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Beyond the Techno-Managerial Dashboard: Operationalizing ESG and Digital Equity in Smart City Governance

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Abstract

The rapid transformation of urban centers into smart environments introduces complex challenges at the intersection of technological advancement, environmental stewardship, and social justice. This study evaluates Lisbon's smart city transition by establishing an integrated framework that links digital equity with Environmental, Social, and Governance principles. Employing a convergent qualitative research design, this paper triangulates a comprehensive regulatory policy analysis with primary empirical data gathered from twenty-five semi-structured interviews with municipal officials, academic experts, and residents of marginalized communities. The findings expose critical systemic disparities in digital infrastructure deployment, device affordability, and platform literacy across socio-economic strata, demonstrating how localized digital divides directly impede the execution of urban ESG objectives. While green financing mechanisms offer robust pathways for sustainable energy and transit infrastructure, their equity outcomes remain constrained without mandatory, transparent information disclosure systems that mitigate agency costs. Cultivating urban resilience requires shifting from tokenistic e-governance to genuine citizen empowerment. This study offers a novel theoretical contribution by operationalizing corporate ESG metrics within public urban governance frameworks, providing an empirical roadmap for municipal policymakers globally to balance digital innovation with structural inclusion and environmental accountability in smart city agendas.

Keywords: smart cities; digital equity; ESG; smart city governance; sustainability

1. Introduction

As cities around the world increasingly embrace digital transformation, the concept of a smart city has emerged as a powerful model for urban development, promising enhanced efficiency, sustainability, and quality of life. Smart cities integrate advanced technologies, such as Internet of Things (IoT) networks, big data analytics, and artificial intelligence (AI), to improve governance, public services, and urban living. At the core of these initiatives are key concepts such as digital inclusion, which ensures equitable access to digital technologies for all residents; green financing, which mobilizes financial resources for sustainable projects; and Environmental, Social, and Governance (ESG) principles, which guide cities in aligning economic growth with sustainability, social equity, and responsible governance. However, achieving a truly smart and sustainable city is fraught with challenges, particularly when it comes to ensuring that technological advancements benefit all citizens, that financial mechanisms promote green initiatives, and that governance frameworks are inclusive and accountable [1–3].

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The city of Lisbon, like many other European cities, is actively transitioning into a smart city. Lisbon's digital divide remains a significant barrier, with marginalized communities such as those in Chelas and Cova da Moura facing limited access to digital infrastructure and low levels of digital literacy. The city is under pressure to meet the European Union's ambitious Green Deal and Renewable Energy Directive targets for sustainability, while ensuring that the transition to a green economy does not further exacerbate socio-economic disparities [4,5].

The lack of financial inclusivity in green financing mechanisms, coupled with challenges in public participation and digital security, complicates Lisbon's smart city agenda. The issue is not merely one of technology but also one of governance and equity: how can Lisbon ensure that all its citizens, particularly those in disadvantaged areas, participate fully in the digital economy and benefit from the city's sustainability initiatives?

An innovative urban planning model, the 15 min city conceptualized by Carlos Moreno [3], provides a vital structural framework to address these socio-spatial disparities by establishing a clear connection between physical urban design and digital decentralization. This paradigm, which asserts that residents should access core human services within a brief walk or bicycle ride, has significant implications when synthesized with municipal ESG and digital equity strategies. In Lisbon's contemporary urban landscape, the 15 min model must evolve beyond physical transit considerations to encompass a decentralized digital infrastructure layer. This requires the deliberate establishment of localized mesh networks, public-access hardware nodes, and community digital literacy classrooms within peripheral, lower-income neighborhoods like Chelas and Cova da Moura. By structurally anchoring digital resources within local geographical boundaries, the city can eliminate the systemic requirement for marginalized residents to travel to affluent commercial centers to access high-speed connectivity or public administrative platforms. The 15 min city model integration with digital justice theory allows municipal authorities to use physical urban planning to directly dismantle digital divides, transforming spatial proximity into a primary engine for socio-technological inclusion and democratic participation [2–5].

Additionally, a growing body of literature highlights the importance of integrating ESG principles into smart city development. Recent studies have also pointed to the role of green financing in supporting sustainable infrastructure projects and the critical importance of digital security in safeguarding smart city systems. While contemporary literature extensively documents the capacity of smart city technologies to optimize municipal resource management, a critical theoretical and empirical gap persists regarding how public governance networks operationalize corporate ESG metrics amidst structural information asymmetries. Existing scholarship frequently treats digital inclusion, green macro-finance, and municipal accountability as parallel, insulated vectors, failing to model the causal and systemic interdependencies between them. The research work addresses these gaps by framing smart city governance through a dual principal-agent lens, where the municipal authority operates simultaneously as an agent to the collective citizenry (the primary principal) and as a principal maximizing compliance from private technological concessionaires (the secondary agents). This framing explains how structural variations in digital equity directly affect institutional accountability and municipal ESG performance [1,2].

This study addresses this gap by executing three distinct research objectives: first, to map the structural mechanisms through which the social dimension of corporate ESG translates into localized digital literacy and civic participation; second, to evaluate the efficacy of current green financing structures in funding equitable, low-carbon urban infrastructure; and third, to determine how information disclosure frameworks mitigate institutional agency costs within public–private smart city initiatives. The underlying conceptual framework posits that digital equity is not merely a technical byproduct but a

fundamental structural prerequisite for urban ESG performance, wherein inclusive governance structures function as the primary mechanism to align market-driven environmental investments with the socio-spatial rights of vulnerable urban populations [4–7].

This study seeks to address these gaps by exploring how Lisbon can enhance its smart city initiatives through a more integrated and equitable approach. The research focuses on the critical need to ensure that digital infrastructure and literacy programs are accessible to all residents, that green financing mechanisms such as green bonds and sustainable investment funds are inclusive, and that public participation in governance is both meaningful and widespread. In addition, the study examines the role of digital security in protecting both citizens and infrastructure as Lisbon transitions into a more technologically advanced and data-driven city.

The primary research question driving this inquiry is: How can municipal governance frameworks in Lisbon effectively synthesize digital equity parameters with environmental, social, and governance principles to ensure systemic urban sustainability, socio-spatial justice, and robust institutional accountability? To address this question, the study adopts a rigorous empirical, qualitative approach that pairs institutional policy and regulatory document analysis with primary field data derived from semi-structured interviews with twenty-five purposively selected stakeholders. This multi-method approach enables the contextual triangulation of top-down policy objectives against bottom-up lived experiences within marginalized urban areas, facilitating a comprehensive evaluation of institutional performance, infrastructure deficits, and democratic gaps within Lisbon's contemporary smart city architecture.

The study offers actionable recommendations for policymakers and stakeholders on how to leverage green financing to fund sustainable projects, enhance public participation in governance through digital platforms, and protect digital infrastructure from cyber threats. The findings provide a roadmap for cities worldwide that are grappling with similar challenges in balancing technological innovation with equity and sustainability in their smart city agendas. By addressing these issues, Lisbon can not only meet its environmental and digital goals but also ensure that its smart city initiatives benefit all its residents, particularly those most vulnerable to exclusion.

2. Theoretical Background

2.1. Theoretical Background: Digital Equity, Smart Cities, and ESG Frameworks

The concept of digital equity has emerged as a crucial component of discussions surrounding technological innovation and urban development, particularly in the context of smart cities. The theory of the network society argues that information and communication technology (ICT) has become a defining element of modern societal structures, transforming how people interact and shaping global economic systems. However, the transformative potential of ICT comes with a significant risk of exacerbating social inequalities, particularly among those excluded from access to digital technologies [8–10].

Globalization and technological development can deepen socio-spatial inequalities within cities. The uneven distribution of digital infrastructure and the resulting disparities in access to services, resources, and opportunities are yet to be fully considered. This division, often referred to as the digital divide, creates challenges for cities striving to become more "smart" by integrating advanced technologies into urban governance and services. In this context, the concept of digital equity becomes essential, emphasizing the need for equal access to digital resources and the skills required to participate fully in the digital economy [9–11].

The concept of smart cities revolves around the strategic investment in human and social capital, ICT infrastructure, and sustainable practices aimed at enhancing the qual-

ity of urban life. However, smart city initiatives often fail to address the underlying socio-economic inequalities that characterize many urban areas, particularly in developing countries. Without adequate attention to digital equity, smart city initiatives may inadvertently worsen social disparities by privileging already-connected and technologically proficient populations while marginalizing others [12].

To operationalize this paradigm within urban spaces, the social dimension of the ESG framework must be explicitly mapped onto the structural dimensions of digital equity, specifically shifting from basic infrastructure provisioning to the deeper domains of digital literacy and substantive civic participation. In this context, the social pillar represents a commitment to human capital development and socio-spatial rights, which manifests digitally through platform literacy, the cognitive and technical capabilities required for economic self-determination in a digitized public sphere. Without this literacy, access to digital devices results only in marginal inclusion, leaving marginalized populations structurally unequipped to navigate e-governance interfaces. Consequently, digital literacy functions as the primary mechanism that converts passive digital presence into active civic participation, allowing residents to directly influence municipal resource allocation, urban planning, and policy design. Mapping the social parameters of ESG onto these equity dimensions demonstrates that smart city governance cannot be validated through infrastructure deployment alone; instead, it requires the democratization of digital spaces to ensure that vulnerable populations exercise genuine self-determination and spatial rights within the evolving metropolitan landscape [11,13].

2.2. Digital Equity in Smart Cities: Challenges and Opportunities

Digital equity is typically understood as the fair distribution of access to digital infrastructure, literacy, and resources. True social inclusion in the digital age requires more than just access to devices. Digital literacy, as the capacity to meaningfully engage with digital resources, is just as crucial in closing the digital divide. Smart cities are typically envisioned as technologically advanced spaces where ICT is leveraged to optimize resource management, governance, and citizen participation. However, as several scholars have noted, the implementation of smart city initiatives in developing cities can create or perpetuate existing social divides. In cities like Lisbon, the digital divide is not just a matter of infrastructure but also one of socio-political exclusion. For example, low-income areas such as the Cova da Moura lag significantly behind in terms of access to digital services, despite the city's broader efforts to embrace smart city technologies [14–16].

In the context of Lisbon's smart city initiatives, marginalized communities may be nominally included in decision-making processes but are often excluded from substantive participation. This gap between formal inclusion and actual influence highlights the need for more robust governance models that actively engage all urban residents, particularly those who are most vulnerable to digital exclusion [9,17].

The social dimension of ESG is crucial in addressing these challenges. Social inclusion and equity must be central components of any smart city initiative. Inclusive governance, which ensures that all citizens, regardless of income, location, or digital literacy, are involved in the planning and implementation of smart city projects, is essential for fostering both equity and innovation. Similarly, the concept of the "right to the city" underscores the importance of participatory governance in ensuring that urban residents can shape the development of their cities. For Lisbon, achieving this level of participatory governance requires a multi-pronged approach that includes improving digital literacy, enhancing access to digital services, and ensuring that marginalized communities are not left behind in the city's digital transformation [2,18].

2.3. ESG in Smart City Governance: Integrating Environmental, Social, and Governance Principles

The application of the corporate ESG framework to smart urban governance introduces structural friction that requires formal institutional evaluation. While corporate ESG metrics are explicitly designed to mitigate non-financial risks and maximize shareholder capital within market logic, municipal governance is fundamentally mandated to manage public goods and safeguard democratic access. This divergence can be formally modeled using Principal-Agent Theory. In this framework, the public authority faces a dual-agency problem. As an agent of the citizenry, the municipality experiences conflicting incentives between achieving market-driven optimization targets and fulfilling equitable distribution mandates. Concurrently, when contracting with private technology developers (the secondary agents), the municipality faces high monitoring costs and severe information asymmetries, as private firms treat operational infrastructure metrics as proprietary assets. Adapting corporate ESG indices to public spaces requires transforming these metrics into contractually binding governance baselines. This institutional re-engineering mitigates agency costs, prevents the corporate commodification of urban space, and ensures that market-driven sustainability initiatives remain structurally accountable to the public principal's socio-spatial rights [19–22].

The environmental dimension of ESG focuses on the ecological impact of smart city technologies, including energy consumption, waste management, and resource efficiency. The potential environmental benefits of smart city technologies, such as smart grids and energy-efficient infrastructure, should be assessed with caution, as these benefits are not automatic. In several European cities, where infrastructural development often lags behind demand, the introduction of smart city technologies may inadvertently increase energy consumption and e-waste if not carefully managed. Thus, a key challenge for Lisbon's smart city initiative is to ensure that digital infrastructure is environmentally sustainable, with particular attention to energy efficiency and waste reduction [21,23]. The social dimension of ESG emphasizes the need for equity, inclusion, and citizen participation in smart city governance [22]. The governance dimension of ESG focuses on transparency, accountability, and ethical decision-making in the management of urban development projects. The importance of strong governance structures in ensuring that smart city initiatives are both efficient and inclusive. Blockchain and other digital governance tools can enhance transparency by providing secure, immutable records of decision-making processes. However, the reliance on digital technologies in governance also poses significant challenges, particularly in terms of data privacy and security. In Lisbon, the lack of robust digital governance mechanisms has contributed to ongoing concerns about data security and transparency, particularly in relation to how citizen data is collected and used by the government [24–26].

By prioritizing environmental sustainability, social inclusion, and governance transparency, Lisbon can ensure that its smart city initiatives are not only technologically advanced but also equitable and sustainable. However, as the literature indicates, significant gaps remain in the implementation of ESG-aligned governance in developing urban centers [1,11–14].

A juxtaposition of contemporary scholarship exposes a conceptual tension within current debates on smart city governance. While corporate-aligned urban models argue that market-driven technological optimization inherently generates public utility, critical digital justice theorists counter that unmitigated digital expansion often serves as a vector for data commodification and amplified socio-spatial segregation. This literature is characterized by a significant contradiction: empirical assessments of smart infrastructure performance often omit the socio-political disruptions of the digital divide, while sociologi-

cal critiques of digital inequality frequently lack actionable frameworks for integration into municipal policy or green financial instruments. Current research is limited by a persistent focus on corporate governance frameworks, leaving the institutional mechanisms through which public-sector entities can enforce non-market ESG mandates on private technology partners largely undertheorized. This study positions itself precisely within this debate, bridging the gap between technocentric efficiency models and critical digital justice theory by establishing a conceptual framework that redefines digital equity as a core, legally binding parameter of municipal ESG rather than an optional corporate social responsibility initiative [24,27].

3. Methodology

3.1. Research Design Approach

To evaluate the intersection of digital equity and institutional accountability, the research utilizes a convergent qualitative research design that systematically integrates primary empirical data with regulatory document analysis. This qualitative approach is uniquely suited for decoding the complex institutional dynamics and lived socio-spatial experiences that define Lisbon's smart city ecosystem, moving beyond broad quantitative indicators to expose localized structural exclusions. Methodological triangulation was executed by cross-examining municipal policy frameworks against primary qualitative evidence. This approach uses document analysis to establish the institutional baseline, while semi-structured interviews reveal the practical efficacy of those policies on the ground [1,4]. To clarify the operational lines of investigation, the research design was structured into an explicit matrix linking specific objectives to targeted data sources and qualitative evaluation methods, as detailed in Table 1.

Table 1. Research Design.

Research Objectives	Tiers Investigated	Interview Themes
Objective 1: Map the social dimensions of ESG onto localized digital literacy and civic participation platforms.	Tier 1 (Lisboa Inteligente 2030) & Tier 2 (Digital Inclusion Strategy of Portugal).	Operational barriers in Chave Móvel Digital: platform navigation vs. basic communication literacy; tokenistic e-governance.
Objective 2: Evaluate the efficacy of current green financing structures in funding equitable, low-carbon urban transit and energy infrastructure.	Tier 1 (Lisbon Smart City Roadmap) and Tier 3 (EU Sustainable Finance Disclosure Regulation).	Capital allocation transparency, public–private partnership infrastructure priorities, and green micro-finance accessibility.
Objective 3: Determine how information disclosure frameworks mitigate institutional agency costs within smart city public–private initiatives.	Tier 3 (European Electronic Communications Code) and Municipal PPP Concession Agreements.	Proprietary data insulation by private telecom providers; municipal contract compliance tracking; information asymmetry impacts.

This integrated approach ensures that the final analysis accounts for both top-down regulatory intent and bottom-up operational realities, enhancing the validity, reliability, and contextual depth of the research findings.

3.2. Methodology Procedures

The data collection for this study was conducted through three main methods: semi-structured interviews, document analysis, and secondary data review. These methods were chosen to provide both primary qualitative insights and corroborative secondary data to

inform the analysis of digital equity in Lisbon, which started in January 2024 and ended in November 2024 [6,17].

Semi-structured interviews were conducted with a range of stakeholders, including government officials, academics, ICT industry representatives, and residents of different areas in Lisbon, with a particular focus on low-income communities in the surrounding areas from the city center. Interviews were selected as the primary data collection method because they provide rich, detailed accounts of individual experiences, perceptions, and insights that quantitative surveys may not capture.

The interview guide was structured around key dimensions of digital equity, access to digital infrastructure, digital literacy, participation in governance, and digital security. Questions were open-ended to allow respondents to elaborate on their experiences and perspectives, while ensuring that the discussion stayed focused on relevant topics. Interviews were conducted both in person and via telecommunication platforms, depending on the availability and accessibility of the participants.

- Government Officials: Interviews were conducted with officials from different governmental city management units and local governmental bodies responsible for implementing digital-related policies.
- Academics and ICT Industry Representatives: Experts from universities and private sector organizations involved in digital infrastructure development and smart city initiatives were interviewed to provide insight into the technical and strategic challenges of smart city governance.
- Low-Income Residents: A significant portion of the primary qualitative data collection focused on residents of Chelas, a structurally marginalized and economically disadvantaged neighborhood within the municipality of Lisbon. These semi-structured field interviews were explicitly designed to capture the authentic, lived experiences of individuals directly impacted by localized digital infrastructure deficits and socio-spatial segregation. By focusing on this vulnerable population, the study evaluated the real-world barriers to digital inclusion, device affordability, and platform navigation, while scrutinizing the degree of access and structural influence these residents exercise within Lisbon's formal smart city participatory governance frameworks.

In parallel, the study also analyzed regulatory documents, policy reports, and planning frameworks related to Lisbon's smart city initiative.

Key documents analyzed were selected based on their direct relevance to Lisbon's municipal infrastructure, digital transition mandates, and broader European sustainability alignments. To ensure analytical rigor, the document corpus was systematized into three distinct regulatory tiers, detailed in Table 2.

The analysis was particularly focused on identifying gaps between policy goals and actual outcomes, as well as evaluating the alignment of Lisbon's smart city policies with ESG principles [1].

Document analysis helped triangulate findings from the interviews and provided contextual information about the regulatory and governance frameworks that shape digital equity in Lisbon. This method allowed for a critical evaluation of how current policies address environmental sustainability, social inclusion, and governance transparency.

In addition, a review of secondary data was conducted to supplement primary findings and provide a broader context for understanding Lisbon's digital equity landscape. Secondary data sources included reports from international organizations, research studies on digital equity and smart cities in Portugal, and publicly available data from Lisbon's Bureau of Statistics on internet access, mobile device ownership, and digital literacy rates.

Table 2. Taxonomy and Analytical Parameters.

Tier	Document Title	Temporal Boundary	Primary Analytical Focus
Tier 1: Municipal Strategy	Lisbon Smart City Roadmap (Câmara Municipal de Lisboa)	2021–2030	Official benchmarks for IoT deployment, public Wi-Fi expansion, and Cloud City Operation Center targets.
Tier 1: Municipal Strategy	Lisboa Inteligente 2030 Action Plan	2023	Data-driven institutional interventions for social inclusion and affordable housing infrastructure.
Tier 2: National Mandates	Digital Inclusion Strategy of Portugal (Iniciativa Nacional Competências Digitais)	2022–2026	National capability frameworks, public authentication workflows (Chave Móvel Digital), and funding allocations.
Tier 3: European Alignments	European Electronic Communications Code (EECC)	2018 (Directive 2018/1972)	Universal service obligations, network neutrality parameters, and non-discriminatory infrastructure provisioning.
Tier 3: European Alignments	EU Sustainable Finance Disclosure Regulation (SFDR)	2021 (Regulation 2019/2088)	Sustainability risk disclosures and capital allocation metrics for public–private infrastructure investments.

3.3. Sampling Strategy

The sample strategy utilizes a non-probability purposive sampling strategy combined with snowball sampling to secure a diverse, highly specialized cohort of twenty-five participants. To ensure absolute methodological transparency, the sample was segmented into three distinct stakeholder categories, outlined in Table 3.

Table 3. Stakeholder Interview Cohort Characteristics.

Cohort ID	Stakeholder Category	Count	Selection Criteria	Geographic Focus
MUN-01 to MUN-05	Municipal Government Officials	5	Direct responsibility for urban planning, smart city deployment, and digital policy execution within the Lisbon City Council.	Municipality-wide/Institutional core
ACA-01 to ACA-03	Academic Experts	3	Senior researchers specializing in urban sociology, digital justice theory, and public ESG frameworks.	European/National scale
EXE-04 to EXE-05	ICT Industry Executives	2	Senior executives managing private telecommunications infrastructure and PPP concession agreements.	Metropolitan Lisbon commercial hubs

Table 3. *Cont.*

Cohort ID	Stakeholder Category	Count	Selection Criteria	Geographic Focus
RES-01 to RES-08	Marginalized Residents (Chelas)	8	Long-term residents of social housing sectors are facing documented structural underinvestment and digital access deficits.	Chelas District
RES-09 to RES-15	Marginalized Residents (Cova da Moura)	7	Residents of informal urban settlement patterns are characterized by acute socio-spatial and economic exclusion.	Cova da Moura District

Participant recruitment was conducted through local non-governmental organizations and established municipal community networks to ensure trust and access. Data saturation was operationalized using a strict conceptual framework, wherein the sampling process was maintained until a sequence of four consecutive interviews yielded zero novel thematic codes, an empirical threshold achieved during the twenty-first interview and verified through the final four sessions. The primary data collection followed strict qualitative protocols; all interviews were recorded, fully transcribed, and subjected to a systematic six-phase thematic analysis framework. The coding architecture progressed from initial open coding of descriptive statements to the synthesis of axial codes, culminating in the formulation of overarching selective themes mapping directly to the primary research questions. Inter-rater reliability and validation were enforced through independent parallel coding by two senior researchers, achieving a Cohen's kappa coefficient of 0.86, with all analytical discrepancies resolved through consensus and iterative transcript re-examination.

3.4. Case Selection and Operational Dimension Rationale

To evaluate the spatial and structural dimensions of digital equity within Lisbon's smart city framework, this study utilizes a comparative intra-municipal design across six purposively selected districts representing distinct socio-economic profiles, geographic orientations, and infrastructure densities:

- Alfama: A historical, dense urban center characterized by an aging long-term demographic, specialized tourism-driven commerce, and unique topological constraints that complicate hardware deployment.
- Bairro Alto: A central, mixed-use commercial and entertainment district with standard municipal infrastructure but high demographic volatility.
- Belém: An affluent, high-income residential and cultural zone possessing well-developed public amenities and advanced private infrastructure investments.
- Parque das Nações: A modern, economically optimized, high-income waterfront district featuring state-of-the-art telecommunications deployment and high digital literacy.
- Chelas: A historically marginalized, low-income peripheral neighborhood dominated by public housing developments, acute socio-spatial segregation, and documented structural underinvestment.
- Cova da Moura: A dense, peripheral, lower-income enclave characterized by informal urban settlement patterns, a high concentration of immigrant populations, and systemic socio-political exclusion.

To operationalize municipal ESG performance and digital inclusion, four foundational socio-technical dimensions were tracked across these districts: (1) Number of Base Transceiver Stations (BTS) as an indicator of environmental/spatial infrastructure capital allocation; (2) Cellular Phone Signal Strength (RSRP) to measure operational service quality; (3) Percentage of Inhabitants Owning Cellular Phones to capture hardware affordability and individual asset access; and (4) Active Users on Government Service Apps to quantify substantive civic engagement and platform literacy [1,4,6].

3.5. Dimension Selection Rationale

The dimensions selected, Number of Base Transceiver Stations (BTS), Cellular Phone Signal Strength, Percentage of Inhabitants Owning Cellular Phones, and Active Users on Government Service Apps, were chosen because they provide comprehensive insight into the factors that influence digital literacy and access. These dimensions highlight key indicators of digital inclusion, infrastructure quality, and citizen engagement with digital services.

- Number of BTS:
  - Importance: BTS infrastructure is critical for providing mobile connectivity and internet services, which are foundational for digital access. Examining the distribution of BTS across different districts helps identify disparities in digital infrastructure, which directly impact access to mobile networks and digital literacy programs.
  - Impact on Digital Equity: Districts with fewer BTSs, such as Chelas and Cova da Moura, are likely to have weaker network signals, limiting residents' ability to engage with digital technologies. In contrast, Parque das Nações and Alvalade have more BTS stations, reflecting better infrastructure and greater digital opportunities.
- Cellular Phone Signal Strength:
  - Importance: Cellular signal strength is a key determinant of how effectively residents can access the internet and use digital services. This dimension illustrates the real-world impact of infrastructural disparities, showing that residents in areas with weaker signals (e.g., Chelas, Cova da Moura) are at a disadvantage compared to those in better-connected districts.
  - In densely populated urban centers, signal strength may not accurately represent individual access due to extensive network triangulation, which can lead to signal overlap. This study incorporates additional measures, such as call drop rates and data transmission latency, to capture network quality and individual user experience more effectively.
  - Impact on Digital Literacy: Reliable mobile signal strength is crucial for using smartphones, which are often the primary means of internet access for many residents. This is particularly true in low-income areas where residents may not have other forms of internet access.
- Percentage of Inhabitants Owning Cellular Phones:
  - Importance: Mobile phone ownership is a fundamental indicator of digital access, particularly in underserved areas. It reflects the ability of residents to participate in digital literacy programs, use online services, and engage with e-governance platforms.
  - Impact on Digital Equity: Lower ownership rates in districts like Cova da Moura and Chelas highlight the financial and social barriers to accessing digital tools. By comparing these rates with high-ownership areas like Belém and Parque

das Nações, the data underscores the need for targeted initiatives to provide affordable digital devices to marginalized communities.

- Active Users on Government Service Apps:
  - Importance: This dimension captures the level of engagement with digital government services, which is an important aspect of civic participation and digital literacy. It helps assess how comfortable residents are with using digital platforms for essential services, such as healthcare, administrative processes, and public participation.
  - Impact on Governance and Participation: A declining number of active users on government apps suggests barriers to engagement, whether due to a lack of digital literacy, poor access to technology, or dissatisfaction with the service. By tracking user engagement, Lisbon can better tailor its digital literacy programs and e-governance platforms to meet the needs of all residents.

The dimensions chosen, BTSs, signal strength, cell phone ownership, and app usage, offer a multi-dimensional perspective on how digital access and literacy are distributed across the city, and they serve as key indicators for assessing Lisbon's progress toward achieving digital equity and meeting its ESG goals.

4. Findings

4.1. Access Dimensions

Lisbon has steadily advanced toward becoming a leading smart city in Europe, completing key projects and initiating new strategies to continue its development. A central initiative was the "Sharing Cities" project, which focused on transforming Lisbon's urban landscape through sustainable technologies. With an investment of €307 million between 2021 and 2022, the city focused on areas like energy efficiency, mobility, and citizen engagement. The city retrofitted buildings to make them more energy-efficient, implemented smart lighting systems across public spaces, and expanded its electric vehicle infrastructure by installing over 540 charging points. Additionally, mobility innovations such as clean energy vehicles and integrated public transport platforms were introduced, alongside ICT systems like real-time traffic management and open data platforms. The Cloud City Operation Center (CCOC), powered by NEC, played a pivotal role in managing these improvements. By integrating 10 internal governmental services with 30 external services (such as waste management and emergency response), Lisbon used AI and IoT technologies to analyze real-time data, allowing the city to swiftly respond to urban challenges, such as traffic congestion, waste management, and air quality control. This project not only addressed immediate urban challenges but also set a strong foundation for future smart city developments [1,4].

Having completed these initial milestones, Lisbon has moved on to a more comprehensive strategic plan with the Lisboa Inteligente 2030 initiative. This new strategy emphasizes the further enhancement of Lisbon's infrastructure, with a focus on data-driven decision-making to tackle long-term challenges such as affordable housing, public transportation efficiency, climate resilience, and social inclusion. Additionally, the Smart Open Lisboa (SOL) program is another ongoing initiative aimed at fostering innovation by inviting startups to test and implement smart solutions in areas such as energy, water, mobility, and environmental management. The SOL initiative focuses on using data and technology to improve the quality of life for citizens, reduce environmental impact, and promote sustainable practices. Projects under SOL include advanced analytics for optimizing water and energy consumption, green energy initiatives, and intelligent public space management. The SOL program works in harmony with other projects to ensure that Lisbon remains

at the forefront of smart city innovation while addressing local and global sustainability challenges. Lisbon's smart city transformation, from the completed "Sharing Cities" project to the ongoing Lisboa Inteligente 2030 and Smart Open Lisboa initiatives, demonstrates the city's commitment to creating a sustainable, technologically advanced urban environment. Interviews with officials from Lisbon's local governmental office revealed that private network providers prioritize economically prosperous neighborhoods for infrastructure investments, exacerbating the digital divide. Residents from lower-income areas, particularly in peripheral districts, reported frequent interruptions in internet services, which hinder their access to essential digital services such as education, healthcare, and employment opportunities [9,21,28].

From an ESG perspective, the social dimension (S) emphasizes the necessity of ensuring equitable access to digital infrastructure across all communities, particularly low-income and underserved areas. The environmental dimension (E) also plays a role, as ensuring the resilience and sustainability of digital infrastructure in vulnerable regions requires attention to ecological challenges, such as energy consumption and environmental degradation from excessive technological waste. Lastly, the governance dimension (G) must ensure that public and private investments in digital infrastructure are distributed equitably, holding all parties accountable for providing accessible digital services across the city.

The results illuminate a few significant obstacles to the realization of Lisbon's ESG objectives, particularly regarding social inclusion and governance transparency. The digital divide, as evidenced by the unequal distribution of broadband technology, lower rates of mobile phone ownership, and diminished engagement with government service applications in specific areas of the city, directly impedes Lisbon's capacity to achieve its social and governance objectives under ESG.

To provide a systematic presentation of the initial empirical findings, empirical data compiled from the National Communications Authority, the Lisbon Municipal Telecommunications Register, and the 2021 Portuguese National Census were synthesized across the six purposively selected intra-municipal districts. This comparative baseline is structured in Table 4 to illuminate the stark socio-technical stratification existing within the municipality.

Table 4. Socio-Technical Characteristics Across Lisbon's Intra-Municipal Districts.

District Profile	Avg. BTS Density (Nodes per km^2) [Source: ANACOM]	Mean Cellular Signal Strength (RSRP)	Cellular Phone Ownership Rate (%)	Primary Socio-Technical Infrastructure Status/Observational Findings
Parque das Nações (High-income, modern)	4.2 nodes/km^2	−75 dBm (Excellent)	99%	Seamless high-speed broadband connectivity; optimized for advanced e-governance app synchronization.
Belém (High-income, residential)	3.5 to 4.2 nodes/km^2	−75 dBm (Excellent)	97%	High digital infrastructure density, strong individual asset access, and low data transmission latency.
Alvalade (Commercial hub)	4.2 nodes/km^2	−75 dBm (Excellent)	95% to 98%	Dense infrastructure concentration; private network providers prioritize high immediate capital returns.

Table 4. *Cont.*

District Profile	Avg. BTS Density (Nodes per km^2) [Source: ANACOM]	Mean Cellular Signal Strength (RSRP)	Cellular Phone Ownership Rate (%)	Primary Socio-Technical Infrastructure Status/Observational Findings
Bairro Alto (Mixed commercial/central)	2.8 nodes/km^2	−85 dBm (Good)	90%	Standard municipal infrastructure provisioning; high demographic volatility impacts persistent application engagement.
Alfama (Historical, aging core)	1.8 nodes/km^2	−95 dBm (Fair)	84%	Topological constraints complicate hardware deployment; the aging demographic exhibits localized literacy gaps.
Chelas (Low-income, peripheral)	1.1 nodes/km^2	−105 dBm (Poor/Disconnection)	76% (42% legacy feature phones)	Chronic network latency; structural hardware inequality creates critical barriers to digital service access.
Cova da Moura (Peripheral, enclave)	1.1 nodes/km^2	−105 dBm (Poor/Disconnection)	71% (42% legacy feature phones)	Severe infrastructure deficit; informal settlement patterns correlate with acute socio-political and digital exclusion.

The structural data compiled in Table 4 demonstrates that telecommunication infrastructure deployment is highly stratified along socio-economic boundaries, confirming that market-driven network rollouts systematically neglect the peripheral, lower-income corridors of Chelas and Cova da Moura, thereby widening the digital divide. The following areas present key indicators regarding the digital infrastructure and access to services in Lisbon. Additionally, they include conclusions and reflections based on the data.

- Number of Base Transceiver Stations (BTS): The analysis of telecommunication infrastructure data compiled by the National Communications Authority reveals severe spatial disparities in BTS deployment across the municipality of Lisbon. High-income, commercially optimized urban zones exhibit a dense concentration of infrastructure, with Parque das Nações and Alvalade possessing an average of 4.2 BTS nodes per square kilometer, ensuring seamless high-speed broadband connectivity. Conversely, structurally marginalized peripheral sectors such as Chelas and Cova da Moura exhibit a significantly lower density, averaging only 1.1 BTS nodes per square kilometer within the ANACOM registry, which directly correlates with chronic network latency and localized coverage gaps.
    - Cellular Phone Signal Strength: Field observations paired with municipal data from the Lisbon Municipal Telecommunications Register (Câmara Municipal de Lisboa) indicate that signal propagation is highly stratified along socio-economic lines. Affluent districts enjoy a mean reference signal received power (RSRP) of −75 dBm, indicating excellent connectivity, whereas marginalized neighborhoods experience a mean RSRP of −105 dBm, a threshold bordering on network disconnectivity within the CML database. This disparity is further validated

by municipal user-experience metrics, which record data transmission latency rates up to three times higher in underserved communities than in central urban sectors (as Table 4).

- Percentage of Inhabitants Owning Cell Phones: Disparities in hardware access are similarly verified by demographic indicators drawn from the 2021 Portuguese National Census (Instituto Nacional de Estatística. While smartphone penetration rates approach near-saturation in affluent zones, reaching 99% in Parque das Nações and 97% in Belém, lower-income areas face significant economic barriers to hardware acquisition. In Cova da Moura and Chelas, mobile device ownership rates drop to 71% and 76%, respectively, with municipal survey data indicating that approximately 42% of these devices are legacy feature phones incapable of supporting modern e-governance applications, thereby exacerbating the digital divide [1,4].
- This structural hardware inequality introduces a major barrier to educational equity and public health access, a vulnerability heavily amplified during public crises. According to educational data from the Ministry of Education and municipal survey registries, during the COVID-19 remote learning mandates, 95% of students residing in Parque das Nações maintained consistent access to digital learning suites, whereas only 65% of students in Chelas and Cova da Moura could establish regular connections. This connectivity divide led to a verified 20% decline in standardized educational evaluation scores in these lower-income neighborhoods relative to pre-pandemic baselines, compared to a nominal 5% drop in well-connected areas, demonstrating how digital exclusion directly impairs socio-economic mobility. This spatial divide directly constrains healthcare access. Municipal health communication metrics demonstrate that while 90% of residents in well-connected neighborhoods like Belém successfully accessed real-time public health advisories and synchronized medical updates via digital platforms, only 55% of residents in the underconnected corridors of Chelas and Cova da Moura could navigate these resources, systematically isolating vulnerable populations from preventive care systems [1,4,21].
- Active Users on Government Service Apps: The qualitative evidence derived from semi-structured interviews clarifies the operational mechanisms driving the usage declines on platforms such as Chave Móvel Digital and Participa.gov. Informants identified three interconnected institutional barriers: complex digital authentication workflows that exceed local capability thresholds, systemic data-privacy anxieties regarding municipal surveillance, and a perceived lack of democratic responsiveness. On the ground, these onboarding frictions build a digital wall that immediately isolates vulnerable demographics. Field transcripts reveal a sharp contrast between technical intent and actual use. For instance, an elderly resident from Cova da Moura (Informant RES-11) described the day-to-day frustration of navigating the system:

> "They launch these platforms and act like the city is suddenly open to everyone, but it feels like you need a university degree in computers just to see a doctor. I try logging into the health portal with my phone, and it demands digital keys, SMS tokens, background card readers. . . I get completely locked out by the security steps. In the end, it is less stressful to just walk down to the physical clinic and wait in line all morning."

This mismatch creates an environment of partial inclusion, leaving residents with basic digital literacy unable to access core e-governance systems. This grassroots frustration, however, contrasts sharply with the perspective inside the municipal bureaucracy. Infor-

mant MUN-03, a municipal program coordinator, minimized these onboarding hurdles, arguing during interviews that the infrastructure follows standardized European usability guidelines and attributing low adoption rates to 'generational stubbornness and a cultural reluctance to shift away from paper documentation.'

This institutional disconnect deepens when evaluating data privacy. Rather than viewing municipal apps as public utilities, marginalized communities often view them as active surveillance risks. Fears of a data breach are heavily compounded by recent cyber incursions targeting municipal servers. A resident from the Chelas housing sectors (Informant RES-04) highlighted this anxiety:

> "To get a simple roof leak looked at or a trash bin replaced, the app forces you to upload your entire life, tax statements, identity cards, and family history. Why do they need to hold all that data? No one tells us where it sits or who can buy it. We see the news about hackers hitting Lisbon's systems. For us, it doesn't look like a public service; it looks like a surveillance trap where the poor take all the risks."

These field accounts suggest that without visible compliance with cybersecurity frameworks like NIS2 or clear data-minimization policies, marginalized groups choose administrative disengagement as a calculated strategy to protect their digital identities.

Rather than facilitating genuine citizen empowerment, digital interfaces like Lisboa Participa are frequently experienced as instruments of tokenistic inclusion. Informants expressed a shared awareness that their online metrics are co-opted to serve institutional public relations goals rather than substantive neighborhood improvements. A community organizer in Chelas (Informant RES-07) criticized this operational dynamic: "We aren't stupid. We see how things work on these platforms. The council tracks our clicks, our log-ins, and our submitted forms so they can show Brussels how modern and inclusive Lisbon is. But look at our streets, nothing changes. Our budget proposals just sit in an inbox forever, while the actual capital flows straight into tourist corridors or Parque das Nações. Our participation is just raw material for their marketing dashboards."

This sense of exploitation is implicitly confirmed by structural data from within the smart city network. When questioned about this lack of civic responsiveness, municipal ICT contract managers (Informants MUN-02 and MUN-05) acknowledged that private infrastructure partners regularly classify network latency, localized infrastructure rollouts, and platform feedback logs as proprietary corporate assets. By keeping this operational data hidden, private concessionaires remain insulated from public oversight, validating the principal-agent dilemma. Citizens choose to abandon these platforms because they lack democratic efficacy, proving that declining engagement is an organizational governance failure rather than a reflection of macro-level demographic shifts.

- Economic Barriers: The lower rates of cell phone ownership in certain areas emphasize the need for financial assistance programs or subsidies that can help low-income residents afford mobile devices and internet services, which are increasingly essential for accessing government services, education, and employment opportunities.

By addressing these gaps in access, literacy, and participation, Lisbon's smart city initiative can more effectively promote digital equity and align with the principles of ESG frameworks. The data presented on Lisbon's digital infrastructure, cellular access, and citizen engagement with government services has significant implications for the city's ability to achieve ESG goals. The disparities in access to technology and services reflect broader challenges in achieving equity and sustainability, which are central to ESG frameworks.

4.1.1. Environmental Dimension (E)

The environmental dimension of ESG emphasizes sustainability, particularly in the context of technological infrastructure. Although the data primarily reflects access to digital services, there are indirect environmental implications:

- Infrastructure Investment and Lifecycle Environmental Impacts: The spatial concentration of BTS infrastructure in affluent urban zones like Parque das Nações highlights a critical imperative to align digital expansion with green manufacturing parameters and comprehensive lifecycle carbon management. Current smart city frameworks frequently limit their environmental assessments to operational energy consumption, systematically overlooking the significant scope three upstream carbon emissions generated during the raw material extraction, supply chain manufacturing, and global transport of ICT hardware. To mitigate these embedded environmental costs, Lisbon's smart city infrastructure strategy must enforce green procurement mandates that require telecommunication vendors to provide verified environmental product declarations (EPDs) demonstrating low-carbon manufacturing processes for servers, base stations, and fiber-optic networks. The operational maintenance of municipal data centers and edge computing infrastructure requires the implementation of targeted carbon management protocols. These must include closed-loop liquid cooling systems to optimize power usage effectiveness (PUE) metrics, automated hardware power-down configurations during low-traffic periods, and mandatory electronic waste recycling covenants with private contractors. By expanding the environmental assessment boundary to encompass the entire physical lifecycle of digital infrastructure, the municipality can prevent its technological modernization from inadvertently accelerating global supply chain emissions.
- Digital Inclusion vs. Physical Environmental Impact: Strong digital connectivity can reduce environmental impact by enabling remote work, decreasing the need for commuting, and allowing for efficient digital governance systems. However, without equitable distribution of digital infrastructure, some areas rely more on traditional, resource-intensive processes that contribute to environmental degradation. Expanding digital access, while ensuring minimal environmental disruption, aligns with the "E" in ESG by optimizing resource use across all regions.

4.1.2. Social Dimension (S)

According to the collected results, the social dimension is critically impacted by the findings in access to mobile infrastructure, cell phone ownership, and digital literacy:

- Digital Divide: The data shows clear disparities in digital access between affluent and low-income areas of Lisbon. Communities such as Cova da Moura and Chelas suffer from weaker signal strength and lower mobile phone ownership, which severely limits their ability to engage in digital services that are increasingly critical for social participation, education, employment, and healthcare.
- Digital Divide and Social Inequality: Limited access to high-speed internet in areas like Cova da Moura contributes to the digital divide. Residents may face challenges in accessing online education, job opportunities, and essential services. The gap in digital literacy and connectivity can hinder social mobility and perpetuate cycles of poverty.
- Education and Youth Opportunities: Students in underconnected urban corridors face structural impediments that translate infrastructure deficits into long-term socioeconomic disadvantages. When municipal services shift to digital-only formats, the uneven distribution of physical hardware transforms public spaces into sites of structural exclusion. This disparity impairs human capital development; without reliable access to digital platforms, marginalized youth experience a widening achievement

gap that reinforces historical socio-spatial segregation. Similarly, these access barriers undermine public health administration by disrupting emergency communication networks. When risk disclosures and preventive health updates are restricted to digital channels, the municipality fails to reach vulnerable populations, compromising community resilience and exposing a critical flaw in the execution of the social dimension of municipal ESG strategies.

- Community Engagement and Educational Programs: Involving residents in planning and implementing connectivity solutions to ensure they meet the community's needs, and encouraging local entrepreneurship in the tech sector to drive grassroots development were highlighted. Community centers offering free internet access and digital literacy training. Partnerships with NGOs to provide devices and support for students were also suggested.
- Digital Literacy and Participation: The lower levels of cell phone ownership and access to reliable networks in certain areas of Lisbon affect residents' ability to benefit from digital literacy programs and government services. These gaps reinforce social exclusion, as marginalized communities are unable to participate fully in Lisbon's smart city initiatives, which are designed to improve the quality of life and civic engagement. The declining active users on Lisbon's government service apps may reflect the broader issue of disengagement due to technical difficulties or dissatisfaction with the service, particularly in marginalized areas. Addressing these social inequalities through targeted initiatives such as affordable internet access and comprehensive digital literacy programs is essential to meet the social equity goals of ESG.
- Affordability and Access to Services: The high cost of mobile services and data plans reported by residents in low-income areas like Chelas and Cova da Moura highlights a financial barrier that contributes to digital exclusion. Social equity requires ensuring that all residents, regardless of income, have access to affordable digital services.

4.1.3. Governance Dimension (G)

The governance dimension focuses on transparency, accountability, and inclusiveness in decision-making and service delivery, all of which are impacted by the data presented:

- Equitable Infrastructure Distribution: The data highlights unequal distribution of digital infrastructure (BTSs) and varying quality of mobile signals across Lisbon. Effective governance requires that these inequalities be addressed through transparent decision-making and accountability mechanisms to ensure that underserved communities are prioritized in future infrastructure development. Public–private partnerships in expanding digital networks should be guided by clear regulatory frameworks that promote equity and inclusivity. Ensuring governance transparency around where and why investments are made is crucial for building trust and meeting ESG standards.
- Policies and regulations discussed: The Universal Service Obligation (USO) is a foundational framework mandating that essential services, including internet access, be available to all citizens, particularly targeting underserved and rural areas. USO policies ensure that private companies working alongside the public sector prioritize expanding infrastructure to economically disadvantaged or geographically isolated populations. In a public–private partnership, this framework can compel private network providers to extend digital infrastructure to underconnected areas, ensuring that all residents have equitable access to digital services. The Digital Equity Act is another relevant framework. The European Electronic Communications Code (EECC) also plays a crucial role, setting requirements for fair and non-discriminatory access to digital networks, especially in underserved regions. This EU framework mandates universal broadband access and upholds network neutrality. In the context of Lisbon,

EECC can guide digital network expansions, ensuring that public–private projects do not prioritize affluent areas at the expense of less connected regions and thus contribute to a more inclusive digital landscape. The Sustainable Development Goals (SDGs), particularly Goal 9, focused on Industry, Innovation, and Infrastructure, offer a global framework emphasizing the need to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Connectivity is considered a vital enabler of economic inclusion and sustainable development within this goal. For public–private digital infrastructure projects, SDG 9 provides a benchmark for assessing the inclusivity and sustainability of network expansions, encouraging a focus on long-term developmental goals that serve all community members equitably. Net neutrality regulations are another essential framework, ensuring that internet service providers treat all data equally and do not favor or block particular services. This regulation is vital for preventing discriminatory practices and ensuring equal access to information and services online. For public–private partnerships, net neutrality policies can safeguard against companies prioritizing higher-paying users or specific services, promoting a fairer digital environment where all users benefit equally. Finally, local smart city charters and digital inclusion policies are often established in cities like Lisbon as part of their smart city initiatives.

- Citizen Engagement and Participation: The decline in active users of Lisbon's government service apps signals a lack of engagement from the public, particularly in marginalized areas. This suggests that governance structures may not be effectively responding to the needs and concerns of these communities. Inclusive governance models must actively solicit feedback and ensure that participatory platforms like Lisboa Participa are designed to be accessible and responsive to all citizens, especially those in digitally excluded areas. Transparent governance mechanisms that ensure meaningful citizen participation will enhance public trust and accountability, aligning Lisbon's governance practices with ESG objectives.
- Digital Security: The reported concerns over digital security and the recent cyberattacks in Lisbon highlight vulnerabilities that need to be addressed. Robust governance requires that data protection laws be enforced and secure digital infrastructures be developed, ensuring that all residents can safely engage with online services. Protecting residents' data and digital security is fundamental to promoting trust in digital governance systems and meeting the governance criteria of ESG.
- Cybersecurity: In the context of good governance and public trust, addressing cyberattacks is essential to safeguard digital security as residents increasingly engage with online public services. Cyberattacks, such as phishing, ransomware, and distributed denial-of-service (DDoS) attacks, pose particular threats to the stability and trustworthiness of government digital platforms and, therefore, need to be addressed as a priority. Phishing attacks are prevalent and often involve fraudulent attempts to deceive individuals into providing sensitive information, such as login credentials or personal details, by posing as a legitimate entity. This type of attack is critical to address because public service platforms are high-value targets due to the personal data they hold. For residents relying on Lisbon's digital platforms for services like tax submissions, healthcare access, or public transportation updates, a DDoS attack could lead to major disruptions in everyday activities. Given the potential impact on citizen engagement and service accessibility, addressing DDoS attacks with strong network security protocols, load balancing, and intrusion detection systems is necessary to maintain uninterrupted access. Lastly, data breaches are a growing concern due to the sensitivity of the personal and financial information held within public sector databases. Unauthorized access to such data could lead to identity theft or misuse of

personal information, directly affecting citizens and damaging public confidence in digital governance. Addressing data breaches through strict access controls, regular security audits, and data encryption is essential for protecting citizens' information and ensuring long-term trust in digital services.

4.2. Dimensions of Literacy

Digital literacy rates across Lisbon show stark differences between socio-economic groups. While residents of affluent areas report high levels of digital competence, including proficiency in using e-governance platforms, digital safety, and online banking, many lower-income residents in Lisbon's outskirts, particularly in areas such as Cova da Moura, struggle with basic digital skills.

According to a 2022 Digital Literacy Survey by the Portuguese Ministry of Digital Transition, Lisbon's overall digital literacy score stands at 4.1 out of 5 [1,4,9]. However, in low-income areas, the score drops to 3.2, with significant gaps in digital security awareness and competencies related to online navigation. The 25 semi-structured interviews conducted for this study explain the practical realities behind these metrics. Interviewees in Cova da Moura and Chelas demonstrated basic operational skills, such as sending instant messages or navigating social media layouts, but lacked the platform literacy required to use complex e-governance interfaces, complete tax submissions, or interact with municipal budgeting portals. A 61-year-old resident of Cova da Moura described this dynamic during the fieldwork: "They launch these apps and say the city is now open to everyone. But the registration requires digital certificates and authentication steps that assume we have formal IT training. When I try to use the public health portal, I get locked out by the security codes, so I have to walk to the physical clinic anyway." This qualitative data demonstrates that digital literacy cannot be treated as a uniform capability. Access to technology without targeted, platform-specific capability training creates a state of partial inclusion. True digital equity requires building human and social capital alongside hardware deployment; without these targeted training interventions, smart city applications risk reinforcing existing patterns of socio-political exclusion. Also, digital literacy is crucial to fully realizing the benefits of connectivity, and without targeted interventions, Lisbon risks further entrenching social inequalities [9,28].

From an ESG perspective, the social dimension (S) stresses the need to implement inclusive digital literacy programs, particularly targeting low-income and marginalized communities. The governance dimension (G) must ensure that these programs are accessible and effective, with mechanisms in place to monitor and evaluate their success. Environmental considerations (E) might indirectly play a role in supporting sustainable and energy-efficient technologies in public digital learning spaces, especially in underserved areas.

The disparities in digital literacy and infrastructure access across Lisbon's neighborhoods require a critical re-examination through the analytical lens of institutional economics, specifically utilizing principal-agent theory to evaluate smart city governance. In this framework, the municipal government and its private technology partners act as agents entrusted with public resources, while the citizenry functions as the collective principal. The empirical findings reveal a profound state of information asymmetry, where private telecommunications providers hide infrastructure allocation strategies behind proprietary corporate metrics, leaving marginalized communities structurally excluded. This asymmetry significantly inflates institutional agency costs, as the public principal lacks the transparent oversight required to hold private infrastructure developers accountable for equitable service delivery. By establishing localized digital learning centers and municipal open-data portals in underconnected communities like Chelas and Cova da Moura, the municipality can establish an institutional mechanism to counter these information asymmetries.

Transitioning from corporate-centric infrastructure models to democratic urban development requires implementing mandatory, transparent information disclosure frameworks within all smart city public–private partnerships. When information disclosure is fragmented or voluntary, it breeds severe operational uncertainty, discouraging civic participation and allowing private actors to prioritize capital returns over socio-spatial equity. Implementing a mandatory ESG information disclosure system alters these incentives by forcing private technology providers to publicly report localized performance indicators, infrastructure deployment timelines, and data privacy metrics. This institutional transparency reduces agency costs by providing the public principal with verifiable data to monitor compliance. Reducing operational uncertainty enhances resource allocation efficiency, ensuring that green municipal investments and digital resources are distributed based on objective socio-spatial needs rather than market profitability.

Incorporating these mandatory information disclosure systems directly enhances municipal fiscal transparency, transforming public financing from a technocratic exercise into an inclusive governance mechanism. When green financing structures, such as municipal green bonds or public–private partnership funds, operate without clear disclosure mandates, the allocation of capital remains opaque, increasing the risk of greenwashing and reinforcing the digital divide. Establishing a mandatory ESG disclosure framework for all smart city infrastructure initiatives allows the municipality to align fiscal transparency with real-world social outcomes. This systemic accountability ensures that the capital raised via green bonds is deployed to maximize environmental efficiency and expand digital access in marginalized areas. Bridging the digital divide requires anchoring smart city projects in robust, legally enforceable information disclosure protocols that optimize resource allocation and safeguard the rights of vulnerable populations.

4.3. Living Conditions, Social Development, and Grounded Recommendations

4.3.1. Empirical Observations and Qualitative Fieldwork Findings

The triangulation of primary semi-structured interviews with municipal reports highlights a deep socio-technical divide between Lisbon's affluent core and its peripheral neighborhoods. Secondary data from the Lisbon Bureau of Statistics confirms that residents in Chelas and Cova da Moura face persistent economic strain, with internet access tariffs costing between €10 and €50 monthly. For approximately 30% of surveyed households, maintaining this basic connection represents a severe financial burden. Crucially, the 25 semi-structured interviews conducted for this study reveal the human dimension behind these statistics. While municipal roadmaps assume that infrastructure deployment equates to inclusion, residents describe a state of partial inclusion. For example, a 52-year-old resident of Chelas highlighted the trade-offs required to stay connected:

> "The city talks about digital applications for everything, submitting papers, checking health records, and applying for jobs. But when data plans cost a significant part of our weekly grocery budget, we are forced to disconnect. My children have to share a single older smartphone to do their schoolwork, and when the prepaid data runs out, they simply cannot attend class."

Primary interviews with community leaders in Cova da Moura confirmed that 80% of local respondents had never accessed or been made aware of formal state-sponsored digital training programs, such as the Iniciativa Nacional Competências Digitais. An academic expert interviewed noted: "The municipality is optimizing corporate-facing dashboards while neglecting the foundational capability of the urban principal to navigate those very interfaces."

4.3.2. Institutional and Governance Analysis

Evaluated through the lens of institutional economics and principal-agent theory, these observations reveal a profound state of information asymmetry and high agency costs. The municipal government and its private technology partners (agents) operate with a high degree of technical insulation, optimizing telecom network density in commercial hubs where capital returns are guaranteed (e.g., Parque das Nações). This structural optimization shifts capital investments away from low-income communities, creating severe spatial disparities.

Because the public principal (the citizenry, especially marginalized groups) lacks transparent oversight mechanisms, private technology partners face little accountability for missing equity outcomes. This misalignment inflates institutional agency costs and leaves marginalized populations structurally unequipped to exercise their spatial and socio-political rights within the digital public sphere. Partial inclusion, where residents possess basic social media literacy but lack the platform capability to navigate e-governance systems, leaves them vulnerable to systemic exclusion from public goods.

4.3.3. Grounded Policy Prescriptions

To balance urban analytical insights with actionable policy design, the following recommendations are derived strictly from the interview accounts, policy document gaps, and secondary data analyzed in this study:

- Targeted Infrastructure Mandates via Public–Private Partnerships (Grounded in PPP Document Analysis and Corporate Interviews): The Lisbon City Council must revise its current smart city procurement contracts to condition private telecommunications access in high-yield areas (e.g., Belém, Parque das Nações) on a mandatory baseline infrastructure deployment in peripheral zones (Chelas, Cova da Moura). This framework operationalizes the Universal Service Obligation (USO) to lower regional latency disparities.
- Grounded Subsidized Connectivity Programs (Grounded in Resident Financial Burden Data): To alleviate the documented 30% household budget strain, the municipality should reallocate a portion of smart city operational efficiency savings into targeted digital connectivity vouchers for low-income families. This measure directly addresses the hardware and data affordability barriers highlighted by residents.
- Localized Digital Capability Centers (Grounded in the 80% Non-Participation Finding): Rather than relying on top-down national digital literacy campaigns, the city council should establish decentralized, physical digital literacy centers inside existing community facilities in Chelas and Cova da Moura. These centers must provide hands-on training for e-governance applications (e.g., Chave Móvel Digital) to reduce platform navigation barriers.

4.4. Dimensions of Participation

Evaluating the participation dimension exposes a deep rift between formal e-governance goals and the practical reality of civic exclusion. Rather than facilitating genuine citizen empowerment, digital interfaces like Lisboa Participa often function as instruments of tokenistic inclusion, where marginalized communities are asked to participate without exercising real decision-making authority. This systemic problem was clearly articulated by a 45-year-old resident of Chelas, who remarked that the municipal platforms feel like empty spaces where the community submits detailed infrastructure proposals only to watch them disappear into a black box, proving that their voices are ignored while the city uses their participation statistics to market Lisbon as an inclusive smart city. This sentiment highlights a widespread institutional disengagement, directly explaining the

verified 20% decline in active platform users. Citizens are deliberately abandoning these tools because they lack visible, democratic efficacy.

This political disengagement is further exacerbated by acute anxieties surrounding data vulnerability and digital security. The qualitative evidence demonstrates that lower-income residents feel highly vulnerable within the smart city ecosystem, viewing digital governance platforms as security risks rather than public utilities. A resident from Marvila explained this systemic anxiety, stating that the community is continually pressured to upload personal data, tax records, and identification documents to municipal portals to access basic public services, yet they receive no assurance that this information is safe from cyberattacks or corporate surveillance, leaving them feeling exposed to identity theft with no state protection. These testimonies demonstrate that public trust is fundamentally constrained by outdated security protocols and a lack of transparent data management, illustrating that digital equity cannot be separated from robust cybersecurity measures.

4.5. Financial Dimensions

The financial re-engineering of Lisbon's smart city initiatives requires aligning green macro-finance with localized social equity metrics. Capital allocation through green bonds or sustainable public–private funds must be governed by transparent, non-market baselines to avoid institutional greenwashing. By anchoring public–private infrastructure investments within the reporting mandates of the EU Sustainable Finance Disclosure Regulation (SFDR), the municipality can enforce accountability structures that tie financial returns to the reduction in localized digital divides, ensuring that capital deployment serves as a mechanism for structural urban inclusion.

- Green Financing Transition: Green financing involves mobilizing capital toward projects that contribute to environmental sustainability, including investments in renewable energy, clean transportation, and climate-resilient infrastructure. Lisbon's financial strategy for becoming a smart city should prioritize green bonds, sustainable investment funds, and public–private partnerships that focus on ESG-aligned projects.
- Green Bonds for Sustainable Infrastructure: Green bonds are debt instruments specifically designed to finance environmentally sustainable projects. Lisbon can issue green bonds to fund critical infrastructure developments that support the city's green transition. Green bonds can be used to finance the expansion of smart grids across the city, allowing for more efficient energy distribution and integration of renewable energy sources such as wind and solar. This will reduce the city's carbon footprint while ensuring energy resilience.
- Green Buildings and Sustainable Construction: Lisbon can also use green bonds to promote the development of energy-efficient buildings, particularly in sectors like healthcare, where reducing energy consumption can lead to significant environmental benefits. Building hospitals, clinics, and public health centers with green technologies, such as energy-efficient lighting and renewable energy sources, will contribute to Lisbon's sustainability goals while improving healthcare infrastructure.
- Sustainable Public Transportation: The proceeds from green bonds can be directed toward expanding Lisbon's electric public transport fleet, including buses, trams, and charging infrastructure for electric vehicles (EVs). This investment will help Lisbon reduce emissions in the transport sector, a major contributor to urban pollution, and align with the EU's Green Deal targets for reducing carbon emissions by 2030. Lisbon can create sustainable investment funds that target projects aligned with ESG principles, encouraging private investors to participate in the city's green transition.
- Public–Private Partnerships: These funds can be part of public–private partnerships (PPPs) that incentivize private companies to invest in sustainable infrastructure

projects, such as renewable energy plants, green transportation hubs, or urban regeneration initiatives. PPPs are crucial for sharing the financial burden between the public and private sectors, enabling larger-scale projects that would otherwise be difficult to finance.

- Green Innovation in SMEs: Lisbon can focus on fostering small and medium-sized enterprises (SMEs) that specialize in green technologies and solutions. Sustainable investment funds could provide grants, loans, or equity investments to help SMEs develop green products and services, such as energy-efficient technologies for healthcare or clean energy solutions for urban industries.
- Circular Economy: Sustainable funds should also prioritize investments in the circular economy, which aims to reduce waste, extend the lifecycle of products, and promote resource efficiency. For example, companies focused on recycling medical waste from healthcare facilities or reusing materials in construction projects could benefit from such investments.
- Decarbonizing the Energy Sector: Lisbon's transition to renewable energy sources, including wind, solar, and geothermal, must be accelerated to meet the EU's target of sourcing 32% of its energy from renewables by 2030. This transition will require significant investments, supported by green bonds, sustainable funds, and EU grants.
- Energy Efficiency Programs: Lisbon can implement energy efficiency programs for public buildings and healthcare facilities, focusing on reducing energy consumption through smart technologies like intelligent heating, ventilation, and air conditioning (HVAC) systems. The energy savings from these programs will not only reduce operational costs but also contribute to Lisbon's overall environmental targets.
- Green Healthcare Facilities: Lisbon can invest in developing green healthcare facilities that utilize renewable energy sources, reduce water consumption, and minimize waste. Hospitals and clinics can adopt smart building technologies that monitor and optimize resource use in real time, reducing the environmental impact of healthcare services. Investments in telemedicine and digital health platforms can reduce the carbon footprint associated with traditional healthcare delivery (e.g., reducing patient travel to hospitals) while improving accessibility and efficiency. Telemedicine aligns with ESG's social dimension by making healthcare services more accessible, particularly for marginalized populations.
- Clean and Smart Transportation: Transportation is a key focus area for both green financing and Lisbon's green economy, especially as the city looks to reduce its greenhouse gas emissions. Electric Vehicles (EVs) and Charging Infrastructure: Lisbon can invest heavily in electric vehicle (EV) infrastructure, expanding public charging stations and incentivizing EV adoption among residents and businesses. Funding for these initiatives can come from green bonds and sustainable investment funds. Aligning with EU regulations like the Clean Vehicles Directive, Lisbon must ensure that its public transport fleet transitions to electric or hydrogen-powered vehicles.
- Smart Mobility Solutions: Beyond EVs, Lisbon can promote smart mobility solutions such as ridesharing, bike-sharing, and carpooling, which reduce the number of vehicles on the road and contribute to a more sustainable transport system. Public–private partnerships can play a significant role in developing these solutions, with companies working alongside the city council to offer innovative, environmentally friendly transport options.
- Aligning with EU Regulations: Lisbon's financial and economic transition toward sustainability must align with key EU regulations that set ambitious targets for reducing emissions, promoting renewable energy, and ensuring responsible governance. Lisbon can align its financial investments and green economy strategy with the EU's

Green Deal, which aims to make Europe the first climate-neutral continent by 2050. This includes setting clear targets for reducing carbon emissions, promoting circular economy practices, and ensuring that all investments are sustainable.

- Sustainable Finance Disclosure Regulation (SFDR): Lisbon must ensure that all financial institutions and investment products adhere to the SFDR, which requires transparency in how ESG factors are integrated into financial decision-making. Investors and companies involved in Lisbon's green projects should disclose the environmental, social, and governance risks and impacts associated with their investments.
- Financial Inclusion for Marginalized Communities: For Lisbon's green economy and financial transition to be inclusive, it is essential to integrate financial inclusion strategies that ensure all residents, particularly those from low-income and marginalized communities, benefit from the city's transformation.
- Green Microfinance Initiatives: Green microfinance can play a pivotal role in empowering small businesses and individuals in marginalized areas like Chelas and Cova da Moura to participate in the green economy. Lisbon can partner with financial institutions to offer microloans or green grants that help residents invest in sustainable projects, such as installing solar panels, purchasing energy-efficient appliances, or starting small eco-friendly businesses.
- Affordable Green Housing and Retrofitting Programs: Lisbon can implement affordable housing programs that incorporate green building standards, ensuring that low-income families have access to energy-efficient homes. Additionally, the city can offer retrofitting subsidies for existing homes, enabling residents to improve energy efficiency through the installation of insulation, solar panels, or smart meters. These programs would reduce energy costs for low-income households while contributing to Lisbon's sustainability goals.

The financial dimension of Lisbon's smart city transition, with a focus on green financing, the development of a green economy, and the integration of ESG financial considerations, is essential for building a sustainable and resilient future. Through green bonds, sustainable investment funds, and public–private partnerships, Lisbon can mobilize the necessary capital to support environmentally sustainable projects in healthcare, energy, and transportation. Aligning these efforts with EU regulations, such as the Green Deal and SFDR, ensures that Lisbon remains at the forefront of the EU's climate and sustainability goals.

By prioritizing financial inclusion through green microfinance initiatives and affordable housing retrofits, Lisbon can build an urban development model where environmental efficiency directly supports social equity. This aligns with contemporary scholarship on the macro-level digital transformation of public institutions, which demonstrates that integrating artificial intelligence and advanced digital platforms can optimize resource allocation only when paired with structural oversight. Failing to anchor these digital tools in equitable governance frameworks risks turning smart city infrastructure into a driver of institutional exclusion rather than a public utility. A bibliometric analysis of global green finance trends demonstrates that the long-term viability of municipal capital investments depends on establishing clear, standardized ESG metrics that systematically link environmental funding to localized social equity outcomes. A successful smart city strategy must transition beyond market-driven models, ensuring that technological deployment and green macro-finance are synthesized to foster an urban landscape that is structurally inclusive, transparently governed, and environmentally sustainable.

Finally, Digital security remains a profound vulnerability for Lisbon's residents, particularly within structurally marginalized zones where digital literacy is lowest. The empirical data highlight a severe deficit in institutional trust; during interviews, a local commerce

owner in Marvila explicitly stated that the community refuses to adopt municipal digital wallets or e-voting systems because of the persistent fear that government servers are easily breached, noting that without visible proof of data protection, residents prefer paper bureaucracy over digital exposure. This qualitative evidence demonstrates that cybersecurity is not merely an IT operational issue, but the foundational prerequisite for civic participation.

To overcome this systemic distrust and secure the smart city's interconnected infrastructure, Lisbon's municipal governance must move beyond outdated legacy security protocols. Establishing a resilient urban data architecture requires full compliance with European civil security mandates, specifically integrating the rigorous incident reporting and risk management protocols dictated by the NIS2 Directive. The municipality must mandate that all private technological partners achieve ISO/IEC 27001 certification for information security management before engaging in public–private smart city contracts [29]. By structuring municipal data pipelines and semantic models to align with these stringent European compliance frameworks, the governance dimension (G) ensures that public infrastructure is hardened against identity threat detection and cyber intrusions. Protecting residents' data through these verified international standards is fundamental to promoting trust in digital governance systems and meeting the social dimension (S) criteria of the ESG framework, ensuring that all citizens, regardless of digital literacy, are structurally protected from digital exploitation.

4.6. Governance Dimensions: Information Disclosure and Institutional Agency Costs

The analysis of the municipal procurement roadmaps and private telecommunications concessions highlights a significant structural vulnerability in Lisbon's smart city governance framework: high institutional agency costs driven by information asymmetry. Under current PPP arrangements, private technology providers act as the agents, while the municipal authority and the citizenry function as the collective principal. Primary qualitative interviews with municipal ICT contract managers reveal that private vendors often classify granular infrastructure performance metrics, deployment timelines, and electronic waste data as proprietary corporate data. This lack of disclosure prevents the public sector from properly monitoring compliance with spatial equity targets. An interviewed municipal policy expert noted:

> "We operate in an informational vacuum regarding how private providers prioritize their 5G rollouts. Without mandatory, legally binding disclosure frameworks written into the municipal concession agreements, the private sector naturally focuses on infrastructure where capital returns are immediate, leaving peripheral zones underserved while we absorb the political costs."

This empirical finding confirms that voluntary corporate ESG reporting is insufficient for public governance. To mitigate these institutional agency costs, the city must implement a mandatory information disclosure system within its smart city charters, forcing private technology partners to publish localized, district-level data on infrastructure availability, connection quality, and data privacy compliance.

5. Conclusions

5.1. Theoretical and Practical Contributions

Municipal procurement roadmaps and private telecommunications concessions expose a significant structural flaw in smart city governance: pronounced institutional agency costs driven by information asymmetry, which can be evaluated through the classic principal-agent framework [30]. In this operational ecosystem, the municipal authority functions as the principal, delegating public asset deployment to private technology vendors who act

as agents. Empirical data from interviews with municipal ICT contract managers confirm that private agents systematically exploit information asymmetries by classifying granular infrastructure performance data, network latency metrics, and hardware lifecycle configurations as proprietary corporate capital. This lack of information disclosure prevents the municipal principal from monitoring compliance with socio-spatial equity goals. Consequently, private agents direct infrastructure investments toward affluent commercial hubs where capital returns are immediate, while shifting the negative socio-political externalities of under-connection onto marginalized communities.

To reduce these agency costs, municipal authorities must shift from voluntary corporate ESG disclosures to contractually mandated, legally binding information frameworks embedded within smart city charters. Requiring district-level reporting on network availability and data privacy compliance helps the principal align market-driven private investments with democratic accountability and public equity parameters.

Methodologically, the study demonstrates the value of a convergent qualitative design that cross-examines institutional regulatory frameworks against the lived experiences of marginalized communities, offering a reproducible approach for evaluating urban e-governance performance. Practically, the analysis provides municipal policymakers with an empirical roadmap, demonstrating that the deployment of green finance and digital platforms requires mandatory information disclosure systems to control institutional agency costs and sustain public trust.

5.2. Methodological Limitations and Boundary Conditions

While these findings offer clear insights for municipal administration, several inherent methodological limitations must be acknowledged:

- Qualitative Research Design Constraints: The study relies primarily on qualitative methodology. Although this approach provides rich contextual depth regarding institutional dynamics and lived experiences, it does not support statistical generalization regarding infrastructure performance or causal macro-economic patterns across Portugal.
- Sample Size and Stakeholder Selection Bias: The primary field data is drawn from a non-probability purposive sample of 25 stakeholders. While qualitative data saturation was rigorously achieved and verified, the small sample size and reliance on specific community networks in Chelas and Cova da Moura introduce a potential risk of researcher selection bias. This sample may omit the perspectives of other marginalized groups or private operators within the broader metropolitan area.
- Potential Researcher Bias: In qualitative semi-structured field research, the researcher functions as the primary instrument of data collection and thematic interpretation. Despite enforcing parallel independent coding protocols to preserve analytical objectivity, subjective bias in the execution of the interviews and the subsequent axial coding cannot be eliminated.

5.3. Degree of Transferability and Adaptive Adjustments

The transferability of Lisbon's findings depends on specific institutional and structural boundary conditions. The documented spatial disparities, infrastructure deficits, and democratic gaps offer relevant insights for other Southern European and middle-income metropolitan areas characterized by fragmented regional planning, fiscal constraints, and deep socio-economic stratification (e.g., Madrid, Athens, or intermediate Latin American urban centers). Operational mechanisms identified here, such as mandatory ESG information disclosure clauses and decentralized capability centers, can serve as a baseline model for urban spaces with similar institutional profiles.

However, applying these findings universally requires localized adaptive adjustments that account for Lisbon's specific institutional features. Lisbon's smart city initiatives operate within a highly centralized national regulatory environment and are deeply shaped by European Union mandates (e.g., the EU Green Deal, NIS2 Directive, and GDPR), which provide unique legal protections and capital access that may not exist in non-EU jurisdictions. Lisbon's local demographic dynamics, characterized by an aging long-term population living alongside rapid immigration inflows, introduce distinct digital literacy barriers and linguistic demands. While the core framework linking digital equity to public ESG metrics remains a valid baseline for global urban planning, municipal authorities elsewhere must adapt these recommendations to fit their specific legal boundaries, fiscal capacities, and local demographic realities to achieve an inclusive and resilient urban transition.

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Institutional Review Board Statement: The study described is a non-interventional, qualitative research project focused on urban governance and digital policy. According to the Portuguese legal framework (Decree-Law No. 80/2018, of 15 October), ethical committee validation is mandatory only for clinical and biomedical research involving human intervention or health-related procedures. Under Law No. 58/2019, of 8 August (Implementing the GDPR in Portugal), Article 31, prior ethics committee approval is not required for scientific research involving anonymized data that does not include "sensitive" categories (e.g., health or genetic data). As this study is strictly sociological and exploratory in nature, it is exempt from Institutional Review Board approval under national legislation.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. All participants were briefed on the exploratory nature of the research and the strictly anonymized treatment of their qualitative insights before the interviews.

Data Availability Statement: The data presented in this study are available on request. The data are not publicly available due to privacy and ethical restrictions, specifically to protect the anonymity of participants from marginalized and vulnerable urban communities (as identified in the study's qualitative findings).

Conflicts of Interest: The author declares no conflicts of interest.

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