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Not peer-reviewed version

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Posted Date: 4 February 2026

doi: 10.20944/preprints202602.0320.v1

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Article

A Planning Support System for Automated State of Territorial Planning Reports: The Portuguese Context

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Abstract

Territorial planning in Portugal requires the regular production of State of Territorial Planning Reports (Relatórios de Estado do Ordenamento do Território—REOT) to evaluate the implementation of planning instruments. However, these reports are traditionally produced manually as static documents, limiting their timeliness and effectiveness for decision-making. This study presents the development of an automated Planning Support System that enables the dynamic generation of REOT by integrating official spatial and statistical data. The system combines rule-based logic and artificial intelligence techniques to calculate and interpret territorial indicators, producing up-to-date reports on demand. A dashboard-based platform facilitates continuous monitoring of territorial conditions, supporting evidence-based decisions while maintaining institutional oversight and human validation. Application in the Portuguese context demonstrates that the system enhances consistency, transparency, and responsiveness in territorial planning. These results suggest a transition from episodic reporting to real-time, data-driven territorial monitoring, providing a scalable model for other national and regional planning contexts.

Keywords: planning support system; territorial monitoring; indicators; artificial intelligence

1. Introduction

Territorial planning constitutes a strategic tool for sustainable development, enabling the guidance of public policies, the management of resources, and the integrated planning of land use. In Portugal, the continuous evaluation of Territorial Public Policies (Políticas Públicas de Base Territorial—PPBT) is fundamental for understanding the effects of planning decisions and supporting decision-making at different territorial scales. In this context, the State of Territorial Planning Reports (Relatórios de Estado do Ordenamento do Território—REOT) play a central role, synthesizing the performance of territorial policies and their alignment with objectives defined in national, regional, and municipal plans [1].

Despite their relevance, REOTs are traditionally produced as static documents, prepared manually and episodically, without mechanisms for continuous updating. This limits their usefulness for monitoring and evaluation, as static reports quickly fail to reflect recent territorial changes and dynamics, resulting in rapid obsolescence. The slow update cycle of REOTs is one of the main reasons for their limited credibility and production, as reports are often outdated upon completion [2]. Integrating dynamic dashboards into territorial management, with real-time updates and interactive indicators, represents a solution capable of maintaining REOTs continuously up to date, supporting more consistent, transparent, and data-driven planning decisions.

State reports—REOTs—inevitably operate on public policies defined for the territory, which encompass initiatives and decisions established by the State to achieve collective objectives relevant to society. These policies materialize political intentions and confer upon the State the role of guardian and representative of social interests [3–5]. Within public policies, particularly those with territorial implications, policy formulation cannot be dissociated from monitoring and evaluation, which are essential stages in the policy lifecycle, including problem identification, agenda setting,

policy legitimation, implementation, monitoring, and evaluation [6–9]. Evaluation ensures that policies evolve in a balanced manner, allowing for maintenance, adaptation, or reformulation in response to social, economic, and territorial changes [10,11].

In the context of territorial public policies, monitoring and evaluation serve distinct but complementary purposes. Monitoring tracks the implementation of policies and provides evidence on progress and impacts, supporting evaluation. Evaluation assesses the effectiveness of a policy in terms of outcomes and impacts on the territory and society [12–14]. Monitoring focuses on processes and dynamics, while evaluation concentrates on results and adequacy relative to stated objectives. Together, these procedures promote institutional learning and continuous knowledge construction regarding public policy effects.

The need for monitoring and evaluation in land-use planning is particularly relevant in a globalized context, characterized by rapid transformations and increasing uncertainty [15]. Effective management requires continuous information on the state of the territory, enabling timely adjustments of policies and planning instruments [1]. In Portugal, the Territorial Management System (Sistema de Gestão Territorial Português—SGTP) and the Municipal Master Plan (Plano Diretor Municipal—PDM) constitute the main pillars of territorial governance. However, both the territory and the PDM lack regular monitoring and evaluation mechanisms, limiting the ability to adjust trajectories, assess deviations from planned development models, and produce consistent reports [16].

Evaluation practices must evolve alongside new tools, methods, institutional frameworks, paradigms, and theories, learning from past experiences, such as evaluations of structural and cohesion funds, which introduced more strategic and flexible approaches focused on outcomes. Methodological pluralism ensures that evaluation benefits from diverse sectors and experiences [10,17].

International organizations have increasingly consolidated roles in public policy evaluation, promoting harmonized and coordinated evaluation methodologies, indicators, and concepts [1,10]. Entities such as the European Commission, OECD, and UN stimulate intersectoral and comparable evaluation practices, reinforcing analytical consistency and mutual learning among countries [18]. In the EU context, harmonized evaluation linked to fund access has significantly expanded evaluation practices, particularly for measuring public policy implementation in a coordinated and intersectoral manner.

Intersectoral coordination is increasingly relevant due to the acceleration of social and territorial transformations, whose effects manifest rapidly and unpredictably [19]. Effective public policies rely on collaborative practices that promote cooperation, exchange, and information sharing in strategic decision-making processes [20], ensuring efficiency and effectiveness in policy definition and implementation. Internationally oriented evaluation, with unified strategies and partnership-based approaches, also contributes to territorial cohesion and sustainable development, fostering counterfactual analysis and institutionalization of evaluation processes [21–25].

Against this backdrop, this study reflects on the foundations for developing a Planning Support System for automated and dynamic generation of REOTs, capable of operationalizing the monitoring and evaluation of territorial public policies in Portugal. The system integrates official spatial and statistical data, artificial intelligence techniques, rule-based logic, and dynamic dashboards that update information in real time, enabling tracking of territorial dynamics, generation of updated reports, and provision of interpretable indicators on the state of the territory.

The specific objectives of the study are:

- a) To develop a methodological framework for the definition and automated calculation of territorial indicators relevant for monitoring territorial public policies;
- b) To reflect on the creation of a digital platform supporting the generation of dynamic REOTs, ensuring consistency, transparency, and continuous updating;
- c) To examine the applicability of the system in the Portuguese context, evaluating its benefits compared to traditional processes and promoting institutional learning and citizen participation.

By integrating monitoring, assessment, evaluation, international guidance, and dynamic dashboards into the lifecycle of territorial public policies, this study contributes to a model of territorial planning adapted to contemporary rhythms, featuring dynamic, adaptive, and evidence-based planning capable of responding to the volatility, complexity, and unpredictability of contemporary territories, thereby promoting more effective, efficient, and socially legitimized public policies.

2. Materials and Methods

2.1. Planning Support Systems (PSS)

Planning Support Systems (PSS) are computational platforms that integrate spatial, statistical, and planning data, offering tools for analysis, simulation, and visualization to support decision-making [26,27]. These systems enable scenario exploration, assessment of potential impacts, and real-time monitoring of territorial trends, transforming territorial planning and public policy formulation from a reactive and episodic process into a proactive, evidence-based process.

In Portugal, the adoption of PSS remains limited, despite its potential to overcome the limitations of traditional instruments such as REOTs, which are static and updated sporadically across local, regional, and national scales [3,28]. Dynamic dashboards provide a solution to this limitation, enabling real-time integration of data and generation of updated reports on demand. This approach supports territorial monitoring and evaluation based on indicators customized at the municipal level, while maintaining aggregation across higher scales [3].

The evaluation and monitoring of territorial public policies have evolved over the last two decades into systematic processes, based on territorial indicators [29,30]. These indicators allow measurement, comparison, and interpretation of spatial and social changes, providing an objective basis for assessing policy implementation and impacts [12]. Continuous monitoring is essential to ensure policies respond to changing territorial dynamics. Integrating dashboards and dynamic monitoring systems transforms episodic reports into continuous decision-support tools, improving production frequency, ease of preparation, and the utility of REOTs.

2.2. Territorialization of Public Policies

Land-use public policies have evolved from centralized, restrictive, and minimally evidence-based decisions to more dynamic, inclusive, transparent, and integrated processes [31]. Despite public participation, intersectoral collaboration, and territorial relevance, implementation challenges remain due to the diversity and specificity of territorial contexts [3,32,33].

Land-use public policies are instruments that evolve over time, with implementation assuming a central role in territorial management and strategy formulation [34]. Continuous evaluation and monitoring are fundamental to adapting policies to emerging challenges, ensuring effectiveness, efficiency, and territorial consistency [3]. Mechanisms for producing dynamic REOTs provide a competitive advantage compared to planning processes reliant on outdated information.

2.3. Evolution of Evaluation in Territorial Planning

Evaluation in land-use planning has consolidated as an institutional culture, emphasizing counterfactual impact analysis and routine institutionalization [35–37]. This evolution parallels the shift from object-centered logic, focused on compliance with legal frameworks, to evaluation of implementation processes, emphasizing territorial dynamics, learning, and continuous improvement [9,12,38].

Sectoral evaluations oriented toward specific objectives and components of implementation have increased the number of evaluation exercises, requiring specialized technical skills and structured professional communities [3,13]. In Portugal, such communities are not yet widespread, particularly at the local level [3]. Current evaluation practices occur at different stages of the plan

lifecycle (ex-ante, on-going, interim, ex-post), each with specific functions, including optimization, comparison, characterization, feasibility, assessment, interpretation, and calculation of added value [39,40]. However, no uniformity exists regarding rules, procedures, or indicators [3]. Consequently, state report production often focuses on available information rather than required or desired information.

Integrating dynamic dashboards and automated systems harmonized at the national level is essential to continuously track territorial public policy implementation and support adaptive, evidence-based decision-making.

2.4. European and International Influence on Evaluation and Territorial Planning

Harmonization and compatibility in evaluation procedures are increasingly promoted by the European Union and other international organizations, fostering territorial comparisons, interterritorial learning, and methodological dissemination [5,41,42].

While territorial planning remains a national competence, the EU drives intersectoral and transnational coordination, promoting result-oriented policies with continuous monitoring and systematic evaluation. Programs such as ESPON provide comparative databases, facilitate experience exchange, and strengthen evaluation culture, enabling Member States to develop adaptive, coherent, and effective territorial public policies [5,43].

Harmonization ensures knowledge transferability and data compatibility without imposing standardization. This Europeanization of territorial planning emphasizes coordination and articulation while respecting local specificities and promoting territorial cohesion [3]. Dynamic evaluation systems supported by dashboards and interconnected indicators are central to this process.

2.5. Artificial Intelligence and Intelligent Automation

Artificial intelligence (AI) platforms transform structured, rule-based workflows, enabling automation of indicator calculations, report generation, and territorial analysis [26,44,45]. The next frontier involves managing agentic processes, characterized by complexity, uncertainty, and the need for contextual adaptation. In these processes, agents—human or artificial—act intentionally, autonomously, and goal-oriented, making decisions, executing actions, and adjusting behavior based on feedback.

Integrating PSS, dynamic dashboards, territorial indicators, and advanced AI is expected to: a) Overcome the static nature of REOTs; b) Automate indicator calculation and interpretation; c) Integrate official real-time data; d) Incorporate international and European best practices; e) Support multi-scalar, intersectoral, and adaptive decision-making; f) Consolidate evaluation as a continuous institutional culture; g) Enable management of complex, agentic processes through intelligent automation.

This approach fills existing gaps, aligns with international monitoring and evaluation standards, and promotes a transition from a static, episodic model to a dynamic, continuous, and adaptive process in territorial planning.

3. Institutional Context in Portugal

3.1. The Role of the State of Territorial Planning Report (REOT)

The State of Territorial Planning Report (Relatório de Estado do Ordenamento do Território—REOT) plays a strategic role in monitoring territorial development in Portugal [3]. At the local level, the REOT is mandatory and must be prepared biennially by municipalities, functioning as the output of an integrated process of continuous territorial planning monitoring [46].

The local REOT allows for ongoing understanding of territorial dynamics, evaluating the responses of public policies and identifying unforeseen changes that may require adjustments to

municipal development strategies. The preparation of the REOT, along with the information, indicators, and conclusions it produces, underpins the need to review territorial management instruments, particularly the Municipal Master Plan (Plano Diretor Municipal—PDM), enabling implemented public policies to be adapted based on concrete and up-to-date evidence [47].

In this context, the local REOT represents a fundamental stage in the public policy cycle: defining policies, implementing them, monitoring their effects, continuously evaluating, and, when necessary, correcting or improving policies and strategies. Therefore, its production should not be viewed as a sporadic exercise but as part of a continuous, dynamic (on-going) evaluation process, integrating monitoring and feedback into decision-making [48,49].

The REOT provides a chronologically organized view of territorial progress at the municipal scale, comparing local outcomes with national, regional, and local targets, and assessing whether policies and strategies need adjustment when results fall short of expectations or when higher-level directives change [47]. This function reinforces its strategic position within the Portuguese territorial management system, consolidating the REOT as an essential tool for flexible, responsive, and adaptive planning practices [3,49].

3.2. Monitoring Territorial Dynamics and the Flexibility of the PDM

Contemporary urban and territorial planning emphasizes the flexibility and responsiveness of public policies to changes in territorial contexts during implementation [50]. As Batista & Silva highlight, the territory possesses its own dynamics that are distinct from the planning process and plans [51]. In analyzing plan implementation, analysts must avoid conflating the plan with the territory, recognizing that both are interdependent.

From this perspective, the PDM assumes even greater prominence, both as a plan and as an object of analysis and evaluation, particularly due to its dual reactive and proactive nature. It should be continuously updated in response to new policies, legal instruments, and observed territorial changes, maintaining alignment with strategic objectives [52]. In Portugal, the lack of flexibility in first-generation PDMs proved detrimental, limiting adaptation to development opportunities and compromising coordination with other public policies [53,54]. This issue persisted in second-generation PDMs [3] and appears unresolved in third-generation plans currently under development.

Monitoring territorial dynamics is essential to ensure that the PDM fulfills its function as an adaptive policy instrument. This process involves continuous observation of the territory's state, transformations, and agent interactions, allowing the evaluation of public policy responses and timely adjustments to development strategies [55–57].

Beyond recording the current reality, monitoring enables the construction of historical databases in the form of Territorial Information Systems (Sistemas de Informação Territorial—SIT), ensuring continuity, consistency, and harmonization of territorial evidence [58–60]. Continuous tracking allows for identifying gaps, evaluating PDM performance, and adjusting intervention measures, preventing deviations and inconsistencies in territorial development [3].

Continuous monitoring becomes even more critical in situations of informal urban growth (AUGI) or unplanned development areas, which can compromise the coherence of municipal strategies and require careful observation [61–63]. In this context, the PDM functions as a strategic-operational instrument close to the population, fostering civic contributions to decision-making and increasing public acceptance of interventions [64,65].

3.3. Lack of a Methodological Basis for REOT Production

Although foreseen in the Portuguese Territorial Management System since its inception, the REOT still lacks a structured methodological basis to guide its production in a harmonized and systematic manner.

Current Portuguese experiences reveal a lack of clear guidelines on data collection, processing, and dissemination, leading to case-by-case methodological definitions. These methodologies are

heterogeneous, hindering interoperability between evaluations and indicators. From a pragmatic perspective, the production of state reports in Portugal is largely a legal compliance exercise, without a focus on continuous improvement of territorial planning or public policies [13]. It is a pro forma procedure.

This methodological gap undermines the cascading territorial management system, as deficiencies in local REOTs affect production at regional and national levels. Creating a structured guiding framework is essential to ensure: a) Harmonization in the production of territorial indicators and evidence; b) Compatibility and data aggregation across municipalities, regions, and the national scale; c) Support for continuous evaluation and decision-making at all levels; and d) Strengthening the REOT's role as an active and legitimizing actor in the planning process.

3.4. Modernization and Intelligent Automation

In this context of strengthening the evaluation process and REOT production, the integration of intelligent automation platforms supported by artificial intelligence (AI) presents an opportunity to overcome institutional and methodological challenges. This approach enables, in particular, the processing and integration of large volumes of territorial data and the systematic, frequent, and consistent production of evaluation reports [26,44,45].

Thus, the REOT would evolve from a periodic report into a dynamic, adaptive, and predictive instrument, aligning with the flexibility required of the PDM and the need for on-going monitoring and evaluation, ensuring that public policies are continuously adjusted as the territory evolves.

3. Planning Support System

3.4. Conceptual Architecture of the Planning Support System

The development of a Planning Support System (PSS) must be based on a modular, integrated, and technologically advanced architecture that enables continuous territorial monitoring, automatic calculation of relevant indicators, and dynamic generation of the State of Territorial Planning Reports (REOT). This type of system architecture follows European trends in the application of AI in urban and territorial management, as demonstrated in EU-supported smart city projects aimed at improving urban flows and territorial performance through the integration of AI and open data.

The architecture of a PSS is organized into three layers:

- a) Data Layer – Integrates official and territorialized data, statistical and administrative information (INE, cadastres, cartographies) with public open data and real-time data from urban and mobility sensors. This layer ensures interoperability and compatibility between systems, building dynamic Territorial Information Systems (SIT) that record the temporal evolution of territorial phenomena.
- b) Processing & Analytics Layer – Processes data through methodologically defined territorial evaluation rules and logic. It applies artificial intelligence (AI) to recognize patterns, predict territorial dynamics, and identify discrepancies between policy implementation and observed results. It incorporates Intelligent Automation techniques that go beyond simple tasks, integrating agentic capabilities for managing complex processes and automatic adaptation to new contexts—aligned with smart city approaches that use AI to improve urban flows and territorial operations.
- c) Presentation Layer – Consists of interactive and cross-sectoral dashboards that display the main territorial indicators, thematic maps, comparative analyses, and trends in near real time. Spatial and temporal visualization tools facilitate the understanding of policy impacts and support decision-makers and stakeholders. The automated generation of REOT includes interpretative text, charts, maps, and conclusions aligned with monitored evidence (for example, PowerBI).

3.4. Definition and Operationalization of Territorial Indicators

Territorial indicators are the central element of monitoring. The selection of indicators is based on criteria of political relevance, data availability, and their capacity to continuously reflect the state and dynamics of the territory in relation to public policy objectives.

- a) These indicators are designed to capture, for example:
- b) Demographic and socio-economic evolution (density, income, employment);
- c) Changes in land use and urban occupation;
- d) Mobility and accessibility (including public transport data, traffic, and urban flows);
- e) Environmental indicators (air quality, resource consumption, green area coverage);
- f) Infrastructure and public services (access and capacity);
- g) Deviations and inconsistencies between the plan (PDM or other instruments) and observed territorial transformations.

These indicators must be automatically updated based on inputs from data sources, allowing longitudinal and comparative analyses across periods, territories, and scales. The combination of AI with open data and urban sensors, as in smart city projects, demonstrates that such systems can reflect the territory's operation in real time, thereby enhancing the impact assessment and performance evaluation of policies.

4.3. Data Integration and Automation Workflow

All PSS require structuring their system architecture, which functions as the backbone for organizing the entire automated workflow. This structure is organized into six stages that ensure data integration, processing, and interpretation:

- a) Data ingestion – Automatic extraction of official and open data sources, including sensors and urban platforms, followed by normalization and georeferencing.
- b) Preprocessing – Data validation, cleaning, and harmonization to ensure quality and reliability.
- c) Indicator calculation – Application of rules and models to derive territorial indicators from raw data.
- d) AI analysis – Employment of machine learning techniques and rule-based logic to detect trends, predict dynamics, and anticipate impacts.
- e) Dashboard and SIT updating – Continuous feeding of interactive dashboards and territorial information systems.
- f) Automated REOT production – Synthesis of structured results, conclusions, and recommendations.

This process enables the transformation of the REOT from a traditionally static document into a dynamic and proactive instrument, reflecting the actual evolution of the territory and supporting decision-making informed by current and predictive evidence.

4.4. AI Rules and Intelligent Automation

Automation within the system goes beyond structured tasks—such as metric calculation—by integrating agentic capabilities that allow responses to complex and dynamic situations. This aligns with emerging trends in smart cities, where artificial intelligence is employed to manage complex urban flows, optimize operations, and support real-time decision-making.

- a) Essentially, automating the entire monitoring process that underpins REOT production allows the system's logic to combine:
- b) Transparent rules defined by public policies and technical criteria;
- c) Predictive and descriptive AI to identify emerging patterns, forecast trends, and interpret complex relationships among territorial variables;
- d) Intelligent Automation, which structures and orchestrates the workflow for continuous execution of repetitive or complex tasks, freeing technical resources for critical analysis.

4.5. Automated REOT Production

With system automation, the REOT ceases to be manually prepared and is instead automatically generated. It shifts from being a task to becoming an output. For this to be possible, automated REOT generation must follow a consistent and repeatable process:

- a) Preparation of data and indicators for the reporting period;
- b) Automatic analysis of trends, deviations, and warning signals;
- c) Interpretative synthesis combining quantitative and qualitative analyses;
- d) Construction of the final report, including analytical text, tables, maps, and recommendations;
- e) Export in interoperable formats, such as PDF and web interfaces.

In this way, the REOT evolves from a biennially produced, isolated document into a continuous product of the public policy cycle: policies are defined, implemented, monitored in real time, evaluated on an ongoing basis, and adapted as necessary, based on evidence generated by the methodology.

5. Implementation of a Planning Support System

5.1. Dashboard-Based Platform

. The Planning Support System should be implemented as a support tool within an interactive web platform, based on dashboards with user-friendly interaction and an appealing interface (e.g., PowerBI), enabling continuous access to territorial information and the dynamic generation of REOT. The dashboards should be designed to visualize, analyze, and interpret territorial data intuitively, allowing different users—decision-makers, planning professionals, and interested public—to interact with the indicators and obtain strategic insights.

These dashboards must incorporate summarization capabilities, since information overload can hinder evaluation, with the main functionalities including:

- a) Interactive visualization of spatial and temporal indicators through maps, charts, and dynamic tables;
- b) Customizable filters allowing segmentation by municipality, region, time period, and category of public policy;
- c) Automatic alerts regarding deviations or trends that indicate the need for policy or territorial management instrument review;
- d) Report export, integrating the automatic production of REOT.

A platform with these characteristics would embed the logic of continuous monitoring (ongoing) rather than episodic evaluations, enabling near real-time updates and aligning with trends observed in smart cities, where AI integrates open data, urban sensors, and information systems to optimize urban flows and territorial management

5.2. Data Sources Used

Since a Planning Support System operates with confidential information, whose access and use must be subject to security restrictions, the same security concerns must be applied to the platform's data input. This entails limiting the data sources to official and public sources, including:

- a) Spatial data such as cadastral maps, land use, transport networks, and urban infrastructures;
- b) Statistical data including demographics, employment, socioeconomic, and environmental indicators;
- c) Real-time sensors and data such as urban mobility, air quality, energy consumption, and urban flows;
- d) Public policy data including information on municipal, regional, and national plans, as well as program and project execution;

- e) Historical data capturing the evolution of indicators over time, allowing for comparative and longitudinal analyses.
- f) Relying solely on secure sources ensures that the data are appropriate for analysis, enhances the usefulness of evaluations, and guarantees the reliability of the REOT. All data should be georeferenced and integrated into Territorial Information Systems (SIT), ensuring interoperability across scales and consistency in indicator production.

5.3. Methodological Principles for Monitoring and Evaluation

Monitoring and evaluation in territorial planning operate across three complementary levels: the plan itself, which involves the analysis of objectives and targets; plan compliance, which assesses the extent to which implementation aligns with the intended policies; and the real system, which monitors the territorial dynamics resulting from policy execution (Batista and Silva, 2002). At this latter level, effective monitoring requires a clear definition of objectives, timeframes, indicators, and responsibilities, ensuring that the information produced is actionable and supports future decision-making.

To ensure the effective implementation of a Planning Support System, seven methodological principles must be observed [3]. First, usefulness requires that information be oriented toward improving public policies, validating decisions, and understanding territorial responses to interventions [7,10]. Incrementality refers to the gradual development of the system, allowing it to evolve according to available resources and data, with indicators adjusted as new information becomes accessible (Batista and Silva, 2018). Regularity emphasizes continuous monitoring through periodic cycles of data collection and analysis, using consistent methods over time to enable chronological analyses and the identification of trends [3].

Articulation highlights the need for integration across sectors, levels of government, and stakeholders, promoting horizontal and vertical coordination to support more effective decision-making [37]. Harmonization involves the adoption of compatible indicators and methodologies across municipalities and spatial scales, facilitating reliable comparisons and data aggregation [17]. Selectivity and efficiency stress the importance of using a limited set of representative indicators to avoid information overload while ensuring operational feasibility (Batista and Silva, 2018). Finally, impartiality requires neutrality and transparency in the evaluation process, involving both internal and external actors to reduce bias and ensure credibility [43].

5.5. Application in the Portuguese Context

In Portugal, Municipal Master Plans (PDMs) constitute the primary instrument of local territorial planning, responsible for defining public policies, organizing land use, and guiding the sustainable development of municipalities. First-generation PDMs, developed mainly during the 1990s, were based on outdated growth projections and limited information. Subsequent monitoring revealed significant discrepancies between planning provisions and territorial reality, including the occupation of unplanned areas and difficulties in adapting to emerging territorial dynamics [10,24].

Second-generation PDMs introduced a more strategic and operational approach, providing greater flexibility and allowing for plan revisions. This evolution enables territorial management instruments to be adjusted on the basis of continuous monitoring of territorial dynamics [3]. Within this framework, the State of Spatial Planning Report (REOT) has become a mandatory instrument, produced by municipalities on a biennial basis, and currently serves as the main mechanism for the continuous evaluation of Municipal Master Plan implementation. The preparation of the REOT allows for the assessment of the effectiveness of implemented public policies, thereby providing a robust foundation for decisions regarding the need to revise the PDM.

To adequately fulfill this role, the REOT must integrate information on territorial history, recent dynamics, and emerging trends. This integration ensures continuous and permanent territorial monitoring, rather than sporadic or occasional evaluations, thereby strengthening its contribution to informed and adaptive planning processes [3,10,16,17].

5.6. Integration with Smart City Technologies

The coordinated use of open data, urban sensors, and artificial intelligence technologies enables the development of a more detailed, continuous, and proactive model of territorial monitoring. Municipal GIS platforms support advanced spatial analyses, systematic cross-referencing of information, and the harmonization of data from multiple institutional and sectoral sources. In this context, artificial intelligence and machine learning models enhance the detection of complex patterns and the anticipation of urban trends, moving beyond purely descriptive and reactive approaches. These capabilities are aligned with European smart city initiatives, particularly the objectives of Horizon Europe, which emphasize the strategic use of data to support adaptive public policies. This technological framework strengthens the management of urban flows, mobility, land use, and environmental sustainability by enabling faster and more informed responses to emerging changes and structural transformations. Consequently, a more efficient, flexible, and evidence-based model of territorial management is consolidated [3].

5.7. Evaluation of Indicators and the REOT

The biennial State of Spatial Planning Report (REOT) enables the identification of gaps in the implementation of public policies and the validation of the correspondence between expected outcomes and actual results. It also supports the proposal of adjustments to Territorial Management Instruments, including revisions of the Municipal Master Plan (PDM) when necessary. In addition, the REOT feeds dashboards with both historical and recent data, facilitating longitudinal analyses and the identification of trends over time. Taken together, these functionalities contribute to stronger evidence-based policy support by integrating information from different sectors and levels of governance. Example of Indicators (Table 1):

Table 1. This is a table. Tables should be placed in the main text near to the first time they are cited.

DIMENSION	INDICATOR	FREQUENCY	SOURCE
Land use	PERCENTAGE OF DEVELOPED AREA	ANNUAL	GIS (MUNICIPAL)
Population variation	POPULATION VARIATION	BIENNIAL	INE (NATIONAL STATISTICS)
Mobility	DAILY VEHICLE FLOW	CONTINUOUS	URBAN SENSORS
Sustainability	GREEN AREA PER CAPITA	BIENNIAL	GIS AND URBAN SENSORSa

*Notes: In Land Use: Use to comparison with planned Municipal Master Plan (PDM). Population variation: Use to identification of areas of growth or decline. Mobility: Use to adjustments in traffic and mobility planning. Sustainability: Use to assessment of compliance with environmental targets.

These indicators translate into tangible benefits and positive impacts, particularly by providing continuous feedback to public policies, enabling timely adjustment of plans, programs, and territorial management instruments. They also contribute to greater flexibility in the Municipal Master Plan (PDM), ensuring that planning instruments adapt to new realities and emerging territorial dynamics. At the same time, they enhance transparency and public participation through the integration of open data and the provision of accessible information. Their use further promotes evidence-based decision-making, guiding municipal and regional decisions based on objective indicators and the analysis of territorial trends. Finally, they facilitate national-level harmonization by aligning data and indicators across municipalities, enabling aggregation, comparability, and systematic monitoring.

6. Discussion, Conclusions, and Future Work

The implementation of continuous monitoring systems in tools such as the State of Territorial Planning Reports (REOT) and dashboards integrated into municipal geographic information systems (GIS) offers significant advantages for territorial planning. By enabling systematic tracking of territorial responses to public policies, it becomes possible to generate quantitative and qualitative information that supports real-time adjustments, promoting flexibility and adaptability of territorial management instruments such as the Municipal Master Plan (PDM).

This continuous monitoring transforms the PDM from a static instrument into a dynamic tool, capable of aligning development strategies with emerging territorial dynamics. Furthermore, the provision of harmonized and open data increases transparency, fosters citizen participation, and strengthens the legitimacy of public decisions.

6.1. Limitations and Challenges

The practical application of these systems faces several limitations. Technical, human, and financial capacities vary significantly across municipalities, which restricts the uniform implementation of monitoring and evaluation mechanisms. In addition, weak coordination between government levels and sectors compromises data aggregation and harmonization. Technological dependence also makes these systems vulnerable to inconsistencies and outdated information. Furthermore, the proliferation of indicators without clear selection criteria can lead to information overload, hindering the effective use of data in decision-making processes.

Institutional acceptance of monitoring and evaluation systems largely depends on political will and technical capacity. For monitoring to function effectively as a decision-support tool, both horizontal coordination among sectors and vertical coordination across different levels of government are essential, ensuring system interoperability and consistent data aggregation. In this context, the integration of artificial intelligence (AI) strengthens the approach by enabling the analysis of large volumes of data, the identification of complex patterns, and the generation of predictive scenarios. Nevertheless, final decision-making remains a human responsibility, taking into account local context, qualitative criteria, and strategic objectives. In this sense, AI acts as a catalyst, complementing—but not replacing—technical and political knowledge.

6.2. Scalability and Transferability

Scalability and transferability depend on technological infrastructure, data availability, and institutional capacity. Pilot projects implemented in different contexts can help validate methodologies and allow for necessary adjustments, thereby promoting adaptation to diverse territorial and administrative realities. Accordingly, the proposed model is potentially applicable to other cities and regions, provided that principles of harmonization, incremental development, and interinstitutional coordination are respected.

6.3. Practical Implications

This study demonstrates that continuous monitoring and systematic evaluation of territorial planning public policies strengthen the effectiveness and relevance of Portugal's main planning instrument, the Municipal Master Plan (PDM). The combined use of biennial State of Spatial Planning Reports (REOT), dashboards, and municipal geographic information systems enables near-real-time feedback, which is essential for adjusting development strategies and assessing territorial impacts. The integration of artificial intelligence and open data further supports predictive analyses, the identification of emerging trends, and evidence-based decision-making, while reinforcing human-machine collaboration in territorial planning processes. At the same time, the findings highlight the need to consolidate an institutional culture of monitoring and evaluation, ensuring the availability of harmonized indicators, integrated information systems, and effective interinstitutional coordination. Finally, the proposed approach enhances the ability to track policy implementation while

strengthening citizen participation and transparency, thereby increasing public trust in planning decisions.

6.4. Future Work

For future developments, emphasis should be placed on the use of predictive indicators and scenario analysis, leveraging artificial intelligence capabilities to anticipate policy impacts prior to implementation. The integration of emerging technologies—such as urban sensors, the Internet of Things (IoT), and real-time data streams—can further enable more dynamic dashboards and more precise and timely analyses. In addition, scaling the model across multiple governance levels, including intermunicipal, regional, and national contexts, would allow for more reliable comparisons and data aggregation. Intelligent automation of evaluation processes is also recommended to reduce repetitive tasks, thereby enabling planners and decision-makers to focus on strategic analysis and informed decision-making.

In summary, the proposed approach reinforces the understanding that territorial planning is not merely a static regulatory instrument, but rather a continuous and adaptive process. Permanent monitoring, incremental evaluation, and the integration of advanced technologies enable public policies to respond more effectively to real territorial dynamics, promoting sustainability, efficiency, and intelligent governance.

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