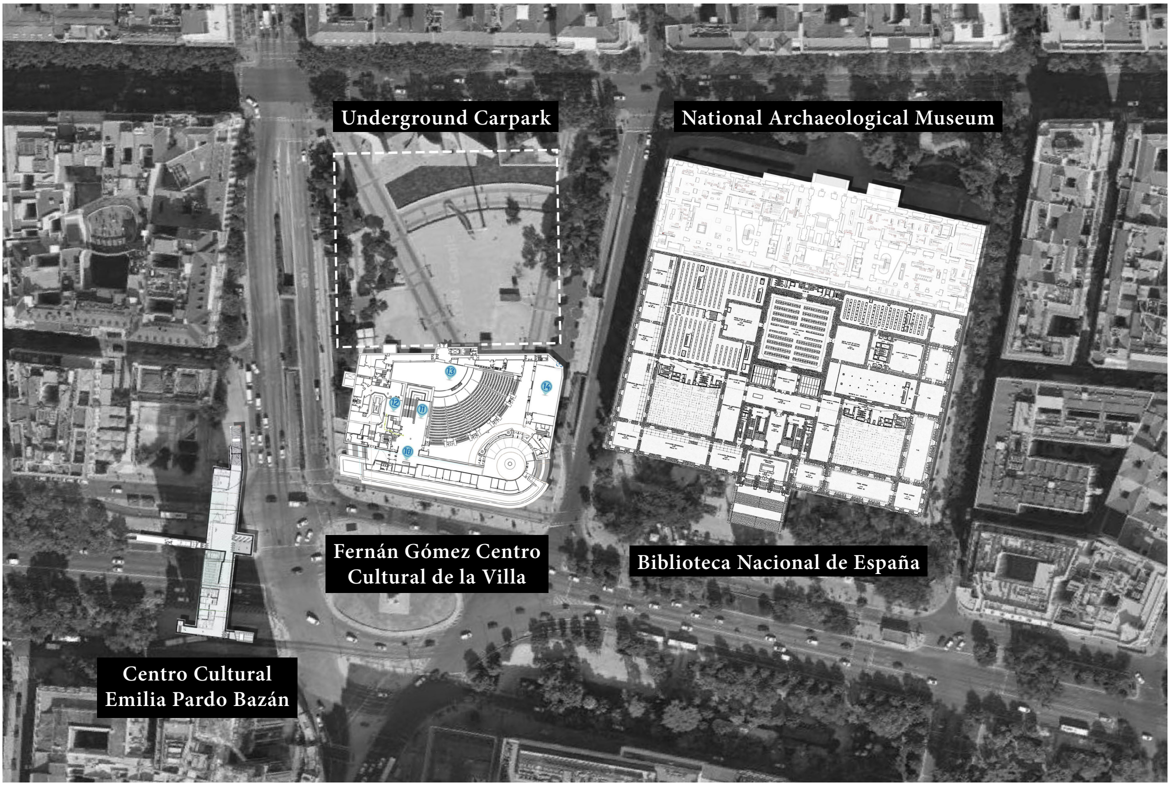
- Royal Palance

- Church

- Monasteries

from Royal Mint to National Library to public space creates a compelling narrative that mirrors Spain's journey toward democratization, making it a natural next step in the evolution of civic institutions for the digital age. Located within Madrid's established network of public spaces, Plaza de Colón offers an opportunity to address the challenges of digitalized democracy - from misinformation to polarization - by integrating new digital infrastructure into existing patterns of civic engagement. The site's extensive underground infrastructure, inherited from its previous institutional uses, provides crucial technical capacity for data center integration, while its position in Madrid's cultural district ensures strong urban connectivity through transportation networks and proximity to civic institutions. This convergence of historical significance, technical readiness, and civic centrality makes Plaza de Colón uniquely positioned to bridge the gap between digital infrastructure and democratic participation.

Figure 18 / Satellite View of the site with the existing building plan. / Author, 2025.



From Royal Power to Digital Democracy

Plaza de Colón's evolution traces Spain's journey from royal power to democratic cultural space. Beginning in the 1780s as the Royal Mint (Real Casa de la Moneda), the site embodied centralized economic control through currency production. In 1712, the area also housed the Palace Public Library, which despite its name primarily served royal court interests. A major democratic shift occurred in 1836 when the library was transferred from royal to government control, becoming the National Library of Spain. This democratization of knowledge expanded in 1867 with the establishment of the National Archaeological Museum, creating a cultural complex that made both literature and historical artifacts publicly accessible.

The site's most dramatic transformation came in the 1970s when it became Plaza de Colón, evolving from a restricted institutional space to an open public plaza. This democratic progression continued with the establishment of the Fernán Gómez Centro Cultural de la Villa and Centro Cultural Emilia Pardo Bazán, converting former institutional buildings into vibrant cultural venues. Each transformation - from royal mint to palace library to national institutions to public cultural centers - reflects Spain's broader evolution from monarchical control to democratic access, making it an ideal site for the next phase of civic infrastructure in the digital age.

Figure 19 / Rotal Mint in Plaza de Colón before 1970 / Ayuntamiento de Madrid.

Figure 20 / National Library of Spain / Wikipedia, 2011.

Figure 21 / Protest held in Plaza de Colón in 2023 / Countingstars, 2023.

Image 21 / Discovery Garden with Fernán Gómez Centro Cultural de la Villa. / Barcelo.com.

Site as Metaphor for Digital Transition

Imagining Plaza de Colón functions as Madrid's living database—where historic memory meets digital potential. Like a dynamic archive being constantly indexed and queried, this urban platform transforms static historical records into active digital commons. When citizens gather here, they reactivate dormant data, converting the plaza's embedded cultural memory into searchable, shareable experiences. The space operates as both storage and processor—preserving Spain's democratic history while simultaneously generating new entries for future access. As digital archives transform from passive repositories to participatory platforms, Plaza de Colón exemplifies how physical spaces can serve as interfaces between stored cultural memory and its real-time activation in civic life.

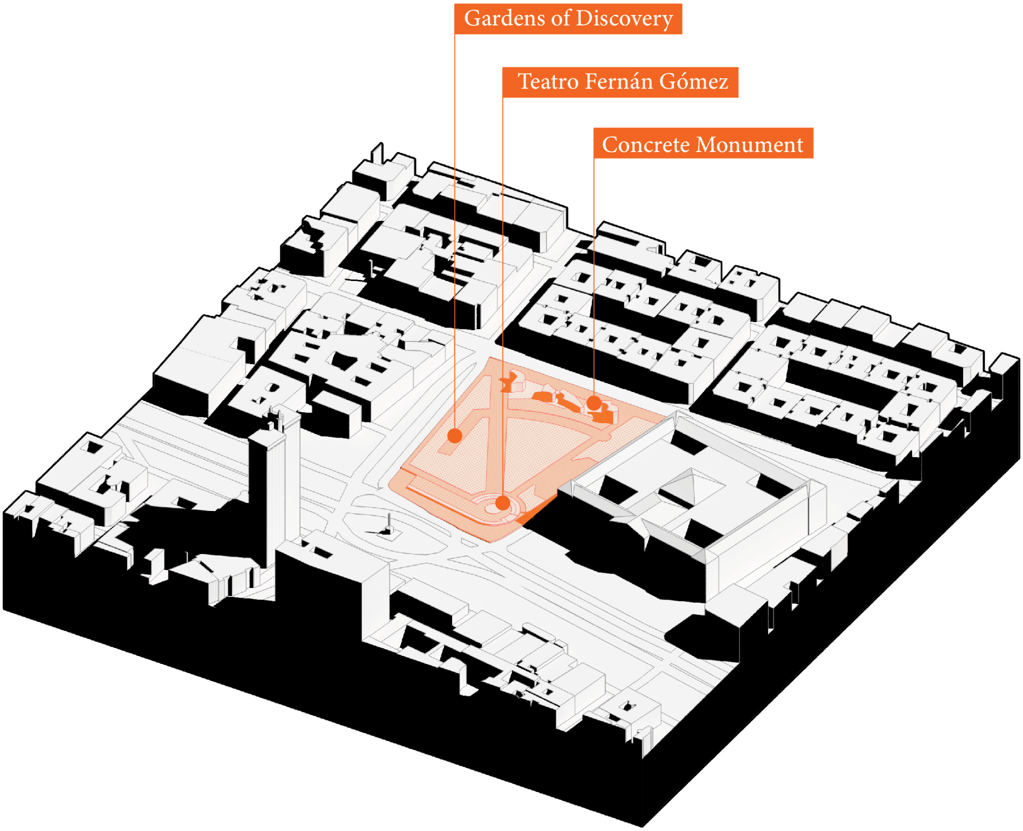


Figure 22 / The Landscape of Plaza de Colon / Author, 2025.

Plaza de Colón serves as an outdoor museum celebrating Spanish history, particularly the Age of Discovery. The Garden of Discovery, Columbus monument, and Turcios's concrete reliefs create a public space where visitors can engage with Spain's colonial past. Its location among Madrid's cultural institutions makes history accessible to all citizens and tourists.

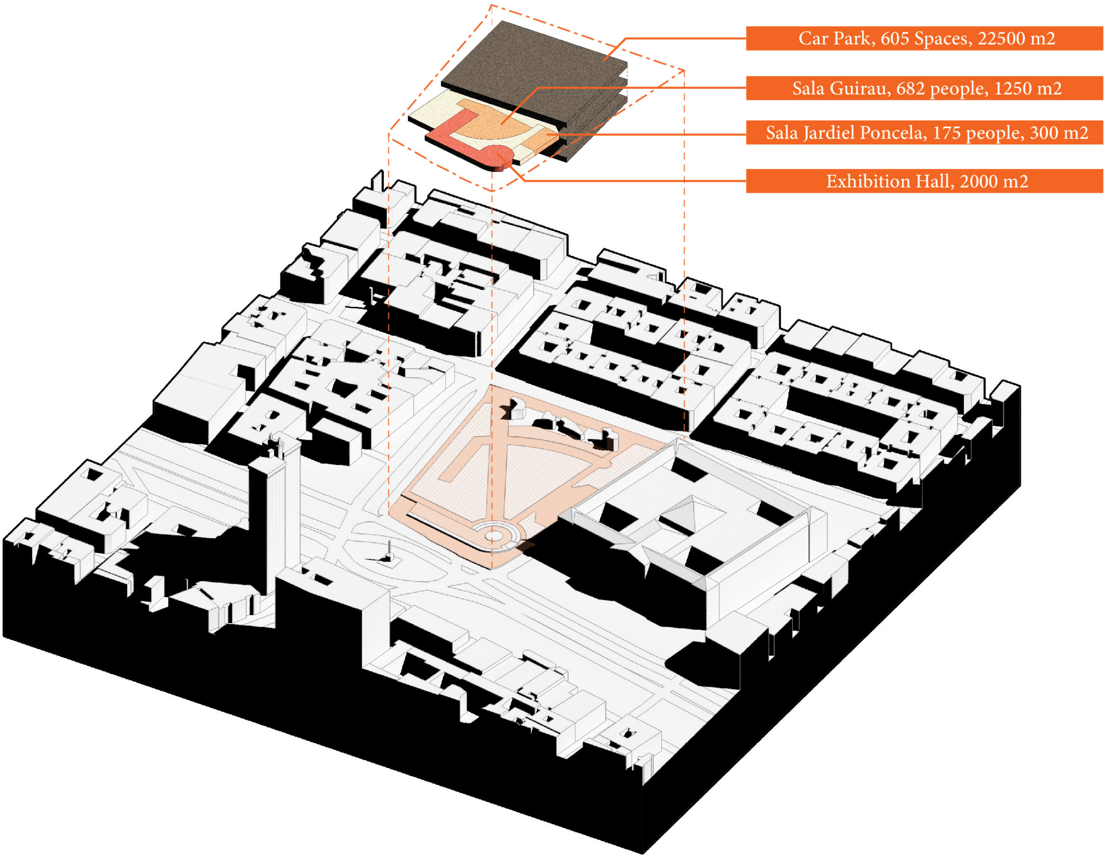


Figure 23 / Existing Programme of the Underground / Author, 2025.

The Cultural Center Fernán Gómez, built in 1977 beneath Plaza de Colón, hosts theatrical performances and exhibitions in its circular structure. Next to it is one of Madrid's largest underground parking facilities that serves the busy Salamanca district.

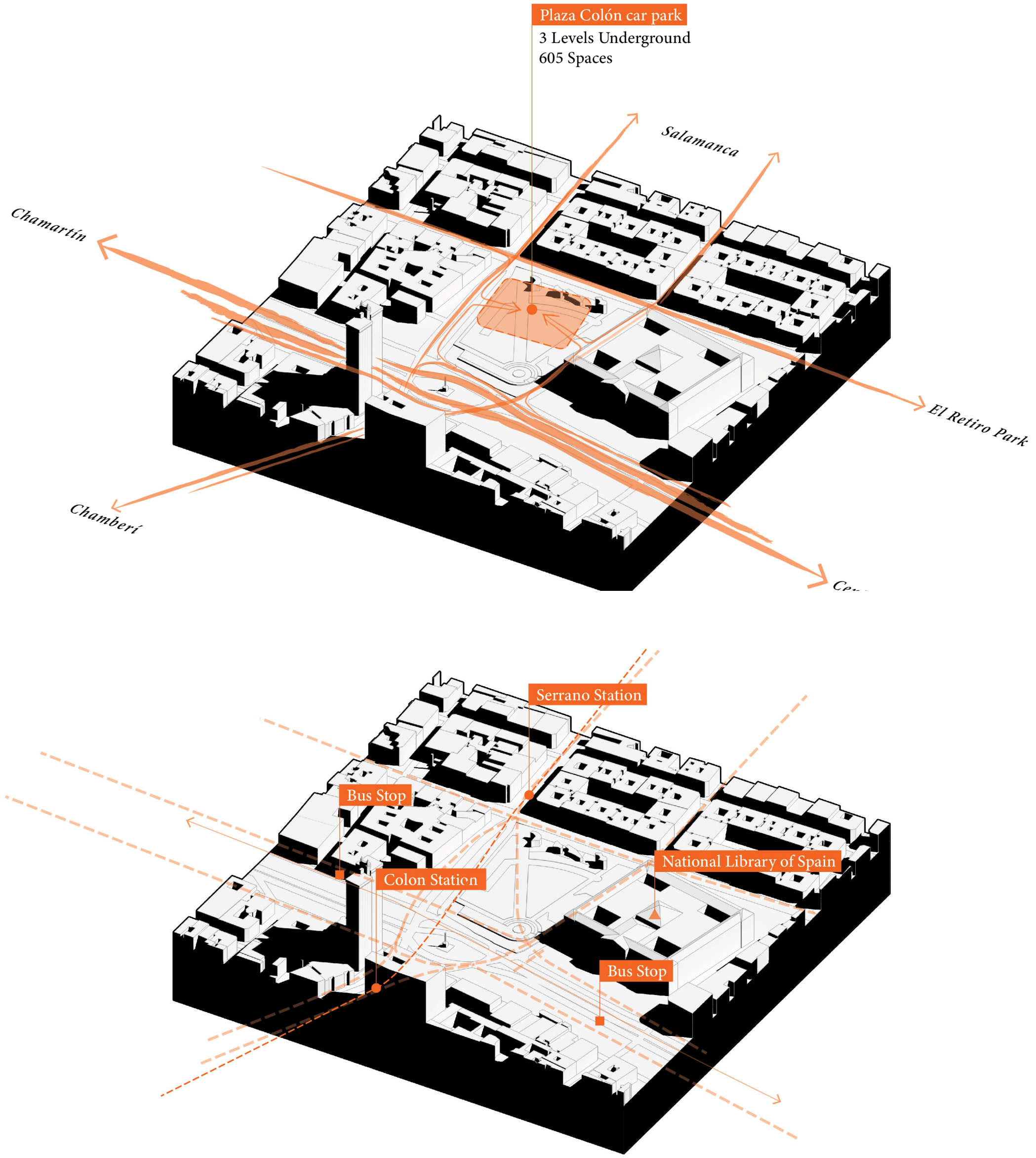


Figure 24-25 / The Pedestrian and Traffic Flow of the Site / Author, 2025.

The design strategy for Plaza de Colón focuses on understanding and leveraging its existing underground infrastructure, including the Cultural Center and parking facility. Key to this approach is analyzing how pedestrians and vehicles currently navigate the space, studying traffic patterns, access points, and movement flows. These circulation patterns inform the optimal placement and design of new architectural interfaces, ensuring any additions integrate seamlessly with the plaza's established underground systems while enhancing public interaction with the space.

Figure 26-29 / Hidden Access of Existing / Google Map.

Plaza de Colón's underground entrances suffer from poor visibility and wayfinding issues. The Cultural Center and parking facility access points are currently obscured within the plaza's landscape, making them difficult for visitors to locate and navigate. Many people pass by without realizing these important public spaces exist below. A comprehensive redesign of the entrances is needed to create more prominent, intuitive gateways that establish clear sightlines and visual markers, ensuring these underground destinations become more accessible and inviting to the public.

05

DISCUSSION

The Archive in Transition

From Container to Circuit

The archive has undergone a profound transformation in the digital age. Traditional archives functioned as static repositories where, as David Berry notes, materials were "hidden away in national libraries, museums, and darkened rooms, restricted in access and guarded by the modern-day equivalents of Jacques Derrida's archons."[28] These physical institutions necessitated careful curation of what deserved preservation.

Digital technologies have dismantled this containment model. The networked digital archive creates immediate feedback between historical materials and contemporary data, operating as a circuit of continuous transmission rather than a static repository. Files become active participants in networks of association, existing in what Eivind Røssaak describes as "a permanent state of mediality, always in temporality, always re-writing itself."[29]

28 Berry, "The Post-Archival Constellation", 103.

29 Eivind Røssaak, "FileLife: Constant, Kurenniemi, and the Question of Living Archives," in Memory in Motion, ed. Trond Lundemo, Ina Blom, and David M. Berry (Amsterdam University Press, 2013), 183–210, https://doi.org/10.1515/9789048532063-006..

▼ Figure 31 / Steel structure archives in the National Library of Spain. / Moleón Gavilanes, 2017 /

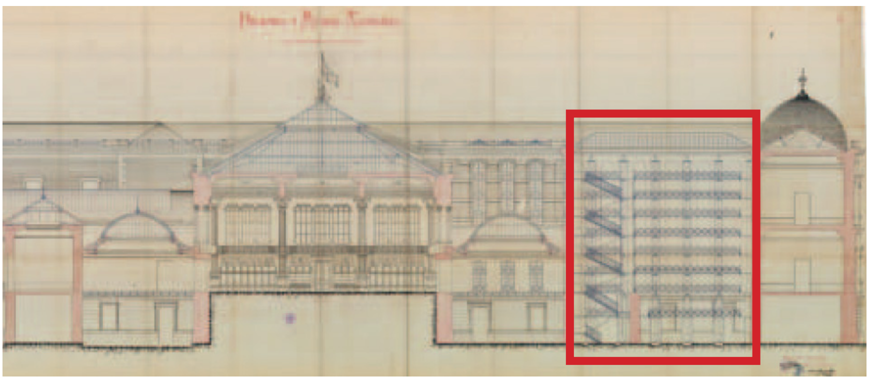


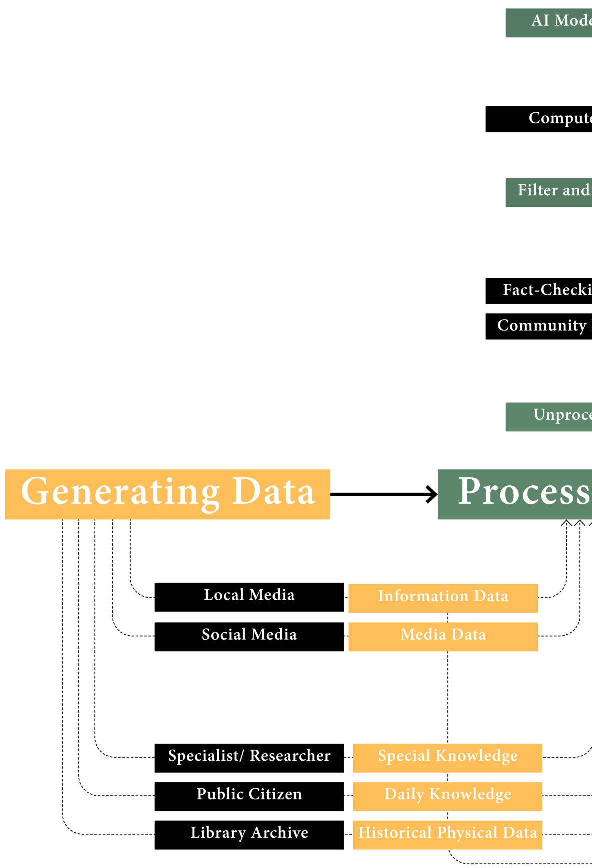
Figure 30 / Section of the closed shelf archive in the National Library of Spain. / Moleón Gavilanes, 2017 /

The Flow of Knowledge: Creation to Application

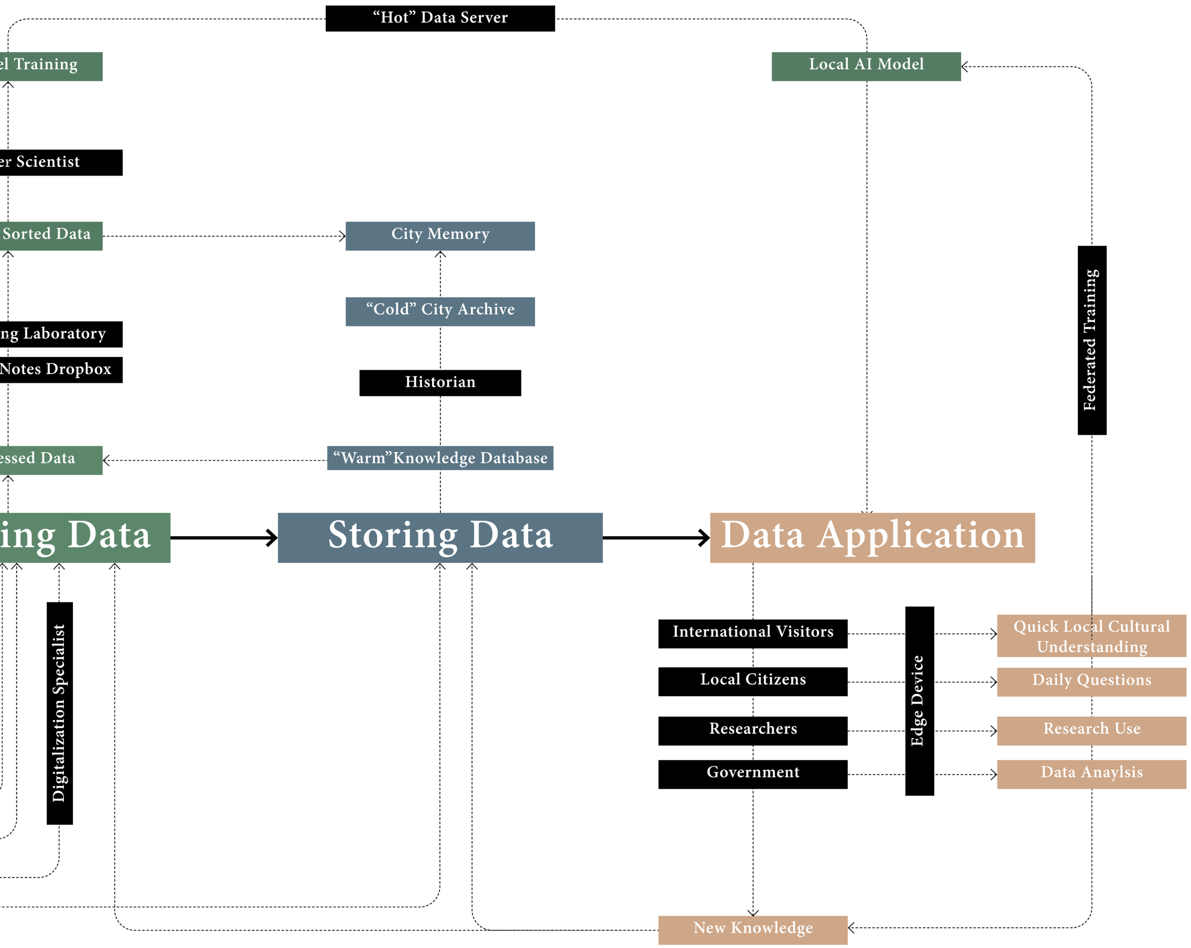
In the post-archival condition, knowledge follows a dynamic, cyclical path rather than remaining static in storage. This flow begins with data creation, as materials are digitized or created digitally. These materials then enter processing systems where they are cataloged, tagged, compressed, and prepared for storage. However, unlike traditional archives where storage represented an endpoint, digital archives maintain materials in a state of potential activation.

The flow continues with analysis, where computational systems—particularly AI and machine learning technologies—process archival materials to identify patterns, establish connections, and generate new insights. These technologies transform dormant historical data into active knowledge by surfacing forgotten relationships and creating new interpretations across diverse materials.

This analysis then feeds application, where processed knowledge returns to the public sphere through digital literacy centers, interactive exhibitions, and community programming. The public doesn't merely consume this knowledge but participates in its further development through contribution, annotation, and reinterpretation, creating new data that rejoins the cycle.



▼ *Figure 32 / Actor network diagram showing the interactions between actors and the flows of data. / Author, 2025.*



The Archive + Data Center: Programmatic Synthesis

Integrating archives with data centers creates a powerful hybrid typology that materializes the transformation of memory practices in the digital age. As Berry notes, the digital archive "is no longer simply a passive storage space but becomes generative itself in algorithmically ruled processuality."[30] This generative quality transforms the archive from preservation mechanism to knowledge production facility.

Data centers provide the computational infrastructure necessary for this transformation, enabling advanced processing of archival materials that reveal previously hidden patterns and relationships. The physical integration of storage and processing becomes visible in this synthesis, making tangible what Røssaak describes as the "technical and social profile" of files.[31] Through this arrangement, the archive becomes a platform for the creation of "synthetic memory"—knowledge emerging from computational analysis rather than human recollection.

Architecturally, this synthesis manifests as transparent infrastructure where server rooms with glass walls make visible the processing of historical materials. Interactive displays demonstrate how algorithms

30 Berry, "The Post-Archival Constellation", 108.

31 Røssaak, "FileLife", 184.

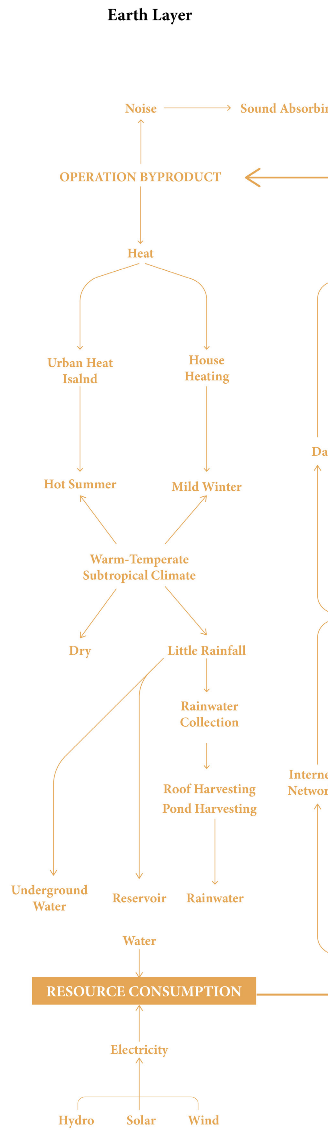
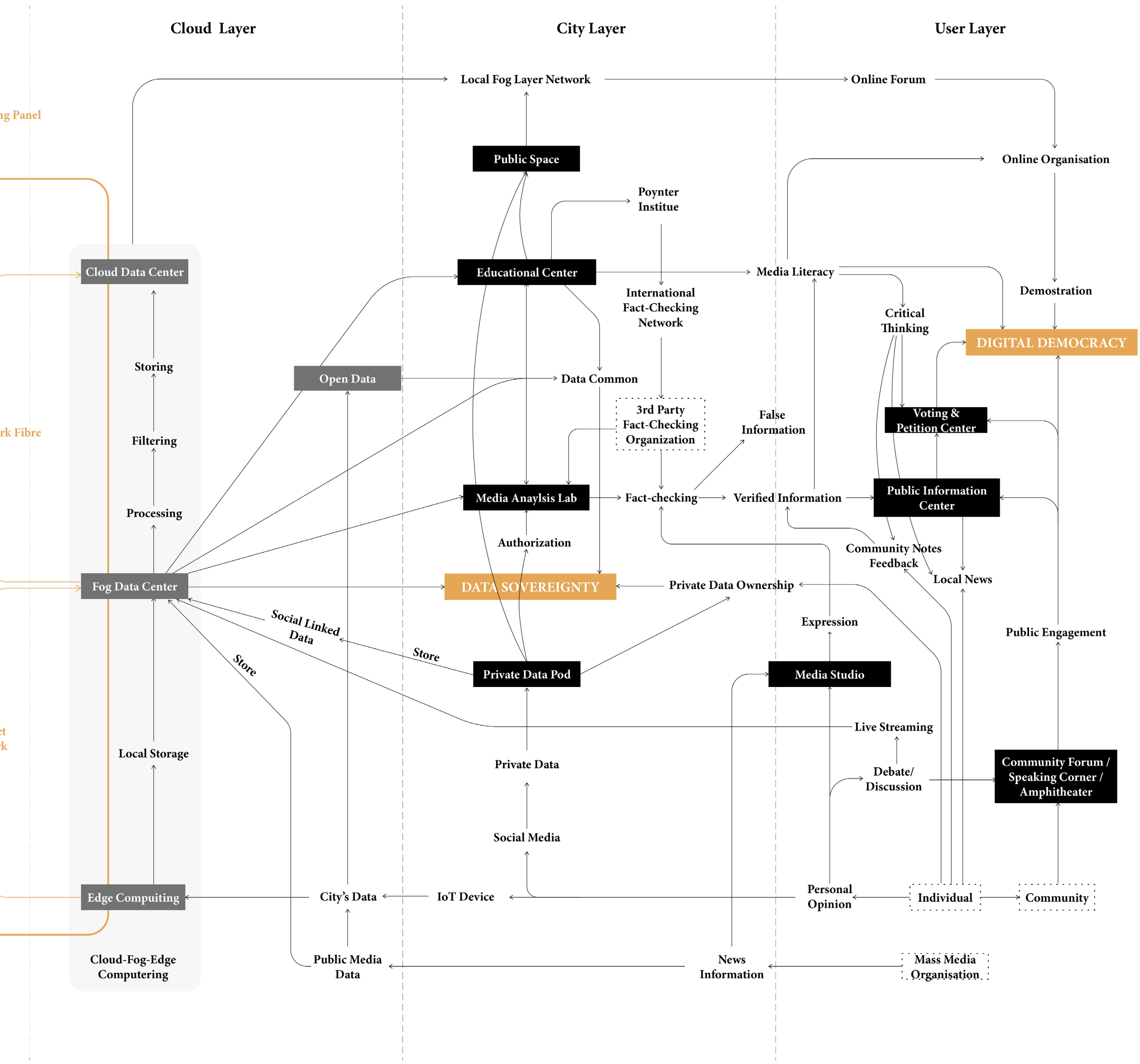


Figure 33 / This diagram examines the multi-layered relationships between natural resource usage, digital sovereignty, and digital commons. It maps the connections across different scales of infrastructure, from resource extraction and energy consumption to the development of civic digital spaces that promote democratic engagement and community control over data systems. / Author, 2025.


Cloud Layer
City Layer
User Layer
Local Fog Layer Network
Online Forum
Public Space
Online Organisation
Poynter
Institue
Cloud Data Center
Educational Center
Media Literacy
International
Fact-Checking
Network
Critical
Thinking
Demostration
DIGITAL DEMOCRACY
Storing
Open Data
Data Common
3rd Party
Fact-Checking
Organization
False
Information
Voting &
Petition Center
Filtering
Processing
Media Anaylsis Lab
Fact-checking
Verified Information
Public Information
Center
Authorization
Community Notes
Feedback
Local News
Fog Data Center
DATA SOVEREIGNTY
Private Data Ownership
Social Linked
Data
Store
Store
Expression
Public Engagement
Private Data Pod
Media Studio
Live Streaming
Local Storage
Private Data
Debate/
Discussion
Community Forum /
Speaking Corner /
Amphitheater
Social Media
Edge Computing
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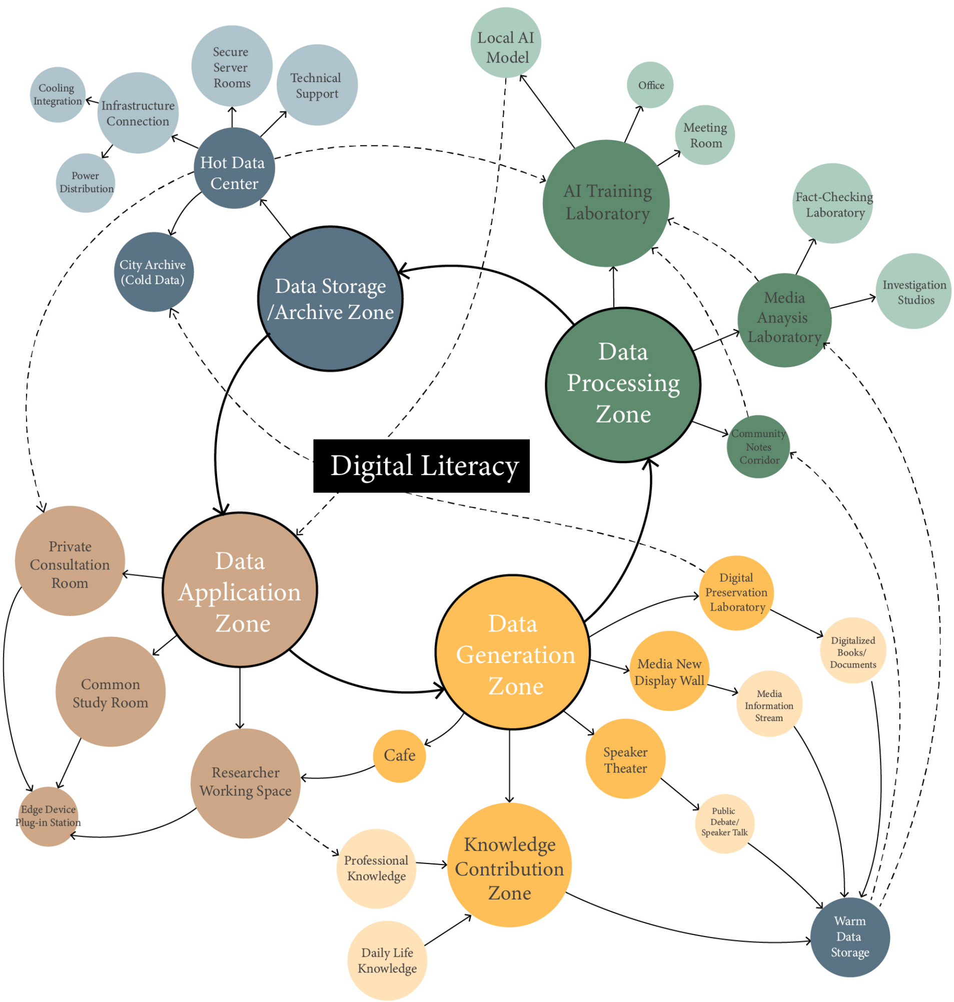
Mass Media
Organisation



identify patterns across documents, while public spaces allow visitors to trace information's journey from historical artifact to contemporary application. Environmental systems contribute to this transparency, with server heat warming public spaces and cooling systems becoming architectural features, countering the myth that digital technologies are immaterial.

This hybrid typology stands as physical embodiment of the archive's transition from container to circuit—where cultural heritage isn't simply stored but continuously activated through technological engagement and democratic participation in what Blom characterizes as "a dialectics of remembering and forgetting."[32]

Figure 34 / Bubble Diagram of Proposed Program for the Integrated Archive and Digital Infrastructure. / Author, 2025.

32 Blom, "Rethinking Social Memory".

Toward Digital Civic Institutions

33 European Movement International, “Digital Sovereignty.”

34 European Movement International.

35 Liesbet van Zoonen, “Data Governance and Citizen Participation in the Digital Welfare State,” July 6, 2020, https://www.researchgate.net/publication/342714306_Data_governance_and_citizen_participation_in_the_digital_welfare_state.

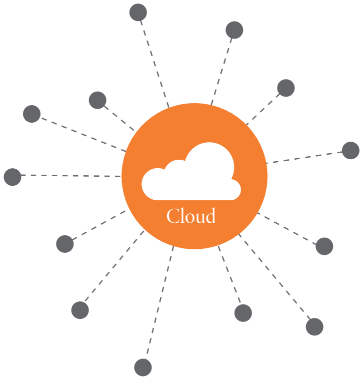
Addressing the Triple Crisis

The transformation of archives from static containers to dynamic circuits provides a framework for addressing Madrid’s triple crisis of digital knowledge. The architectural challenge is to create spaces that respond to these evolving conditions rather than simply housing traditional archival practices.

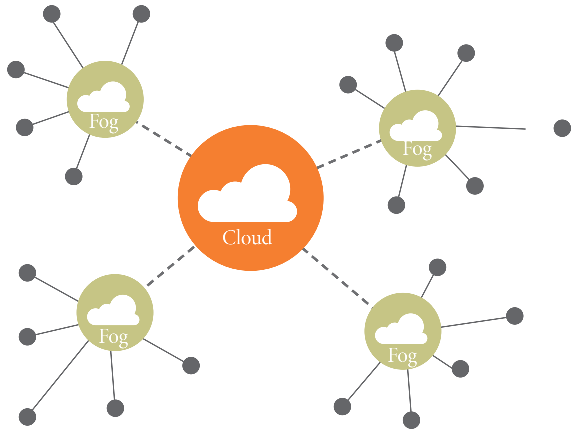
Infrastructure invisibility can be countered by making the materiality of digital systems central to architectural expression. As archives transition from hidden repositories to active circuits, their physical infrastructure can similarly move from concealment to visibility. This aligns with the European Movement International’s call for a digital infrastructure that “contributes to making better decisions, to deliver better outcomes and to improve the sustainability of production” while ensuring fundamental rights and democratic participation.[33]

The digital literacy crisis requires environments where data processes become legible and interactive. When technical operations are revealed rather than concealed, citizens gain embodied understanding of how their data moves through systems. This approach addresses what researchers have identified as a profound challenge: “4 out of 10 adults in Europe are without basic digital skills. Citizens must be able to use technology and digital media in safe, responsible, critical and effective ways in order to fully participate in their democracy.”[34]

Archive digitalization disruptions can be reimagined as opportunities for new civic institutions. Currently, as noted in research on data governance, “client councils play no role at all in the municipalities’ choice of data techniques, their use and application” despite the fact that these systems directly impact citizens’ lives.[35] A new architectural approach can counter this trend by creating hybrid spaces where cultural heritage is not simply stored but continuously activated through technological engagement and democratic participation.



Cloud-Edge Computing (Current)



Cloud-Fog-Edge Computing (Future)

▲ *Figure 35 / The introduction of Fog layer between the hidden cloud server and users. / Author, 2025.*

The Cloud-Fog-Edge Model

The cloud-fog-edge model offers an architectural framework that aligns with the evolving nature of archives while transforming who controls and benefits from digital knowledge.[36] This model counters the current paradigm where private corporations maintain exclusive control over data infrastructure and the insights it produces.

In today's digital ecosystem, technology companies extract vast amounts of personal data from citizens while keeping both the infrastructure and resulting knowledge hidden behind proprietary walls. This asymmetrical relationship creates what researchers call a fundamental democratic deficit where individuals contribute data but have no meaningful participation in how it's processed or applied. As studies on data sovereignty explain, while data-driven technologies yield benefits, they also "confront different agents and stakeholders with challenges in retaining control over their data."[37]

The cloud-fog-edge model disrupts this arrangement by

36 "Exploring Computing Models: Edge Computing vs Fog Computing vs Cloud Computing," Scale Computing, May 16, 2023, https://www.scalecomputing.com/resources/edge-computing-vs-fog-computing-vs-cloud-computing#:~:text=Cloud%20computing%20is%20a%20centralized,processed%20closer%20to%20edge%20devices.

37 Patrik Hummel et al., "Data Sovereignty: A Review," DOAJ, https://doaj.org/article/271eb9fb2a1b48a681d30ad866cf522b.

creating public infrastructure for collective data processing. The cloud layer establishes community-controlled alternatives to corporate data centers, ensuring that the physical foundation of digital memory serves public rather than exclusively private interests. This addresses the problem identified in digital sovereignty research where citizens are "being reduced to consumers of digital services rather than valued in the" full capacity of their democratic citizenship.[38]

The fog layer introduces hybrid civic institutions where citizens participate directly in processes previously hidden from view. These spaces combine technical infrastructure with educational programs, allowing community members to learn data analysis skills, contribute to machine learning model development, and shape how algorithmic systems interpret cultural materials. This supports the approach advocated by digital sovereignty experts who emphasize "the need for users to better understand commercial and state powers in the digital sphere and to appropriate their technologies, data and content."[39]

The edge layer completes this framework by empowering citizen devices as active participants in the distributed knowledge network. Smartphones, tablets, and personal computers become secure nodes where individuals retain ownership and privacy control over their data while still contributing to and benefiting from collective intelligence. This approach implements what researchers describe as "citizen data sovereignty"[40]—where individuals maintain meaningful control over personal information while participating in community knowledge systems. Rather than forcing users to surrender data to corporate platforms, this architectural model ensures that personal devices can securely interact with the fog and cloud layers while keeping sensitive information protected.

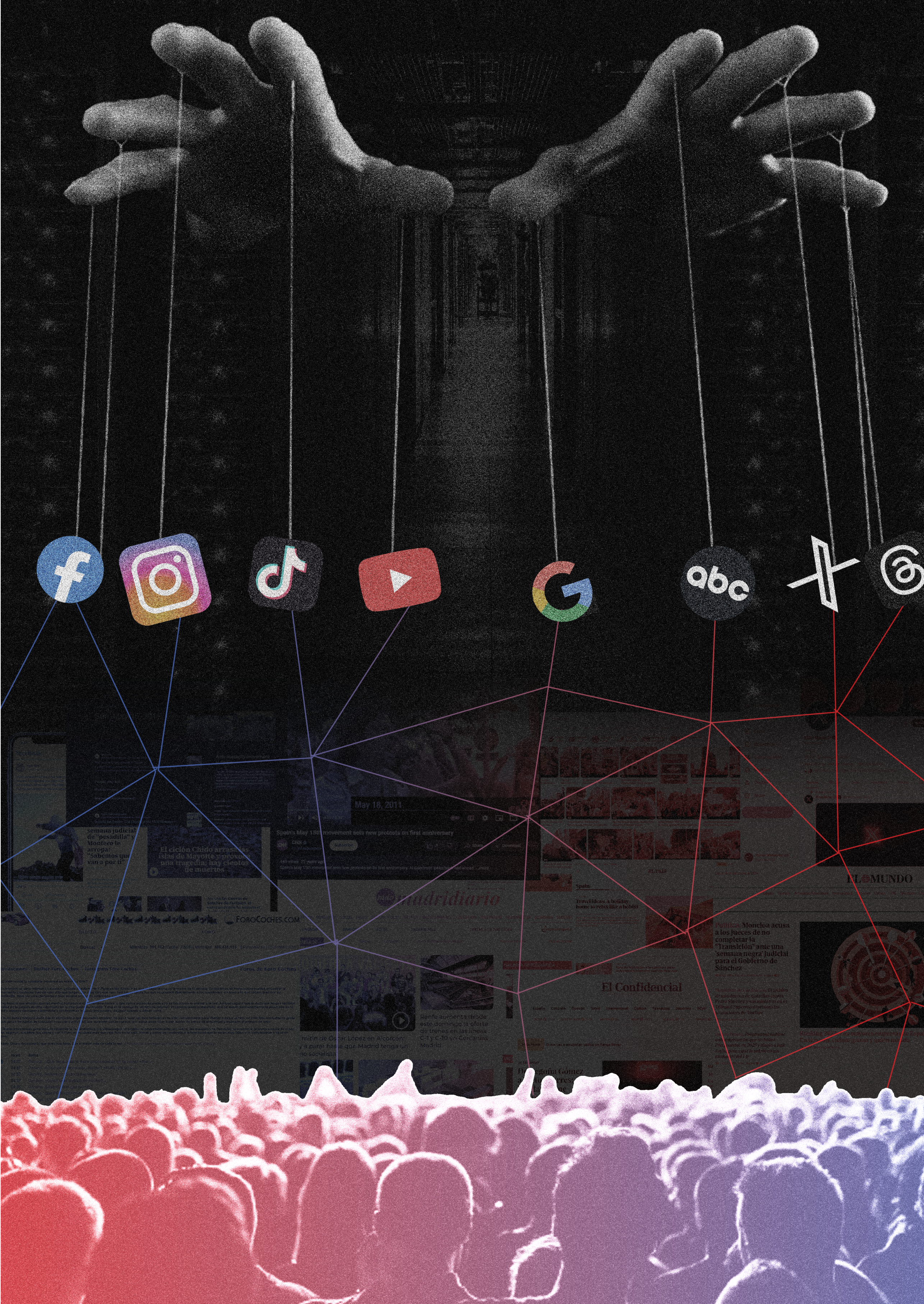
This distributed system enables citizens to selectively share insights without compromising privacy, creating a more balanced relationship between individual data rights and public knowledge resources. This architecture of participation transforms data infrastructure from corporate asset to civic resource. Instead of extracting value from communities, these institutions create environments where citizens contribute to, learn from, and benefit from collective digital knowledge.

38 "Digital Sovereignty," Policy Review, https://policyreview.info/concepts/digital-sovereignty.

39 "Digital Sovereignty."

40 "Citizen Data Sovereignty is Key to Wearables and Wellness Data Reuse for the Common Good," npj Digital Medicine, https://www.nature.com/articles/s41746-024-01004-z.

Figure 36 / Media Control: Hands manipulating digital information flow. / Author, 2025.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Theoretical Contributions

41 Blom, "Rethinking Social Memory_Archives", 13.

This research makes four significant theoretical contributions to our understanding of archives and digital infrastructure:

First, it extends Berry's "post-archival constellation" framework by demonstrating how architectural interventions can materialize the conceptual shift from static containment to dynamic circulation in the digital age. While Berry articulates how digital archives operate across multiple layers (from hardware to interface), this project shows how these abstract layers can be translated into concrete spatial arrangements that make digital processes visible to citizens. The architectural intervention becomes an epistemological tool that reveals how technical structures determine archival content.

Second, this research develops a new conceptual framework for civic digital institutions through the cloud-fog-edge model. This model extends existing technical architectures by introducing a civic layer (the fog) that transforms technical infrastructure into spaces of public engagement. This responds to what Blom identifies as the need to question "what concepts we have of 'the social'"[41] in light of computational changes to memory systems.

Third, this research contributes to understanding the material dimensions of digital memory by revealing physical resources consumed by digital infrastructure. By challenging what Blom calls the "languages of containment have taken a deep hold over our thinking on memory," the project counters the myth of digital immateriality and creates "techno-socio-material entanglements" where resource flows become part of civic understanding.

Finally, it advances social memory theories by showing how technical and social aspects of memory production can be integrated through architecture, creating spaces where social memory is actively produced through collaborative engagement with technical systems.

Research Limitations

Despite its contributions, this research faces several important limitations that suggest directions for future inquiry:

First, while proposing strategies for revealing digital infrastructure, it cannot fully resolve the tension between security requirements and public transparency. Data centers require restricted access to protect sensitive information, creating an inherent conflict with democratic visibility. Future research should explore more nuanced architectural approaches that balance security concerns with transparency through carefully designed partial access systems.

Second, the research acknowledges the limitations of architecture itself in addressing the complexity of digital infrastructure. Some concepts explored in this research, such as SOLID (Social Linked Data) (Appendix B), represent important frameworks for data sovereignty but remain too abstract to be directly translated into architectural interventions. The physical building alone cannot resolve all aspects of digital infrastructure's complexity, suggesting the need for interdisciplinary approaches that combine spatial design with policy and technical innovation.

Third, the research recognizes the fundamental mismatch between the rapid evolution of technology and the relative permanence of architecture. Digital systems evolve exponentially faster than buildings can be modified, creating a temporal disconnect where facilities may become technically obsolete during construction. Rather than designing specifically for current technologies, this suggests future research should focus on creating adaptable knowledge commons—spaces where communities can continuously develop digital literacy regardless of technological change.

These recognition points to a critical shift in architectural thinking: the primary value of civic digital infrastructure may lie less in housing specific technologies and more in fostering enduring communities of practice that outlive both the technologies and potentially the buildings themselves.

06

CONCLUSION

The exploration of Madrid's digital infrastructure reveals a critical juncture where technical innovation and civic engagement must converge. The anticipated 80% expansion of data center capacity by 2026 presents not just technological challenges but an opportunity to reimagine our relationship with digital archives and infrastructure. By transforming Plaza Colón—a site that has evolved from Royal Mint to National Library to public plaza—we propose a new architectural paradigm that makes the invisible visible.

The transition from "container" to "circuit" in archival practice demands new spatial expressions where digital processes become legible to citizens. Our cloud-fog-edge model introduces a civic layer that bridges technical requirements with democratic participation, creating what Berry describes as "a new archival imaginary" where knowledge is constantly modulated and augmented rather than simply stored.

This architectural intervention addresses the triple crisis of infrastructure invisibility, digital literacy gaps, and archive digitalization by creating spaces where the "gathering" of an archive becomes a process of sharing rather than sheltering. Server rooms with transparent walls, resource flows made visible through architectural features, and interactive displays showing algorithmic processes collectively transform technical infrastructure into civic platforms for understanding and engagement.

While architecture alone cannot resolve all complexities of digital sovereignty, it provides crucial physical spaces where social memory is no longer understood as an artifact of media organization but as active participation in knowledge production. This reimagined civic institution stands not just as a building but as a manifestation of a more democratic digital future—one where archives are not hidden repositories but dynamic community resources actively producing new forms of collective memory at the intersection of technology and civic life.

Bibliography

Angelil, Marc, and Anna Klingmann. “Hybrid Morphologies: Infrastructure, Architecture, Landscape” *Daidalos: Architecture, Art, Culture,* no. 73 (1999): 16–25.

Berry, David M. “The Post-Archival Constellation: The Archive under the Technical Conditions of Computational Media.” *In Memory in Motion*, edited by Eivind Røssaak, Trond Lundemo, and Ina Blom, 103–26. Amsterdam University Press, 2013. https://doi.org/10.1515/9789048532063-006.

Blom, Ina. “Rethinking Social Memory_Archives, Technology, and the Social.” *In Memory in Motion*, edited by Eivind Røssaak, Trond Lundemo, and David M. Berry, 103–26. Amsterdam University Press, 2013. https://doi.org/10.1515/9789048532063-006.

Bratton, Benjamin H. *The Stack: On Software and Sovereignty. Software Studies*. Cambridge, Massachusetts: MIT Press, 2015.

Cervera, Marc. “Spain to Boost Data Centre Capacity 80% by 2026.” *4Imagazine*, October 11, 2024. https://4imag.com/spain-to-boost-data-centre-capacity-80-by-2026/.

Chun, Wendy Hui Kyong. *Programmed Visions: Software and Memory*. First MIT Press paperback edition. Software Studies. Cambridge, Mass London: The MIT Press, 2013.

Corbo, Stefano. *Exteriorless Architecture: Form, Space, and Urbanities of Neoliberalism.* Routledge Research in Architecture. New York, NY: Routledge, 2023.

European Movement International. “Digital Sovereignty and Citizens’ Rights,” November 2021. https://europeanmovement.eu/policy/digital-sovereignty-and-citizens-rights-2/.

Gilbert, Stephen, Katie Baca-Motes, Giorgio Quer, Marc Wiedermann, and Dirk Brockmann. “Citizen Data Sovereignty Is Key to Wearables and Wellness Data Reuse for the Common Good.” *Npj Digital Medicine* 7, no. 1 (February 12, 2024): 27. https://doi.org/10.1038/s41746-024-01004-z.

Graham, Stephen, ed. *Disrupted Cities: When Infrastructure Fails*. New York London: Routledge, 2010. https://doi.org/10.4324/9780203894484.

Hummel, Patrik, Matthias Braun, Max Tretter, and Peter Dabrock. “Data Sovereignty: A Review.” B*ig Data & Society* 8, no. 1 (January 2021): 2053951720982012. https://doi.org/10.1177/2053951720982012.

Latour, Bruno. “Introduction: How to Resume the Task of Tracing Associations*.” *In Reassembling the Social*, by Bruno Latour, 1–17. Oxford University PressOxford, 2005. https://doi.org/10.1093/oso/9780199256044.003.0001.

Maak, Niklas, and Neil Holt. *Server Manifesto: Data Center, Architecture and the Future of Democ-*

racy. Berlin: Hatje Cantz, 2022.

Moleón Gavilanes, Pedro. De pasadizo a palacio: las casas de la Biblioteca Nacional. Madrid: Biblioteca Nacional de España, 2017.

Pohle, Julia, and Thorsten Thiel. "Digital Sovereignty." *Internet Policy Review* 9, no. 4 (December 17, 2020). https://doi.org/10.14763/2020.4.1532.

Røssaak, Eivind. "FileLife: Constant, Kurenniemi, and the Question of Living Archives." *In Memory in Motion*, edited by Trond Lundemo, Ina Blom, and David M. Berry, 183–210. Amsterdam University Press, 2013. https://doi.org/10.1515/9789048532063-006.

Scale Computing. "Exploring Computing Models: Edge Computing vs Fog Computing vs Cloud Computing." May 16, 2023. https://www.scalecomputing.com/resources/edge-computing-vs-fog-computing-vs-cloud-computing#:~:text=Cloud%20computing%20is%20a%20centralized,processed%20closer%20to%20edge%20devices.

The Straitstimes. "Thirsty Data Centres Are Making Europe's Dry Summers Even Drier." *Jul 27,* 2023. https://www.straitstimes.com/world/europe/thirsty-data-centres-are-making-europe-s-dry-summers-even-dryer.

Van Zoonen, Liesbet. "Data Governance and Citizen Participation in the Digital Welfare State." *Data & Policy* 2 (2020): e10. https://doi.org/10.1017/dap.2020.10.

Young, Liam, ed. Machine Landscapes: Architectures of the Post-Anthropocene. Architectural Design Profile, no 257. Oxford: John Wiley & Sons, 01.

Appendix A
Case Studies

Estimate the data center Requirements

SOCIAL MEDIA DATA:

Madrid population:
3.3 million (city) + 3.4 million (metro area) = 6.7 million
Social media users (65% of population): 4.4 million users

Per user per year (approximate):
Text posts: 600 posts × 280 characters = ~168 KB (higher usage in urban area)
Images: 250 photos × 2 MB = 500 MB (including Instagram, WhatsApp sharing)
Videos: 75 videos × 50 MB = 3.75 GB (including TikTok, Instagram Reels)

Per user annual total: *~4.4 GB*

City total per year: ~19.36 PB
(Petabytes)

NEWS MEDIA DATA:

Major news outlets: 15-20 sites (including El País, El Mundo, ABC, La Razón, etc.)
Regional digital media: 10-15 sites
TV stations' digital content: 5-7 channels

Daily content per major site:
Articles: 150 × 20 KB = 3 MB (including multiple languages)
Images: 200 × 2 MB = 400 MB
Videos: 25 × 50 MB = 1.25 GB
Live streams archives: 5 hours × 1 GB/hour = 5 GB

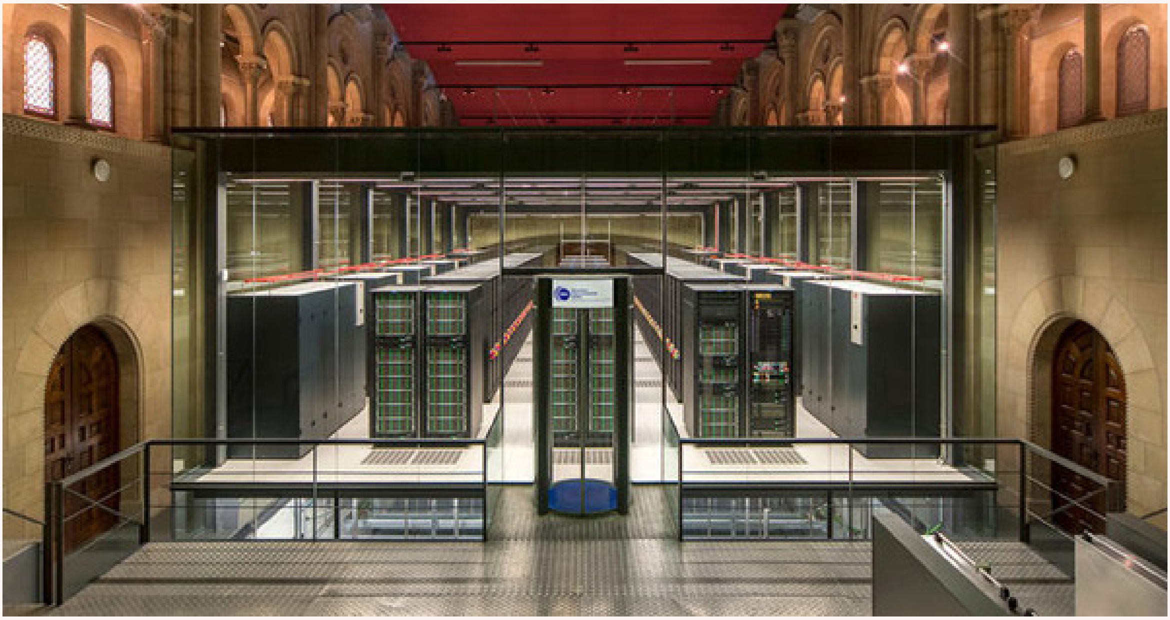
Annual total for news: ~4.8 PB

Additional Local Content:

Government records and documents: 0.5 PB
Cultural events and tourism content: 0.3 PB
Public transportation and urban data: 0.2 PB

Total Annual Data: ~25.16 PB
For a 10-year archive: ~251.6 PB (including redundancy and backup)

Primary storage: 251.6 PB
Backup copies: 251.6 PB
Disaster recovery: 251.6 PB (Offsite)
Total storage with full redundancy: ~503.2 PB



Chapel Torre Girona

Data Center Physical Space Requirements:

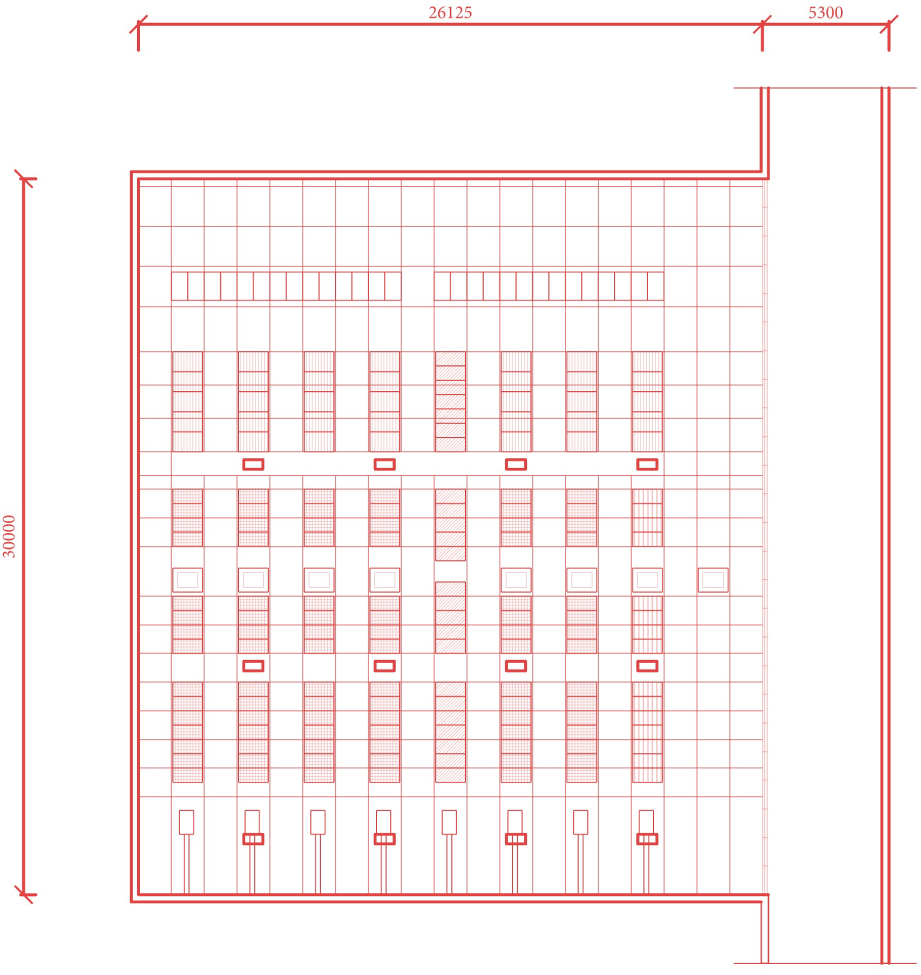
Server Area (1,200-1,400 m²):
Storage density: ~1 PB per rack
Need ~800 server racks (including redundancy)
Each rack requires 2.5 m² (including maintenance access)
Hot/cold aisle configuration
Cable management pathways
Space for future expansion (20%)

Cooling Infrastructure (400-500 m²):
Large Cooling uniMultiple cooling zones
Air handling units
Water treatment systems
Chiller plants
Heat exchangers
Free cooling systems for winter

Power Distribution (300-400 m²):
Multiple UPS rooms
Battery banks
Power distribution units
Transformer rooms
Switchgear
Generator connection points

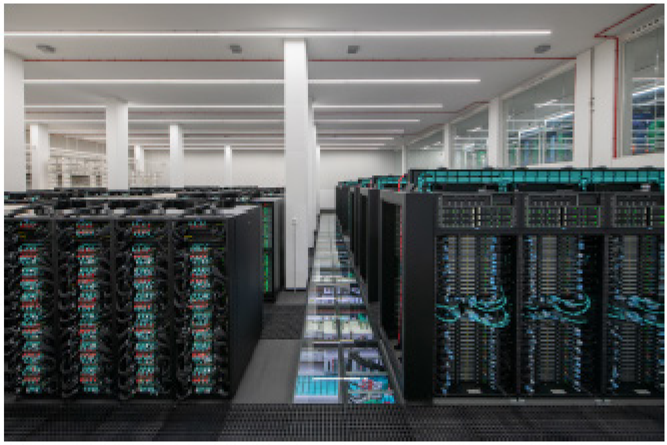
Total Space Required: 2,400-3,000 m²
Building Specifications:
Minimum ceiling height: 4.5 meters
Floor loading capacity: 1,500-2,000 kg/m²
Raised floor height: 0.8-1 meter
Separate security zones
Multiple entry/exit points
Vehicle access for equipment delivery

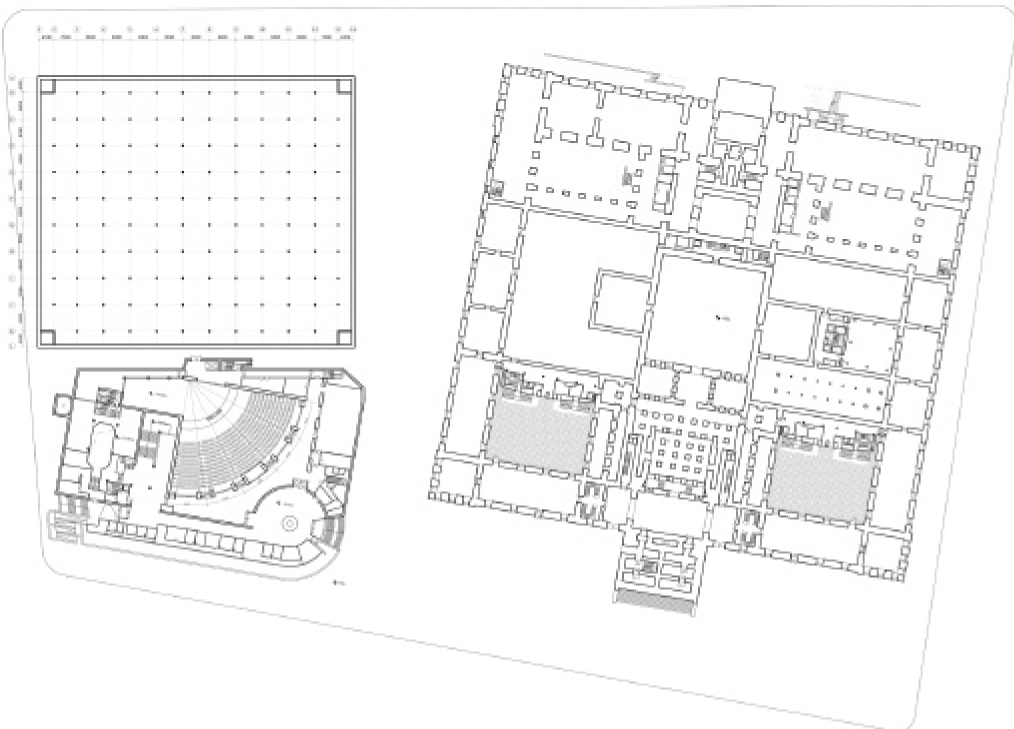
Data Center Reference



MaraNostrum 5 Supercomputer in Barcelona

- General Purpose Partition
- Management and Communications & Experimental Partitions
- 248,000 TB Hard Drive
- Air Conditioning
- Accelerated Partition & Rack with Processing Chips





Occupied Area

The supercomputer occupies a room with an area of 800m², equivalent to about 3 tennis courts.

Service (e.g. refrigeration and electrical transformers) occupy almost three times as much: 2000m²

Appendix B
Other Research Framework

Data Commons Framework

SOLID (Social Linked Data), developed by Sir Tim Berners-Lee, reimagines how personal data is stored and accessed on the internet.[42] Instead of companies storing user information on their servers, SOLID gives each person their own "data pod" - a personal storage space they control. When apps or services want to access someone's data, they must request permission from that individual's pod rather than automatically collecting and storing it. This transforms the current model where companies hold and control user data to one where citizens maintain sovereignty over their personal information.

Drawing inspiration from this decentralized model, the digital commons framework envisions how urban architecture can evolve to support this transition toward citizen data control. The transformation unfolds across three phases:

42 Tim Berners-Lee, "Solid: Your Data, Your Choice.," Solid, November 21, 2024, https://www-statista-com.tudelft.idm.oclc.org/statistics/871513/worldwide-data-created/.

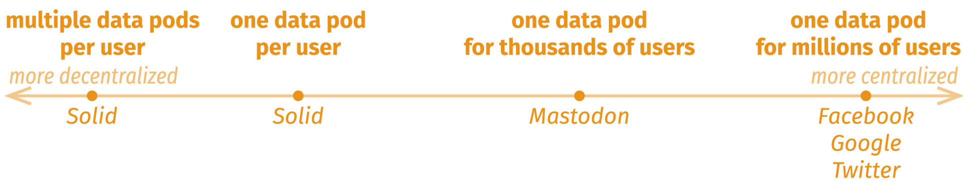
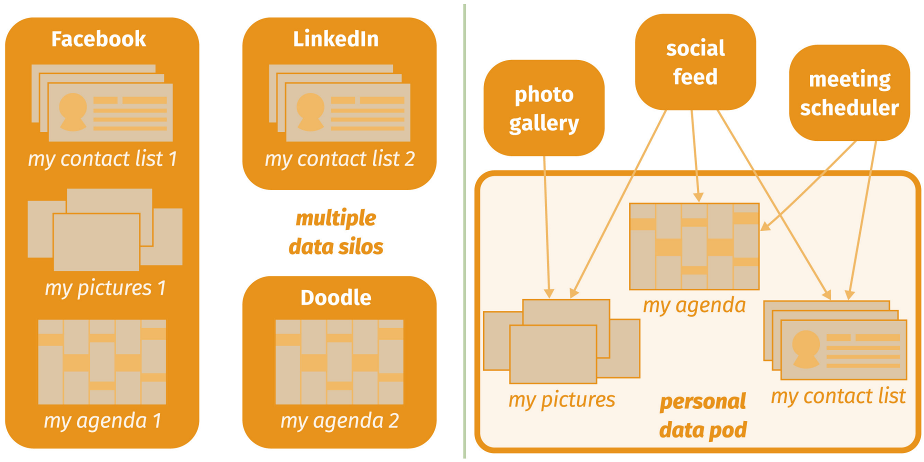


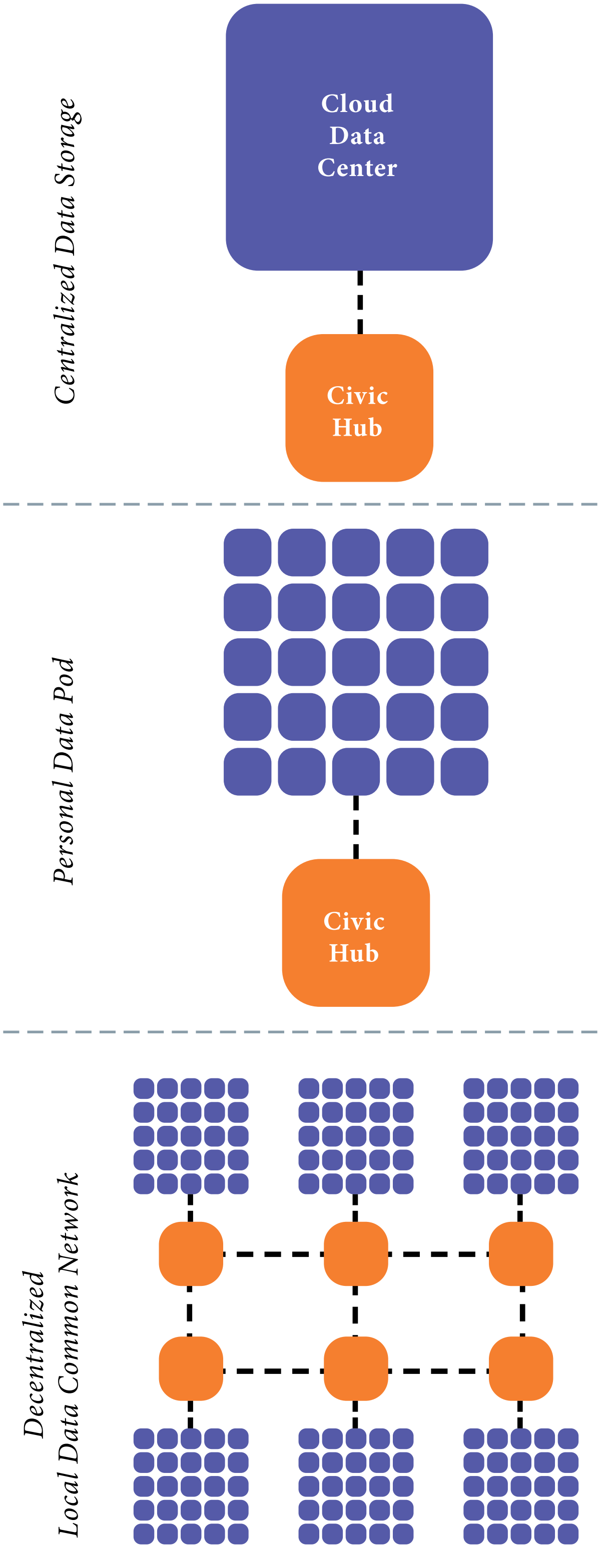
Image 27 | Degrees of Decentralization by Ruben Verborgh



Centralized Web Application

Decentralized Web Application

Image 28 | Comparision of Centralized Web Application and Decentralized Web Application by Ruben Verborgh


Centralized Data Storage
Cloud Data Center
Civic Hub
Personal Data Pod
Civic Hub
Decentralized
Local Data Common Network

Phase One (2025-2035): Civic Foundation

The first phase establishes new civic institutions focused on digital literacy and democratic participation:

- Fact-checking facilities and media literacy centers

- Public interface spaces for digital education

- Community forums and verification laboratories

- Educational programs about data rights and digital citizenship

This phase builds public understanding and trust while preparing for technical transformation.

Phase Two (2035-2045): Data Pod Integration

As SOLID adoption grows, civic architecture begins hosting personal data infrastructure:

- Secure data pod storage facilities
- Individual data vaults for citizens
- Privacy-preserving architecture
- Transparent protocols for data access
- Democratic oversight systems

The civic programs above continue while expanding to include education about personal data sovereignty.

Phase Three (2045-2050): Integrated Commons

The final phase achieves full integration of civic and technical functions:

- Complete decentralized data infrastructure
- Mature public education and verification systems
- Optimized resource flows between technical and public spaces
- Enhanced democratic oversight of digital systems

This phased evolution allows cities to gradually transform their digital infrastructure from centralized corporate control to democratic commons, building public trust and technical capability along the way. The framework provides a model for how urban architecture can support this transition toward citizen data sovereignty.