

Toward Santos 5.0: An Integrated Smart City Governance Framework for a Brazilian Port City

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Abstract—This paper presents an IEEE-style case study of the municipality of Santos, Brazil, from the perspective of smart-city governance. The article addresses the central research problem identified in the original diagnostic study: Santos already has relevant smart-city assets, but these assets remain institutionally and technologically fragmented. To strengthen methodological rigor, the revised study explicitly distinguishes its primary documentary corpus from theoretical and benchmark references, applies an IESE-inspired nine-axis analytical matrix, and triangulates findings through international references such as Barcelona, Singapore, and Venice. The diagnosis confirms that the main bottleneck is not the absence of innovation projects, but the lack of an integrating governance architecture capable of connecting data, policies, investments, and citizen participation. In response, the paper proposes the Santos 5.0 framework, centered on a Municipal Data Platform, the evolution of the Operations Control Center into a predictive intelligence hub, digital citizen participation, climate resilience, mobility integration, and a blue-economy innovation agenda. The article contributes a structured governance framework and an implementation roadmap for transforming Santos from a city with isolated smart initiatives into an integrated, sustainable, and human-centered smart city.

Keywords—Smart cities, urban governance, digital transformation, urban mobility, climate resilience, Santos 5.0, IESE Cities in Motion.

Table I. Acronyms and terms used in the article

Acronym / term	Meaning in this article
CCO	Operations Control Center, the municipal structure that integrates traffic, public safety, emergency, and civil-defense operations.
ICT	Information and communication technologies.
IESE	Business school responsible for the Cities in Motion framework used here as a multidimensional analytical reference.
LED	Light-emitting diode technology, associated with public-lighting modernization and telemanagement.
PDR	Direct Participation in Results Program, a municipal performance-management instrument cited in the Santos diagnosis.
PMDS	Municipal Digital Strategy / digital-service modernization agenda, as referenced in the source study.
SDG	Sustainable Development Goal.
VLT	Light rail transit system used in the Baixada Santista metropolitan mobility network.
Santos 5.0	The proposed human-centered, data-driven, and integrated governance framework for Santos approaching its 500th anniversary in 2046.

I. INTRODUCTION

A smart city should not be understood only as a technologically connected urban system. In contemporary urban studies, smartness is increasingly associated with the capacity of a city to learn, coordinate institutions, use data ethically, and respond to complex social, environmental, and economic challenges. Therefore, the intelligence of a city depends on the integration of mobility, environment, energy, education, health, public safety, digital inclusion, climate resilience, and economic development into a coherent governance model [1], [3], [4].

In Brazil, the consolidation of this paradigm is still limited by fragmented public policies, sectoral information silos, weak interoperability, and difficulties in transforming planning instruments into integrated implementation. Santos, in the state of Sao Paulo, is an especially relevant case because it combines strong strategic assets with complex urban pressures. The municipality hosts a major port complex, concentrates most of its population and services in a dense insular area, and faces recurring tensions related to freight mobility, tourism, environmental vulnerability, and territorial inequality [6]-[11].

The original diagnosis shows that Santos already possesses significant assets for a smart-city transition, including the Operations Control Center (CCO), public Wi-Fi expansion, digital-service modernization, LED public-lighting modernization, regional mobility infrastructure, a Technology Park, climate planning instruments, and a

relevant cultural and tourism base [6]-[12]. However, these initiatives are not yet fully articulated through a single institutional, technological, and participatory architecture.

This paper argues that the main challenge for Santos is no longer the absence of smart initiatives, but the absence of systemic governance capable of integrating them. The article makes four contributions. First, it clarifies the documentary corpus and the analytical method used in the diagnosis. Second, it maps Santos through a nine-axis matrix inspired by the IESE Cities in Motion framework. Third, it develops the comparison with international references as a source of lessons rather than as a superficial citation. Fourth, it expands the Santos 5.0 framework into an implementation-oriented governance model with indicators, milestones, and institutional implications.

II. CONCEPTUAL AND ANALYTICAL FRAMEWORK

A classic definition of smart cities emphasizes that investments in human and social capital, together with traditional and modern communication infrastructure, should promote sustainable economic development and quality of life through participatory resource management [1]. This definition is important because it avoids a reductionist view in which smart cities are treated as collections of sensors, platforms, cameras, or applications. Technology is necessary, but it generates public value only when connected to planning, institutional coordination, and citizen needs.

The IESE Cities in Motion framework reinforces this multidimensional perspective by assessing cities through interdependent dimensions such as human capital, social cohesion, economy, governance, public management, urban planning, technology, environment, mobility, and international projection [2], [16]. Because the purpose of the present article is not to reproduce the full IESE ranking methodology, but to use it as an analytical reference for a municipal case study, the diagnosis organizes the evidence into nine adapted axes: governance and public management; human capital and social cohesion; economy and blue economy; urban planning and housing; environment and climate resilience; mobility and logistics; technology and digital infrastructure; energy and municipal services; and international projection, culture, and tourism.

For coastal and port cities such as Santos, the smart-city agenda is inseparable from sustainability and climate adaptation. Agenda 2030 and the urban sustainability literature emphasize the need to combine environmental protection, infrastructure efficiency, social inclusion, and resilient planning, especially in cities exposed to flooding, sea-level rise, port externalities, and tourism pressure [4]. Mobility is also central because freight circulation, metropolitan commuting, and tourist flows compete for limited urban space [5], [8].

A second conceptual pillar is collaborative and data-driven governance. Komninos argues that urban intelligence is strengthened by interaction among government,

academia, civil society, and the private sector [3]. Chourabi et al. similarly show that smart-city success depends on governance arrangements that connect institutions, technological infrastructures, public participation, and strategic management [14]. In the Santos case, this means that governance design, rather than technological acquisition alone, is the decisive factor in moving from isolated projects to an integrated smart-city model.

III. METHOD

This article adopts a qualitative, exploratory, and descriptive case-study design based on documentary analysis and international benchmarking. The methodological revision was made to resolve a limitation identified during review: the previous version referred to a restricted documentary corpus but subsequently cited other sources throughout the analysis. The revised version explicitly separates primary empirical documents from theoretical and benchmark references.

The primary documentary corpus comprises official municipal, regional, sectoral, and infrastructure documents directly related to Santos and the Baixada Santista [6]-[12]. These documents are used as the empirical basis for the diagnosis. Theoretical and comparative references [1]-[5], [14]-[16] are used to frame the analysis conceptually, define smart-city maturity criteria, and support international comparison. This separation avoids treating conceptual literature as empirical evidence about Santos.

Table II. Documentary corpus and analytical role

Source group	Main analytical role	References
Municipal planning and urban development	Identifies territorial organization, urban-planning challenges, governance instruments, and long-term development priorities.	[6]
Climate and environmental planning	Supports diagnosis of flooding exposure, climate risks, sanitation priorities, waste management, and resilience actions.	[7], [9]
Regional mobility and logistics	Supports analysis of metropolitan transport, port-city conflict, VLT integration, freight circulation, and active-mobility needs.	[8]
Digital infrastructure and smart-city policy	Supports analysis of connectivity, interoperability, digital services, municipal platforms, and data-governance challenges.	[10], [12]
Port and economic sustainability	Supports analysis of port externalities, economic specialization, blue economy opportunities, and Port-Tech integration.	[11], [12]
Conceptual and comparative literature	Defines smart-city maturity, IESE-inspired dimensions, governance criteria, and benchmark lessons. It is not treated as empirical evidence about Santos.	[1]-[5], [14]-[16]

The analytical protocol followed five steps. First, the documents were screened for evidence related to urban governance, digital infrastructure, mobility, environmental resilience, energy, housing, health, education, economic development, and culture. Second, the evidence was coded according to the nine IESE-inspired axes. Third, findings were triangulated by checking whether each relevant claim was connected to at least one empirical document and to one analytical axis. Fourth, international references were

used to identify comparable governance lessons. Fifth, the Santos 5.0 framework was formulated as a response to the diagnosis rather than as an isolated list of projects.

Figure 1 summarizes the revised research design. The validation logic is based on traceability: each diagnostic statement must be connected to the documentary corpus, each comparison must be linked to a benchmark lesson, and each proposed action must respond to an identified bottleneck.

Research design and validation logic

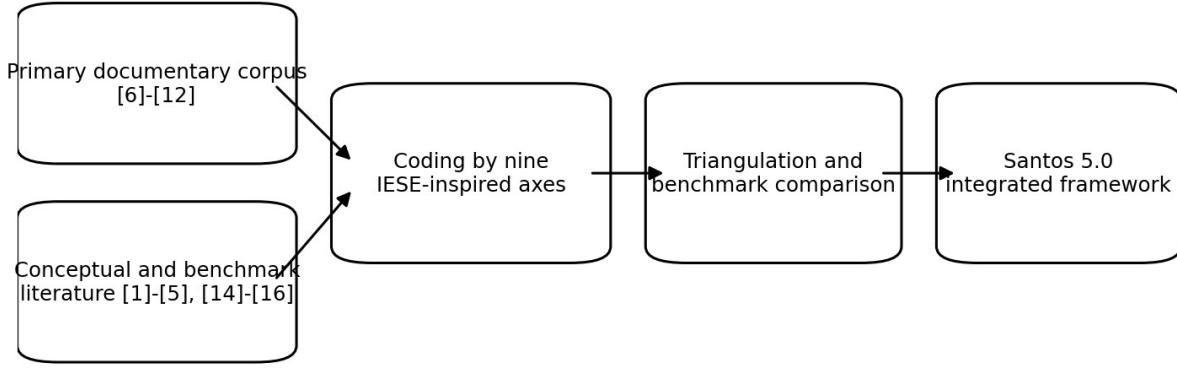


Fig. 1. Research design and validation logic used in the revised study.

IV. DIAGNOSTIC FINDINGS: NINE-AXIS MATRIX

Santos is analyzed here not as a city without innovation, but as a city with multiple innovation assets that require

greater integration. The diagnostic matrix below consolidates the main findings across the nine adapted axes, links each axis to evidence from the corpus, and identifies the strategic implication for Santos 5.0.

Table III. IESE-inspired nine-axis diagnostic matrix for Santos

Axis	Evidence from Santos	Benchmark lesson	Implication for Santos 5.0
Governance and public management	PDR and CCO show institutional capacity, but targets, data, and decision routines remain dispersed among secretariats [6], [12].	Smart-city maturity depends on coordinated governance rather than isolated projects [14].	Create a central digital-governance authority and a shared data architecture.
Human capital and social cohesion	High human-development profile coexists with territorial inequality, aging population, and vulnerable areas such as Dique da Vila Gilda [6], [7], [9].	Smart cities must combine technology with inclusion and quality of life [1].	Prioritize accessibility, digital inclusion, health access, and integrated social indicators.
Economy and blue economy	The port, tourism, services, and Technology Park are strong assets but remain insufficiently connected [11], [12].	Innovation districts become more effective when linked to productive specialization and knowledge ecosystems [3].	Develop a Port-Tech and blue-economy strategy connected to logistics, tourism, marine technologies, and climate innovation.
Urban planning and housing	The insular portion concentrates population and activities, increasing pressure on infrastructure and land use [6], [8].	Compact cities require integrated land-use, mobility, and environmental planning.	Connect the historic center, Valongo, complete streets, housing upgrading, and public-space regeneration.
Environment and climate resilience	Strong sanitation indicators coexist with localized deficits, flood exposure, drainage challenges, and low recycling performance [7], [9].	Coastal references show the importance of predictive risk management and nature-based adaptation.	Integrate rainfall, tide, drainage, civil-defense, and social-vulnerability data into predictive management.
Mobility and logistics	Port freight, tourism, commuting, and local traffic compete for limited urban space. VLT improved regional structure but multimodal integration remains incomplete [8], [11].	Successful smart mobility combines public transport, active mobility, freight regulation, and real-time data.	Implement integrated mobility management, nighttime freight strategies, micro-distribution hubs, and VLT/active-mobility connections.
Technology and digital infrastructure	Digital-service modernization, public Wi-Fi, and system modernization exist, but legacy platforms and interoperability gaps remain [10], [12].	Smart-city platforms should enable a unified citizen view and shared data standards.	Create a Municipal Data Platform connected to Santos Digital and cross-secretariat dashboards.
Energy and municipal services	LED modernization and telemanagement pilots indicate progress, but energy governance is not yet fully integrated with broader urban management [6], [12].	Smart municipal services benefit from energy efficiency, monitoring, and lifecycle cost control.	Adopt full LED telemanagement, energy dashboards, and solar generation pilots in municipal assets.
International projection, culture, and tourism	Santos has strong heritage, tourism, and port identity, but needs stronger integration between tourism, mobility, culture, and the historic center [6], [13].	International projection increases when culture, mobility, waterfronts, and digital services are combined.	Use Valongo and the historic center as a smart gateway connecting tourism, culture, VLT, and digital experience.

The matrix shows that the central weakness is systemic rather than sectoral. Santos has relevant instruments in almost every dimension, but the instruments remain only partially connected. The PDR can support performance management, the CCO can coordinate operations, Santos Digital can expand services, the Technology Park can stimulate innovation, and the VLT can structure metropolitan mobility. However, without a shared data architecture and a central governance mandate, these assets tend to remain distributed across institutional silos.

The same conclusion appears in the environmental and mobility axes. Flooding, drainage, tide behavior, traffic congestion, emergency response, port logistics, and social vulnerability are not separate urban problems. They are interconnected events that require integrated monitoring and

predictive action. A reactive command-center model is therefore insufficient for the next stage of smart-city maturity.

The diagnosis also shows that Santos can transform structural pressures into strategic opportunities. The port-city conflict can become a platform for smart logistics and blue-economy innovation. The historic center and Valongo can become a mobility, tourism, and heritage gateway. Vulnerable areas can become priority territories for climate resilience, sanitation, and social inclusion. These opportunities justify the Santos 5.0 proposal as an integrated framework rather than a list of technological interventions.

V. INTERNATIONAL BENCHMARKING

The revised article uses international references as analytical benchmarks, not as decorative citations. Barcelona, Singapore, and Venice were selected because each one offers lessons relevant to a specific Santos challenge. The comparison is qualitative and interpretive, focused on transferable governance principles rather than direct replication.

Barcelona is relevant for Santos because it demonstrates how digital governance, urban planning, mobility, public space, and citizen services can be connected in a recognizable urban strategy. The lesson for Santos is that a smart-city identity becomes stronger when digital tools are linked to territorial projects, neighborhood regeneration, open services, and citizen participation.

Singapore is relevant because it illustrates the value of centralized coordination, data-driven public management, and predictive urban systems. The lesson for Santos is not to copy a centralized city-state model, but to recognize that complex infrastructure systems require standards, data-sharing rules, integrated dashboards, and clear executive responsibility.

Venice is relevant because it is a coastal heritage city exposed to tourism pressure, climate risk, and infrastructure vulnerability. The lesson for Santos is that resilience, tourism management, heritage preservation, and mobility must be treated as connected agendas, especially in a city where port activities, beaches, cultural assets, and flood exposure coexist in a limited territory.

These benchmarks reinforce the same conclusion: smart-city maturity depends less on the number of digital projects and more on the quality of coordination among data, institutions, territory, and citizens. For Santos, the benchmark analysis supports three strategic choices: a municipal data platform, the predictive evolution of the CCO, and an integrated territorial strategy connecting climate resilience, mobility, tourism, and the blue economy.

VI. SANTOS 5.0 FRAMEWORK

Santos 5.0 is proposed as a human-centered and data-driven governance framework. The term 5.0 is used here to indicate a transition from isolated digital projects to an integrated model in which technology supports inclusion, sustainability, resilience, and quality of life. The framework is organized around a central idea: Santos needs an institutional operating system for urban transformation.

Santos 5.0 as an integrated operating system for urban transformation

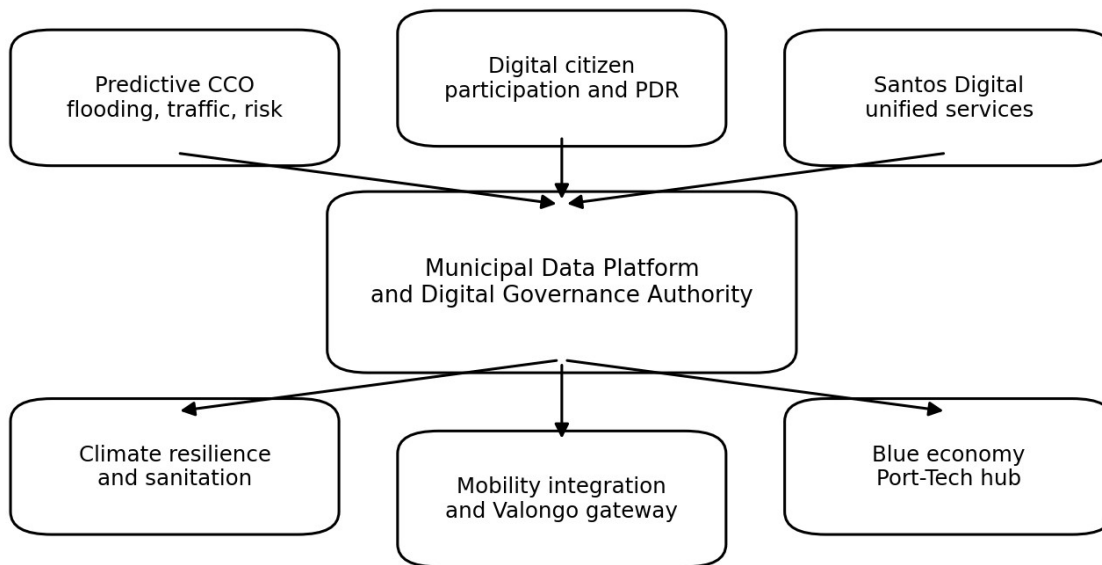


Fig. 2. Santos 5.0 integrated governance framework.

The first pillar is a Municipal Data Platform. This platform should integrate information flows from different secretariats and connect them to Santos Digital through a unified service layer. It should also support data standards, privacy requirements, interoperability, open-data routines, and executive dashboards. The percentage of municipal services accessible through a single digital interface can be used as an initial implementation indicator.

The second pillar is the evolution of the CCO from a reactive operations center into a predictive urban-intelligence hub. In practical terms, this means combining tide, rainfall, drainage, traffic, civil-defense, health, and social-vulnerability data to anticipate flooding, congestion, emergency demand, and other critical urban events. The

objective is to move from recording disruptions to preventing or mitigating them before they become severe.

The third pillar is digital citizen participation. The PDR should be modernized so that goals and indicators are not only internally defined, but also debated through digital participation channels connected to the city service ecosystem. This creates a feedback loop between municipal planning, service quality, and citizen perception.

The fourth pillar connects digital governance to territorial transformation. The framework prioritizes climate resilience in vulnerable areas, mobility integration in the central macrozone, and the redevelopment of Valongo as a gateway that links tourism, heritage, VLT, active mobility, and low-emission transport. In this sense, Santos 5.0 is not a

purely technological agenda. It is a territorial development strategy supported by digital governance.

The fifth pillar is economic specialization through the blue economy. The Technology Park should be more

directly connected to the port, tourism, universities, startups, and environmental innovation. This connection can support applied solutions in logistics optimization, marine robotics, coastal monitoring, clean energy, visitor experience, and climate adaptation.

Table IV. Santos 5.0 implementation roadmap and monitoring indicators

Horizon	Priority actions	Expected result	Possible indicators
Short term	Formalize digital-governance authority; define data standards; map systems; launch first phase of Municipal Data Platform; integrate priority services into Santos Digital.	Institutional mandate and minimum interoperability layer established.	Number of integrated systems; percentage of services in unified interface; number of shared dashboards; citizen satisfaction with digital services.
Short term	Prioritize climate and sanitation actions in vulnerable territories such as Dique da Vila Gilda; connect civil-defense records to georeferenced risk data.	Risk areas become visible in municipal decision routines.	Households served by integrated sanitation; risk-area mapping coverage; response time for alerts.
Medium term	Upgrade CCO with predictive analytics using tide, rainfall, drainage, mobility, and emergency data; integrate public-lighting telemanagement and urban-service monitoring.	CCO evolves from operational response to predictive intelligence.	Number of predictive models in use; alert accuracy; reduction in response time; LED telemanagement coverage.
Medium term	Create mobility integration projects around VLT stations, active mobility, complete streets, and urban freight management.	Reduced conflict between local mobility, tourism, and port logistics.	Integrated stations; bicycle and pedestrian connections; freight-window compliance; congestion indicators.
Long term	Consolidate Valongo as a tourist, cultural, and mobility gateway; connect Technology Park to port, tourism, and blue-economy innovation.	Historic-center regeneration becomes connected to economic specialization.	Startups and projects connected to Port-Tech; visitors using integrated digital services; private and public investment mobilized.
Long term	Institutionalize participatory monitoring of Santos 5.0 and align indicators with ISO 37122 and SDG-related metrics.	Long-term governance becomes measurable, transparent, and citizen-oriented.	Published indicators; public participation rates; annual progress reports; alignment with smart-city standards.

VII. DISCUSSION

The revised analysis strengthens the original argument by demonstrating that the diagnosis is not based on impressionistic observation. It is structured through a defined corpus, an analytical matrix, and benchmark-based interpretation. This is important because Santos already has many visible initiatives that could lead to a superficial conclusion that the city is already fully smart. The nine-axis matrix shows a more precise result: the city is advanced in assets, but incomplete in integration.

The governance implication is that Santos should avoid a project-by-project smart-city strategy. Isolated acquisition of platforms, sensors, applications, or infrastructure tends to reproduce the same fragmentation that the diagnosis identifies. The priority should be institutional architecture: who defines standards, who manages interoperability, who validates data quality, who coordinates cross-secretariat projects, and who reports results to citizens.

The territorial implication is that smart-city governance must be connected to real urban problems. In Santos, the most strategic problems are not abstract. They include flood exposure, drainage, sanitation gaps, port-city mobility conflict, aging population, tourism pressure, historic-center regeneration, and the economic transition toward port-related innovation. Santos 5.0 becomes relevant precisely because it links these challenges to a shared operating model.

The comparative implication is that international references are useful only when translated into local governance capacities. Barcelona contributes lessons on digital participation and territorial projects; Singapore contributes lessons on data coordination and predictive management; Venice contributes lessons on coastal resilience, tourism pressure, and heritage protection. Santos requires an adapted synthesis of these lessons rather than direct imitation.

VIII. CONCLUSION

This paper presented a revised and methodologically reinforced analysis of Santos as a smart-city case study. The findings indicate that the municipality has already moved beyond the stage of a city without innovation. Santos has relevant digital, operational, cultural, environmental, mobility, and economic assets. However, these assets remain fragmented across secretariats, systems, territories, and implementation routines.

The main conclusion is that Santos needs to treat governance integration as its primary smart-city project. The Municipal Data Platform, the predictive upgrade of the CCO, the modernization of digital participation, climate-resilience actions, mobility integration, and the blue-economy agenda should not be implemented as independent projects. They should be coordinated through a central governance architecture with authority, standards, indicators, and public accountability.

The Santos 5.0 framework contributes to this agenda by translating the diagnosis into an operating model for urban transformation. Its purpose is to support the transition from a city with smart projects to an integrated, sustainable, and human-centered smart city. The framework is especially relevant as Santos approaches its 500th anniversary in 2046, a symbolic horizon that can help align investments, institutional reforms, and public communication around a long-term vision.

The study has limitations. It is based on documentary analysis and qualitative benchmarking, and it does not include interviews, direct field observation, cost modeling, or statistical impact evaluation. Future research should deepen the implementation metrics, evaluate financing arrangements, test pilot projects, and compare Santos with other Brazilian port and coastal cities. Even with these limitations, the revised analysis shows that the strategic issue is clear: Santos 5.0 depends on the capacity to transform fragmented innovation into integrated governance.

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