INSTITUTO
UNIVERSITÁRIO
DE LISBOA

Identifying Patterns and Causes in Civic Complaints through the 'Na Minha Rua' App to Improve Urban Management

João Miguel Esteves Soares

Master in Integrated Business Intelligence Systems

Supervisor:
PhD Carlos Eduardo Dias Coutinho, Assistant Professor,
Iscte-IUL

October, 2024

TECNOLOGIAS
E ARQUITETURA

Department of Information Science and Technology

Identifying Patterns and Causes in Civic Complaints through the 'Na Minha Rua' App to Improve Urban Management

João Miguel Esteves Soares

Master in Integrated Business Intelligence Systems

Supervisor:
PhD Carlos Eduardo Dias Coutinho, Assistant Professor,
Iscte-IUL

October, 2024

This thesis stands as a testament to the collective support, guidance, and encouragement of all these individuals and institutions. Their contributions have made this achievement possible, and for that, I am eternally grateful.

Acknowledgments

The journey of completing this thesis has been both challenging and rewarding, marked by the invaluable support of numerous individuals and institutions who deserve my heartfelt gratitude. First and foremost, I extend my sincere appreciation to Instituto Universitário de Lisboa for providing an exceptional educational environment through the Master's Degree in Integrated Business Intelligence Systems. The institution's commitment to academic excellence has significantly shaped my professional and intellectual growth.

I am deeply indebted to the Lisbon City Council and LxDataLab for their generous collaboration in providing the essential data that formed the backbone of this research. Their support has enabled me to bridge theoretical knowledge with practical, real-world applications.

My profound gratitude goes to Professor Carlos Coutinho, whose guidance has been nothing short of extraordinary. His expertise, dedication, and unwavering patience have been instrumental in bringing this work to fruition. Professor Coutinho exemplifies the academic excellence that our institution represents, and his mentorship has transformed this dissertation from a mere academic requirement into a meaningful practical contribution.

This academic journey has not only enhanced my knowledge but has also instilled in me a more disciplined and efficient approach to work. While I take pride in this achievement, I remain humble in the knowledge that there is always more to contribute to society's betterment.

Words cannot adequately express my gratitude to my educational sponsors and parents, João Pedro Soares and Maria José Soares. They are not just the architects of my childhood but the sculptors of the man I have become. Their unwavering support and sacrifices have paved the way for every opportunity I have encountered.

Special thanks go to Maria Carolina Soares and Joana Correia Louro, whose presence has been a constant source of joy and serenity, especially during the most challenging phases of this journey. Their patience and understanding have been invaluable pillars of support.

Finally, I acknowledge my own perseverance in this endeavor. Despite the numerous obstacles and time constraints, I remained committed to this goal, never allowing circumstances to deter my determination to succeed.

Resumo

Alguns organismos municipais desenvolvem plataformas para interação com os seus cidadãos. Nomeadamente, o Município de Lisboa desenvolveu uma plataforma denominada 'Na Minha Rua', para permitir a recolha eficiente de queixas urbanas em Lisboa, gerando dados que podem apoiar decisões de governação urbana. A investigação desenvolvida nesta dissertação propõe uma estrutura analítica para processar e visualizar dados de reclamações da plataforma 'Na Minha Rua'. O estudo em questão centra-se no desenvolvimento de diferentes abordagens de visualização para apoiar o reconhecimento de padrões em dados de reclamações urbanas, através de análise sistemática e representação visual dos dados em causa.

Seguindo a metodologia CRISP-DM, esta investigação desenvolve uma estrutura de painel de controlo para o processamento de dados resultantes de queixas urbanas. A visualização proposta engloba as dimensões espacial, temporal e categórica dessas queixas urbanas, oferecendo capacidades de agrupamento estratégico e de mapeamento preciso da localização. A ferramenta fornece capacidades de mapeamento duplo para visualização espacial, apresentação de padrões temporais e métricas de desempenho padronizadas. A conceção da ferramenta baseia-se em requisitos operacionais documentados, e em estruturas organizacionais municipais. O painel de controlo permite o reconhecimento manual de padrões através da representação visual dos dados das queixas, e inclui mecanismos de acompanhamento do desempenho para cada departamento.

Esta investigação contribui para a análise urbana, contribuindo para ferramentas práticas de governação urbana e para a compreensão teórica do desenvolvimento de cidades inteligentes.

Palavras-chave: queixas urbanas, cidades inteligentes, visualização de dados, governação urbana, análise espacial, análise temporal.

Abstract

This dissertation presents an analytical framework for processing and visualizing data from the ‘Na Minha Rua’ platform, developed by the Lisbon Municipality for recording urban occurrences. The research focuses on developing visualization methodologies for pattern identification in urban complaint data through systematic analysis and visual representation.

Adopting the CRISP-DM methodology, a dashboard framework was developed for processing urban occurrence data, encompassing spatial, temporal, and categorical dimensions. The tool implements strategic clustering and georeferenced mapping functionalities, incorporating dual mapping capabilities, temporal pattern visualization, and standardized performance metrics. The development was based on documented operational requirements and municipal organizational structures, enabling manual pattern identification through visual representations and departmental monitoring mechanisms.

The research contributes to the field of urban analysis, providing practical urban governance tools and expanding the theoretical understanding of smart city development.

Keywords: civic complaints, smart cities, data visualization, urban governance, spatial analysis, temporal analysis.

Index

Figures Index

List of Abbreviations

API - Application Programming Interface

BI - Business Intelligence

CML - Câmara Municipal de Lisboa (Lisbon City Council)

CRISP-DM - Cross-Industry Standard Process for Data Mining

CSV - Comma-Separated Values

DNNs - Deep Neural Networks

DSA - Downtown Seattle Association

GIS - Geographic Information System

ICT - Information and Communication Technology

IoT - Internet of Things

IT - Information Technology

JF - Junta de Freguesia (Parish Council)

LxDataLab - Lisbon Data Laboratory

ML - Machine Learning

NoSQL - Not Only SQL

SMS - Short Message Service

SVMs - Support Vector Machines

UI - User Interface

UK - United Kingdom

USA - United States of America

WebGIS - Web Geographic Information System

XML - Extensible Markup Language

311 - Non-Emergency Municipal Services Number

CHAPTER 1

Introduction

1.1. Urban governance in the digital age

In the 21st century, cities face unprecedented challenges in managing resources, addressing citizen needs, and ensuring sustainable development. The rise of digital technologies has occurred in a new era of urban governance, where data-driven decision-making is becoming increasingly crucial. This digital transformation is reshaping not only how cities operate and interact with citizens, but also how they analyze and respond to urban issues.

The concept of smart cities has emerged as a paradigm for leveraging technology and data to improve urban life. At its core is the idea that by collecting and analyzing vast amounts of urban data, city administrators can make more informed decisions, allocate resources more efficiently, and respond to citizen needs more effectively. However, the mere collection of data is insufficient; cities require sophisticated analytical tools to transform this data into actionable insights.

One of the key components of this digital urban governance is the evolution of citizen-government interactions. Traditional methods of communication between citizens and local authorities are being supplemented, and in some cases replaced, by digital platforms that allow for real-time reporting, tracking, and resolution of urban issues. These platforms, often referred to as e-participation tools, generate valuable data that, when properly analyzed, can reveal patterns and trends crucial for urban management and planning.

In this context, Lisbon, the capital of Portugal, has implemented the ’Na Minha Rua’ application [1]. This platform exemplifies the shift towards digital civic engagement, providing citizens with a tool to report various urban issues directly to the city administration. While the platform effectively facilitates data collection, there is a growing need for sophisticated analytical tools that can process this information systematically, enabling administrators to extract meaningful insights and patterns from the accumulated data.

1.2. Data-driven approaches to urban complaint management

Urban complaint management is a critical aspect of city administration, serving as a direct line of communication between citizens and local governments. Traditionally, this process has been characterized by inefficiencies, delays, and a lack of transparency. While digital platforms have improved data collection, the true revolution lies in developing robust analytical tools that can transform this data into meaningful insights for urban governance.

The effectiveness of modern urban complaint management systems depends on two key components: data collection platforms and analytical tools. While many cities have successfully implemented digital platforms for gathering complaints, there remains a significant gap in the availability of accessible, comprehensive tools for analyzing this data. Effective analytical tools should enable city administrators to:

- Identify recurring issues and prioritize interventions through pattern recognition
- Predict future problem areas using historical data analysis.
- Allocate resources more efficiently based on real-time and historical data.
- Improve response times through automated analysis and early warning systems.
- Generate comprehensive reports for evidence-based decision making.

Despite the potential benefits of data-driven complaint management, several challenges persist in developing and implementing effective analytical tools. These include:

- The need for flexible systems that can handle varying data formats and structures.
- Requirements for real-time processing capabilities.
- Integration with existing municipal systems.
- User-friendly interfaces for non-technical staff.
- Scalability to accommodate growing data volumes.

Moreover, while many cities have invested in data collection platforms, there is still a significant gap in our understanding of how to effectively analyze and utilize this data for improved urban governance. Questions remain about the most effective methods for pattern recognition, the integration of various data sources, and the development of standardized analytical approaches that can be applied across different urban contexts.

In Portugal, while municipalities like Lisbon have implemented advanced e-participation platforms such as ’Na Minha Rua’, there is a growing need for sophisticated yet accessible analytical tools that can help administrators make sense of the collected data. These tools must be designed to support both daily operational decisions and long-term strategic planning, while remaining flexible enough to adapt to evolving urban challenges.

1.3. Research objectives and questions

The primary research question guiding this study is: "How can an analytical tool be developed to effectively process and visualize civic complaints data from the ’Na Minha Rua’ platform to support pattern recognition in urban governance?"

This question encompasses several key aspects of the research and aims to address the following core objectives:

O1: To propose a flexible and comprehensive visualization dashboard that can:

- Process data from the ’Na Minha Rua’ platform.
- Display spatial and temporal patterns in urban issues.
- Present statistical analysis through visual components.
- Support data exploration for operational and strategic planning.

O2: To develop visualization components for:

- Displaying geographical distribution of reported issues.
- Visualizing historical data.

O3: To design a framework for:

- Visual representation of urban complaints data.
- Supporting data-informed decision making in urban governance.
- Presenting service delivery metrics.

The research proposes approaches to transform complaint data into visual representations that could support urban management practices. While the initial design focuses on data from the ’Na Minha Rua’ platform, the visualization framework could be adapted for use with similar urban complaint management systems.

1.4. Methodological framework

This section outlines the methodological framework for developing the proposed visualization dashboard, utilizing the Cross-Industry Standard Process for Data Mining (CRISP-DM) [2], [3]. This methodology provides a structured yet flexible approach for tool development and civic complaint data analysis through six sequential phases, as presented in Figure 1.

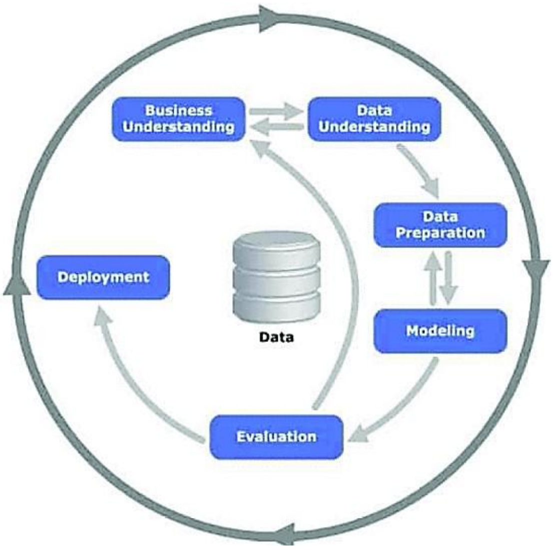

Figure 1- Cross-Industry Standard Process for Data Mining diagram [2]

The Business Understanding phase lays the foundations for the project by analyzing the operational and strategic requirements through the city council "CML (Câmara Municipal de Lisboa)" documentation. This initial phase concludes with a project plan that defines the development stages, aligned with the documented urban management objectives.

The Data Understanding phase examines the data architecture of the 'Na Minha Rua' platform, analyzing the data structure and export formats. This investigation identifies key variables, assesses data quality and documents constraints, providing crucial information for subsequent development phases.

Data Preparation focuses on designing processing capabilities through data cleaning procedures and feature engineering approaches.

The Modeling phase develops visualization components, incorporating spatial representation, presentation of temporal patterns and statistical visualization elements. These components are combined into a proposed system, supporting the exploration of urban data through the visualization tool created.

The evaluation proposes test procedures to evaluate the visualization components with historical data and interface design.

The implementation phase describes potential implementation approaches through system documentation. This final phase proposes mechanisms for future improvements and adaptations of the visualization structure.

This systematic methodology guides the development of a visualization dashboard for exploring urban complaints data. The framework's structured approach provides a basis for developing tools that can meet operational needs while accommodating future requirements.

Chapter 3 extends the methodological approach from the use of CRISP-DM to including the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology for leading the literature review for this research.

1.5. Study significance and potential contributions

This research addresses the pressing need to bridge the gap between data collection and actionable insights in urban governance. Through the development of a comprehensive analytical tool for processing civic complaints data, this study advances the practical application of citizen-reported information in urban management and decision-making processes. The significance and potential contributions of this research span multiple domains, encompassing technical, academic, practical, and societal dimensions.

In terms of technical contributions, this research advances the field through the development of a flexible analytical tool with sophisticated capabilities. The tool systematically processes and analyzes urban complaints data, generating automated insights and visualizations while demonstrating adaptability to diverse data structures and formats. Furthermore, its scalable architecture accommodates increasing data volumes, ensuring long-term viability. The research also yields reusable analytical components, including advanced spatial pattern recognition algorithms, temporal trend analysis frameworks, statistical modeling approaches for urban issues, and interactive data visualization techniques.

The academic contributions of this study are substantial, advancing knowledge across multiple domains of urban analytics and governance. The research enhances understanding of urban data analytics methodologies and pattern recognition in civic complaints, while advancing tool development approaches for urban governance. Additionally, it demonstrates novel methods for integrating data science with urban management practices. The study establishes comprehensive frameworks for systematic analysis of e-participation data, evaluation of urban service delivery mechanisms, assessment of citizen engagement patterns, and translation of raw data into actionable insights.

The practical implications of this research extend to both urban administrators and technical teams. For urban administrators, the study enhances capacity for data-driven decision-making, improves resource allocation efficiency, deepens understanding of urban issues patterns, and enables more effective response planning. Technical teams benefit from standardized approaches to data analysis, reduced manual processing requirements, enhanced data quality management protocols, and systematic documentation of analytical procedures.

The societal impact of this research manifests through improvements in urban governance and citizen engagement. The study advances urban governance through more responsive management practices, evidence-based decision-making processes, efficient resource allocation mechanisms, and transparent issue tracking systems. Citizen engagement is enhanced through demonstrable impact of public reporting, improved service delivery, increased accountability, and enhanced communication of outcomes.

While initially developed for implementation with the ’Na Minha Rua’ platform in Lisbon, the tool’s design principles and analytical approaches demonstrate significant transferability potential. This adaptability enables application in diverse urban contexts and similar e-participation platforms, extending the research’s impact beyond Portugal to benefit urban communities globally.

The study addresses a critical gap in current urban management practices through its focus on developing practical, user-friendly analytical tools. By establishing an effective bridge between data collection and actionable insights, this research advances smart city initiatives and supports the evolution of data-driven urban governance. Ultimately, this work enhances the efficiency and effectiveness of urban management while fostering the development of more responsive and resilient urban communities.

The comprehensive nature of these contributions, spanning technical innovation, academic advancement, practical application, and societal impact, positions this research as a significant advancement in the field of urban analytics and governance. The study’s outcomes provide both immediate practical benefits and foundational elements for future developments in urban management practices.

1.6. Overview of dissertation structure

Chapter 1 establishes the context of urban governance in the digital age, presents the research objectives focused on developing an analytical tool for the ‘Na Minha Rua’ platform, and outlines the study’s significance in improving urban complaint management. Chapter 2 conducts a systematic review using the PRISMA framework, examining current knowledge in smart cities, complaint management systems, spatial-temporal analysis, data analytics, and civic engagement through digital platforms. The review identifies existing research gaps and establishes the study's theoretical foundation. Chapter 3 details the implementation of the CRISP-DM methodology across six phases, from initial business understanding through to deployment. Provides a comprehensive framework for developing the analytical tool while ensuring alignment with urban governance requirements. Chapter 4 presents the technical realization of the analytical dashboard, describing its hierarchical structure, visualization components, and analytical capabilities designed to support decision-making across different levels of Lisbon's municipal services. Chapter 6 evaluates the achievement of objectives, discusses the study's contributions to urban analytics, acknowledges limitations, and proposes future research directions for enhancing urban complaint management through data analytics.

CHAPTER 2

Literature Review

2.1. Literature review methodology

This section outlines the methodology used to conduct a systematic literature review according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, focusing on the identification, evaluation, and eligibility of research relevant to urban management and civic engagement technologies [4].

The PRISMA framework, noted for its rigorous approach to conducting systematic reviews and meta-analyses, was employed to ensure a comprehensive and unbiased review of literature. Comprising a 27-item checklist and a four-phase flow diagram, PRISMA guides the review process from planning to execution, ensuring clarity and reproducibility. This structured approach helps in identifying, evaluating, and critically appraising research to answer well-formulated queries related to urban management and civic engagement through technology.

2.1.1. Keywords, search criteria and query formulation

This systematic literature review adopted a three-phase approach, conducted between April and May 2024, examining publications in English and Portuguese from 2015 onwards. The methodology ensured comprehensive coverage while maintaining alignment with the study's core objectives.

The initial phase established five foundational themes central to the dissertation: Data-Driven Urban Governance, Urban Complaint Management Systems, Spatial and Temporal Analysis in Urban Studies, Data Analytics in Urban Planning, and Civic Engagement through Digital Platforms. These themes were selected for their relevance to analytical tool development and their contribution to both technical and theoretical frameworks.

The second phase decomposed each theme into specific sub-themes for targeted investigation. Data-Driven Urban Governance examined management practice evolution, smart city concepts, and ethical considerations. Urban Complaint Management Systems investigated traditional and digital approaches, global platform case studies, and system effectiveness. Spatial and Temporal Analysis explored urban spatial theories, temporal patterns, and dimensional integration. Data Analytics focused on planning techniques, business intelligence applications, and governance implementation challenges. Civic Engagement analyzed technological impact, digital participation opportunities, and citizen-generated data utilization.

The final phase developed and refined search queries through an iterative process. Primary searches in Scopus and Web of Science combined theme-specific keywords (e.g., "data-driven urban governance"), technical terms (e.g., "spatial analysis"), application contexts (e.g., "smart cities"), and methodological terminology (e.g., "GIS", "predictive analytics"). Query refinement employed subject area limitations (COMP, SOCI, ENVI, DECI), language filters, document type restrictions, and publication year constraints [5], [6], (see appendix A)

This methodical approach generated a comprehensive yet focused literature base, with systematic documentation enabling future replication and updates. The resulting framework provides a robust foundation for understanding current knowledge in urban analytics and complaint management systems, while identifying research gaps this study addresses. This structured methodology supports the development of evidence-based analytical tools grounded in both theoretical understanding and practical application.

2.2. PRISMA results

Following the systematic literature review, following the PRISMA methodology, began with the identification of 306 records through database searches, comprising 143 records from Scopus and 163 from Web of Science. Additional sources, including websites, organizations, and citation searching, contributed 10 more records to the initial pool, as presented in Figure 2.

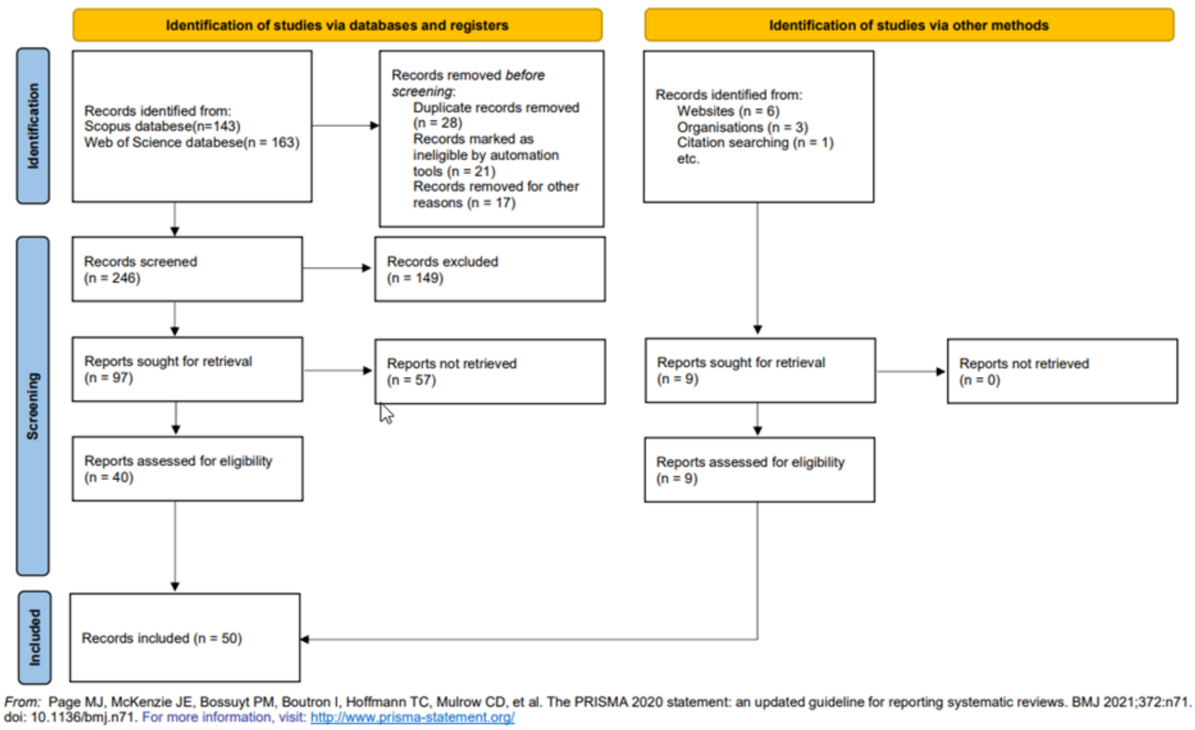

Figure 2- PRISMA Flow Diagram for Literature Review Selection Process

During the pre-screening phase, 66 records were removed: 28 duplicates were eliminated, 21 records were marked as ineligible by automation tools, and 17 were removed for other reasons. This initial filtering process left 246 records for comprehensive screening.

The screening phase revealed that 149 records did not meet the inclusion criteria and were excluded. Of the remaining 97 reports sought retrieval from database searches, 57 were unavailable or inaccessible, leaving 40 reports for full-text assessment. Concurrently, nine reports from additional sources were identified, retrieved, and assessed for eligibility.

The final inclusion phase yielded 50 studies meeting all criteria, covering key themes in urban analytics, smart city implementations, digital complaint management systems, and civic engagement platforms. These selected studies, published primarily from 2015 onwards in English or Portuguese, provided a robust foundation for understanding current practices in urban analytics and complaint management systems.

This systematic approach ensured comprehensive coverage of relevant literature while maintaining focus on studies directly applicable to the development of analytical tools for urban governance. The final selection offered balanced coverage across the research themes, supporting both theoretical understanding and practical implementation considerations.

2.3. Methodologies observed

2.3.1. The evolution of urban management practices

Smart City initiatives: A global perspective

China’s rapid urbanization and smart city development provide a clear example of this evolution. Yan [7], outlines three distinct stages in China’s smart city development: 2008-2012: Initial exploration and piloting, 2013-2015: Pilot exploration and normative development and 2016-present: Deepening and upgrading.

By 2018, China had over 500 smart city pilot projects, accounting for about half of the global total. This rapid adoption was accompanied by substantial investments, with technology investments in China’s smart cities projected to grow from $20.53 billion in 2018 to $38.92 billion by 2023 [7].

In contrast, European smart city initiatives have focused more on addressing specific urban challenges through targeted projects. Ludlow [8] highlights experiences from European smart cities, emphasizing the development of open governance solutions for urban planning. Projects such as Smarticipate, urbanAPI, URBIS, and DECUMANUS have involved the implementation of smart city governance applications in major European cities, focusing on participatory and inclusive approaches to urban management [9], [10], [11], [12].

The role of Big Data and Urban Analytics

The integration of big data and advanced analytics has been a key driver in the evolution of urban management practices. [13] explores how big data is transforming urban governance and long-term urban policy. They argue that urban analytics, defined as big data analytics applied for urban governance and planning, is central to shaping and running smart cities.

Key developments in this area include: Real-time data mining and pattern detection in high-frequency data, development of predictive models for urban phenomena and integration of diverse data sources for comprehensive urban analysis.

However, Kandt and Batty also highlight the challenges in using high-frequency data for long-term urban policy, noting the tension between the fast temporal scale of big data and the slower dynamics of structural urban changes

Shift towards integrated and participatory approaches

A common theme across both Chinese and European experiences is the shift towards more integrated and participatory approaches in urban governance. Yang et al. note that recent developments in China have focused on people-oriented, results-oriented, intensive coordination, and collaborative innovation approaches.

Similarly, Ludlow emphasizes the development of open, co-created, and inclusive urban governance models in European cities. The Smarticipate project, for instance, experiments with open governance solutions for urban planning in Rome, London, and Hamburg, demonstrating a move towards more participatory decision-making processes.

Challenges and opportunities

While the evolution of urban management practices presents numerous opportunities for improved efficiency and citizen engagement, it also faces significant challenges:

1. Data silos and interoperability issues [7].
2. Privacy and security concerns in data collection and use [7], [13].
3. Technological bottlenecks, including sensor technology and communication network capacity [7].
4. The need to balance short-term responsiveness with long-term strategic planning [13].

Long-term implications of urban policy and planning

The evolution of urban management practices towards data-driven, participatory approaches has significant implications for long-term urban policy and planning: Increased emphasis on evidence-based decision-making, greater potential for real-time adaptation of urban services and infrastructure, enhanced ability to model and predict urban phenomena for proactive planning and challenges in reconciling the fast dynamics captured by big data with the slower pace of structural urban changes [13].

As cities continue to evolve and adopt smart technologies, the integration of big data analytics, participatory governance, and long-term strategic planning will be crucial in addressing complex urban challenges. The experiences from both Chinese and European cities highlight the potential of these approaches, while also underscoring the need for careful consideration of their limitations and challenges.

2.3.2 Smart cities concepts and data-driven decision-making

The evolution of smart cities is intrinsically linked to the advancement of data-driven decision-making processes. This section explores the key concepts, technologies, and methodologies that underpin smart city governance and the role of data in shaping urban policies.

Data Science as a driver for smart cities

Sarker [14] emphasizes that data science is driving the change in smart cities in the current age of the Fourth Industrial Revolution (Industry 4.0). Extracting actionable knowledge from city data and building corresponding data-driven models is key to making city systems automated and intelligent. Data science in smart cities involves:

1. Data Collection: From various sources like sensors, Internet-connected devices, and external databases.
2. Data Processing: Cleaning, organizing, and preparing data for analysis.
3. Advanced Analytics: Employing machine learning and deep learning techniques to extract insights.
4. Decision-Making: Using insights to inform urban planning and policy decisions.

Emerging research trends in smart cities

Sharma [15] used Latent Dirichlet Allocation (LDA) to analyze research trends in smart cities. Their analysis revealed several key themes:

1. IoT Integration: The Internet of Things is a fundamental technology in smart city development.
2. Data Analytics: Big data and analytics are crucial for extracting meaningful insights from city data.
3. Energy Management: Smart grids and energy-efficient solutions are prominent research areas.
4. Transportation: Intelligent transportation systems and smart mobility are key focus areas.
5. Security and Privacy: As cities become more connected, cybersecurity is an increasing concern.

IoT platforms for Smart Cities

Monios [16] provides a comprehensive review of IoT platforms for smart cities, comparing both commercial and open-source options. Key findings include:

1. Connectivity: Most platforms support a wide range of communication protocols (e.g., MQTT, HTTP, CoAP).
2. Data Management: Platforms offer varying capabilities for data storage, processing, and analytics.
3. Security: All platforms emphasize security features, though implementations vary.
4. Scalability: The ability to handle large numbers of devices and data streams is crucial.

5. Interoperability: Open standards and APIs are important for integration with existing city systems.

Citizen participation through open data

Desouza and Bhagwatwar [17] highlight how open data initiatives are enabling citizens to develop applications that address urban challenges. This citizen-driven approach to problem-solving is reshaping urban governance:

1. Problem Identification: Citizens can report issues directly through mobile apps.
2. Data Accessibility: Open data portals allow citizens to access and analyze city data.
3. Collaborative Solutions: Hackathons and app competitions encourage innovation.
4. Feedback Loops: Citizen-developed apps provide valuable data back to city officials.

Data-driven decision making in practice

The integration of data science, IoT, and citizen participation is enabling more informed and responsive urban governance:

1. Predictive Maintenance: Using sensor data to anticipate infrastructure failures.
2. Resource Optimization: Better allocation of city resources based on real-time data.
3. Policy Evaluation: Data-driven assessment of policy impacts and effectiveness.
4. Citizen Engagement: Using data to improve communication and services for residents.

Challenges and future directions

While data-driven approaches offer significant potential, several challenges remain:

1. Data Quality and Integration: Ensuring accuracy and compatibility of data from diverse sources.
2. Privacy Concerns: Balancing data collection with citizen privacy rights.
3. Digital Divide: Ensuring equitable access to smart city benefits.
4. Sustainability: Developing solutions that are environmentally and economically sustainable.
5. Skill Gaps: Building capacity in data science and analytics within city governments.

Future research, as outlined by Sarker, should focus on addressing these challenges, particularly in areas such as [14]:

- Developing lightweight machine learning algorithms for resource-constrained devices
- Improving semantic interoperability between different city systems.
- Enhancing cybersecurity measures for smart city infrastructure.

- Incorporating context-awareness in smart city services.

In conclusion, the concept of data-driven smart cities represents a paradigm shift in urban governance. By leveraging data science, IoT technologies, and citizen participation, cities can make more informed decisions, optimize resource allocation, and improve quality of life for residents. However, realizing this potential requires addressing significant technical, ethical, and social challenges.

2.3.3. Ethical considerations in using citizen-generated data

The increasing use of citizen-generated data in smart city applications raises significant ethical concerns, particularly regarding the commodification of personal data and its implications for urban life. Yüksekdağ [18] provides a comprehensive ethical exploration of these issues, focusing on how datafication in smart cities can lead to various forms of commodification.

Types of commodification in smart cities

Yüksekdağ identifies three distinct types of commodification in smart city applications: Direct collection and selling of data points, collection based on economic value and processing and utilization based on economic value.

Ethical implications

The ethical concerns surrounding these forms of commodification include:

- Social Inequality: Exacerbation of existing disparities.
- Devaluation of Social Interactions: Prioritizing economic value over social and cultural aspects.
- Privacy and Autonomy: Risks to individual rights in urban spaces.
- Democratic Participation: Potential sidelining of traditional forms of civic engagement.

Ethical approaches to commodification

Yüksekdağ discusses three main ethical approaches:

1. Categorical Approach: Outright condemnation of certain forms of commodification.
2. Economic Weighing Approach: Balancing economic benefits against potential harms.
3. Social Justice Approach: Considering broader implications on social equality and urban life.

The author advocates for the Social Justice Approach as it allows for a more nuanced evaluation of the ethical implications of data-driven urban governance.

Towards just smart city governance

To address these ethical concerns, several principles for just smart city governance are suggested:

1. Equal Respect: Recognizing the inherent worth of all individuals and their data
2. Inclusion: Preventing marginalization based on data's economic value
3. Value Plurality: Respecting diverse lifestyles and cultural practices
4. Qualitative Insights: Incorporating community perspectives alongside quantitative data
5. Flexible Algorithms: Adapting to different social contexts and values

In conclusion, while data-driven governance offers potential benefits in efficiency and innovation, it also risks commodifying aspects of urban life in ways that can reinforce or exacerbate social inequalities. A social justice approach provides a framework for evaluating and mitigating these risks, ensuring that smart city technologies serve the needs of all urban residents.

As smart cities evolve, it is crucial for policymakers, technologists, and urban planners to engage with these ethical considerations. This involves implementing robust data protection measures and critically examining the values embedded in data-driven urban governance systems. By doing so, we can work towards smart cities that enhance urban life for all residents, rather than simply maximizing economic value at the expense of social equity and cultural diversity.

2.4. Urban Complaint Management Systems

2.4.1. Overview of traditional and digital complaint management approaches

Urban complaint management systems have undergone significant evolution in recent years, transitioning from traditional methods to more sophisticated digital platforms. This shift reflects the changing dynamics of citizen engagement and the increasing role of technology in urban governance.

Traditional complaint management approaches typically involved direct communication channels such as phone hotlines, in-person visits to municipal offices, or written correspondence. While these methods allowed for personal interaction, they often suffered from inefficiencies in processing, tracking, and analyzing complaints [19]. These traditional systems were often labor-intensive and time-consuming, making it challenging for local governments to respond promptly and effectively to citizen concerns.

The advent of digital technologies has revolutionized urban complaint management. Digital platforms, often referred to as 311 systems in the United States, have emerged as powerful tools for citizens to report non-emergency issues and for local governments to manage and respond to these reports efficiently. These systems leverage various technologies, including web platforms, mobile applications, and data analytics, to streamline the complaint management process [20].

One notable example of such digital tools is CitymisVis, as described by Hubert [21]. This tool is designed for the visual analysis and exploration of citizen requests and complaints, representing a significant advancement in how urban issues are perceived and managed. CitymisVis exemplifies the potential of digital platforms to not only collect complaints but also to visualize and analyze them, providing valuable insights for urban planners and policymakers.

The transition to digital platforms has brought about several key improvements:

1. Accessibility: Digital platforms allow citizens to report issues 24/7 from any location with internet access, significantly increasing the ease with which citizens can engage with local government.
2. Efficiency: Automated systems can categorize and route complaints more quickly than manual processes, leading to faster response times and more effective resource allocation.
3. Transparency: Many digital platforms allow citizens to track the status of their complaints in real-time, enhancing accountability and trust in government services.
4. Data Collection: Digital systems facilitate the collection of standardized data, enabling more comprehensive analysis of urban issues and trends over time.
5. Analytics Capabilities: Advanced data analytics tools can be applied to the collected data, helping cities identify patterns, predict issues, and make data-driven decisions [19].

However, it’s important to note that the effectiveness of these digital systems can vary based on factors such as user adoption, data quality, and the responsiveness of local authorities. Hagen [19] found that in smaller cities like Miami, the adoption of new technologies for 311 requests was surprisingly low, with the majority of requests still being made through traditional phone calls. This highlights the importance of considering local context and infrastructure when implementing digital complaint management systems.

Moreover, while digital platforms offer numerous advantages, they also present new challenges. These include potential digital divide issues, where certain segments of the population may have limited access to or comfort with digital technologies, as well as data privacy and security concerns [20].

In conclusion, while digital complaint management systems represent a significant advancement over traditional methods, their successful implementation requires careful consideration of local needs, existing infrastructure, and potential barriers to adoption. As these systems continue to evolve, balancing the benefits of technology with the need for inclusive and accessible services remains a key challenge for urban governments.

2.4.2. Case studies of similar platforms worldwide

The concept of 311 and similar non-emergency civic reporting systems has been adopted in various forms across the globe. These platforms demonstrate diverse approaches to citizen engagement and urban problem-solving. Here, we examine several notable examples:

Philly311 (Philadelphia, USA)

Philadelphia's 311 system, launched in 2008, offers a comprehensive approach to citizen engagement. According to Nam and Pardo, Philly311 serves as more than just a contact center [22]:

- It functions as a "front door" to city services, integrating various departmental hotlines.
- The system enhances transparency and accountability through service tracking.
- Philly311 employs a unique neighborhood liaison program, training community leaders to use the system and report issues directly.
- It drives data-driven management practices, informing the city's performance management system (PhillyStat).

Challenges included initial budget constraints and the need to build partnerships with other city departments.

FixMyStreet

FixMyStreet, launched in 2007 by the charity mySociety, takes a different approach [23], [24]:

- It's an independent platform that works with multiple local councils across the UK.
- Citizens can report issues on a map-based interface, which are then routed to the appropriate local authority.
- The platform is open-source, allowing other countries to adapt it for their use.

This model demonstrates how non-governmental organizations can play a role in civic engagement platforms.

Maersk Seva

Cheng [25] describes an innovative approach in India:

- The system uses machine learning algorithms to analyze and categorize civic complaints.
- It incorporates data from social media and other digital sources, not just direct citizen reports.
- The platform aims to predict future service requests based on historical data and community characteristics.

This case highlights the potential of advanced analytics in civic engagement platforms.

Open311 Initiative

Although not a unique case study, the Open311 initiative is worthy of note [22], [25]:

- It's a collaborative effort to create open standards for 311-type systems.
- The goal is to make civic reporting data more interoperable and accessible across different platforms and cities.
- Cities like Chicago and San Francisco have adopted Open311 standards.

This initiative demonstrates the potential for standardization and data sharing in civic reporting systems.

CitiCafe

Dumrewal [26] presents CitiCafe, a conversation-based platform for citizen engagement in India:

- It uses a virtual agent with a Twitter interface to interact with citizens.
- The platform allows for both reporting problems and gathering information about civic issues.
- It integrates data from various sources, including social media and dedicated complaint forums.

CitiCafe showcases the potential of conversational interfaces and social media integration in civic reporting.

Community Sensing in Developing Regions

Yadav [27] describes a crowdsensing testbed implemented across universities in India:

The system allows for open-ended sensing under broad categories like civic complaints, traffic, and emergencies.

- It supports multiple submission modes, including a mobile app, SMS, and web interface.
- The platform faced challenges in participant engagement and data quality.
- This case highlights the potential and challenges of implementing such systems in developing regions.

These case studies demonstrate the global spread of 311-like systems and the diversity of approaches. Common themes include the integration of multiple communication channels, the use of data analytics for improved decision-making, and the challenges of maintaining citizen engagement. The variations in implementation reflect local needs and technological capabilities, from sophisticated predictive analytics to basic SMS reporting systems.

As these platforms evolve, there's a growing trend towards more interactive and conversational interfaces, integration with social media, and the use of advanced analytics to derive insights from the collected data. However, challenges remain in areas such as data quality, participant engagement, and the effective use of collected information for governance improvements.

2.4.3. effectiveness and limitations of digital complaint systems

Digital complaint systems, such as 311 services and similar platforms, have become increasingly prevalent in urban governance. While these systems offer significant benefits, they also face certain limitations. This section explores both the effectiveness and the challenges of digital complaint systems.

Effectiveness

- Improved Accessibility: Digital platforms provide citizens with multiple channels to report issues, including phone calls, websites, mobile apps, and sometimes social media. This multi-channel approach increases accessibility for a wider range of citizens [19].
- Efficient Data Collection: These systems enable the systematic collection of standardized data on urban issues, facilitating more comprehensive analysis and trend identification [19].
- Enhanced Transparency: Many digital systems allow citizens to track the status of their complaints in real-time, enhancing transparency in government operations [28].
- Data-Driven Decision Making: The wealth of data generated by these systems can inform policy decisions and resource allocation, leading to more responsive and efficient governance [22].

- Citizen Engagement: Digital complaint systems can serve as a venue for citizen engagement, empowering residents to actively participate in improving their communities [22].

Limitations

- Digital Divide: Not all citizens have equal access to or comfort with digital technologies. This can lead to underrepresentation of certain groups in the data collected, particularly older, low-income, or less tech-savvy populations [19].
- Data Quality Issues: Citizen-reported data may be subjective or inconsistent, requiring careful validation and processing. This can be particularly challenging with unstructured data from sources like social media [19].
- Resource Constraints: While digital systems can improve efficiency, they still require significant resources for implementation, maintenance, and response to complaints. Smaller cities or those with budget constraints may struggle to fully utilize these systems [28].
- Privacy Concerns: The collection of location-based complaint data raises potential privacy issues that need to be carefully managed [19].
- Uneven Adoption: Studies have shown that the use of these systems can vary significantly based on socioeconomic factors. For instance, higher-income areas tend to report more frequently, potentially skewing resource allocation [19].
- Complexity in Data Interpretation: Extracting meaningful insights from large volumes of complaint data can be challenging and may require sophisticated analytical techniques [29].
- Integration Challenges: Many cities face difficulties in integrating these new digital systems with existing government processes and legacy IT systems [22].
- Overreliance on Technology: There's a risk of overemphasizing technological solutions at the expense of other forms of civic engagement and community building [28].

Despite these limitations, digital complaint systems have shown significant promise in improving urban governance. Many cities are working to address these challenges through improved design, targeted outreach to underrepresented communities, and enhanced data analysis techniques. As these systems evolve, balancing the benefits of technology with the need for inclusive and accessible services remains a key challenge for urban governments.

Future improvements may include better integration of artificial intelligence for data analysis, enhanced privacy protections, and more robust strategies for bridging the digital divide. Additionally, combining digital systems with traditional engagement methods could help ensure more equitable participation across all segments of the population.

2.5. Spatial and temporal analysis in urban studies

2.5.1. Theories and methods in urban spatial analysis

Urban spatial analysis has evolved significantly, incorporating diverse theories and methods to understand the complex dynamics of cities. This field combines geographical information systems (GIS), statistical techniques, and social science theories to examine urban patterns, processes, and structures.

One fundamental approach in urban spatial analysis is the use of GIS as a tool for expert analysis, practical application, and citizen participation. As highlighted in "GIS in Urban Studies: A Tool of Expert Analysis, Practical Application, and Citizens' Participation," GIS has transformed itself from being solely an expert tool to a platform that enables broader engagement in urban studies. This evolution reflects a shift towards more inclusive and participatory approaches in urban spatial analysis, acknowledging the value of diverse perspectives in understanding urban spaces.

Advancements in visualization techniques have greatly enhanced our ability to analyze urban spatial patterns. The "Adaptive Choropleth Mapper," for instance, exemplifies how open-source web-based tools can facilitate the synchronous exploration of multiple variables across various spatial extents. Such tools are crucial for understanding the multifaceted nature of urban environments, allowing researchers to visualize and analyze complex spatial relationships more effectively.

The integration of temporal dimensions into spatial analysis has opened new avenues for understanding urban dynamics. The study on "Spatiotemporal Evolution and Influencing Factors of Urban Industry in Modern China (1840-1949)" demonstrates how historical spatial analysis can reveal long-term patterns and processes in urban development [30]. This approach combines traditional spatial analysis methods with historical data to provide a more comprehensive understanding of urban evolution over time.

Modern urban spatial analysis methods often incorporate a mix of quantitative and qualitative approaches. Quantitative methods may include spatial statistics, network analysis, and machine learning techniques to identify patterns and relationships in urban data. Qualitative methods, on the other hand, might involve participatory mapping, interviews, and ethnographic studies to capture the lived experiences of urban residents.

Emerging theories in urban spatial analysis include complexity theory, which views cities as complex adaptive systems, and actor-network theory, which examines the relationships between human and non-human actors in urban spaces. These theories complement traditional spatial analysis methods by providing frameworks for understanding the intricate interactions that shape urban environments.

In conclusion, urban spatial analysis has developed a rich toolkit of theories and methods that allow for a nuanced understanding of urban spaces. From GIS-based expert analysis to participatory approaches and historical examinations, these methods provide a multifaceted lens through which to study and interpret the complexities of urban environments. The ongoing integration of diverse approaches promises to further enhance our ability to analyze and address urban challenges in the future.

2.5.2. Temporal patterns in urban phenomena

Urban areas exhibit complex spatiotemporal patterns as they evolve and change over time. Recent studies have leveraged new data sources and analytical techniques to uncover temporal dynamics in various urban phenomena:

- Diurnal and Seasonal Rhythms: Research using social media data has revealed daily and seasonal patterns in urban emotional states and activities. For example, Golder and Macy analyzed Twitter posts to identify diurnal and seasonal mood variations across diverse cultures [31], [32] .
- Long-term Urban Evolution: Historical analysis of urban industrial development, such as the study by Wang on Chinese cities from 1840-1949, can reveal long-term spatiotemporal patterns in urban growth, economic structure, and spatial organization [30].
- Event-based Temporal Patterns: Crowdsensing and social media analysis allow for near real-time detection of urban events and issues. As demonstrated by Yadav, citizen reporting through mobile apps can capture temporal patterns in traffic, civic issues, and other urban phenomena as they unfold [27].

- Cyclical Urban Processes: Studies have identified cyclical patterns in urban shrinkage and growth over decades, with cities experiencing periods of expansion and contraction. Du [31] examined such cycles in Chinese cities from 2008-2018.

By uncovering these temporal patterns, researchers can gain insights into urban dynamics, predict future trends, and inform urban planning and policy. Advanced spatiotemporal visualization and analysis techniques, like those described by Yadav, are enabling more sophisticated examinations of how urban areas change over time [27].

2.5.3. Integration of spatial and temporal dimensions in urban studies

Recent advancements in data availability and analytical techniques have enabled researchers to more effectively integrate spatial and temporal dimensions in urban studies:

- Spatiotemporal Visualization: New tools allow for dynamic visualization of urban phenomena over time and space. For example, Yadav developed an application that uses time slider controls to animate spatial data on maps, enabling visualization of changing patterns. This allows for intuitive understanding of complex spatiotemporal urban processes [27].
- Historical Urban Analysis: Examining long-term urban evolution provides insights into development patterns. Wang analyzed industrial development in Nanjing from 1840-1949 using GIS methods, revealing spatiotemporal trends in urban growth and economic structure over a century. Such historical analyses enrich understanding of contemporary urban forms [30].
- Multi-scale Temporal Analysis: Urban phenomena can be examined across multiple temporal scales simultaneously. Du investigated urban-rural integration in Chinese cities from 2008-2018, considering both short-term fluctuations and longer-term trends. This multi-scale approach provides a more comprehensive view of urban dynamics [31].
- Event-based Urban Analytics: Analysis of discrete events and their spatial impacts over time offers another integration approach. Yadav developed a system for real-time collection and mapping of citizen-reported urban issues, allowing for detection of emerging spatial patterns [27].

The integration of spatial and temporal dimensions enhances urban research by revealing dynamic processes, long-term trends, and complex interactions that shape cities. Advanced computational and visualization techniques are enabling increasingly sophisticated spatiotemporal urban analyses.

2.6. Machine learning techniques in big data analytics

2.6.1. Overview of data analytics techniques relevant to urban planning

The integration of data analytics in urban planning is transforming how cities are designed, managed, and optimized. By leveraging vast amounts of structured and unstructured data, urban planners are better equipped to address complex urban challenges and create more livable and sustainable cities. This section will review key data analytics techniques and their relevance to urban planning, drawing insights from recent literature.

Machine Learning Techniques in Big Data Analytics

Machine learning (ML) algorithms such as deep neural networks (DNNs), support vector machines (SVMs), and decision trees are increasingly applied in urban planning to handle large datasets from various sources.

According to Nti [32] DNNs, SVMs, and decision trees are some of the most widely used techniques in big data analytics. These methods are particularly useful in analyzing complex urban data, such as traffic patterns, environmental data, and demographic shifts. Deep Neural Networks are useful in predictive modelling for traffic management, where real-time data from sensors and IoT devices can be analyzed to predict congestion and optimize routes. However, Support Vector Machine algorithms are applied to land use classification and urban sprawl detection by analyzing high-dimensional spatial data, and Decision Tree algorithms are used to assess urban growth patterns, identifying the main factors contributing to city sprawl.

We must bear in mind that the main challenges in using these machine learning techniques lie in the integration of diverse datasets, which often require specialized preprocessing techniques to improve model accuracy. For instance, handling unstructured data such as social media posts or citizen-generated content poses significant difficulties.

Big Data Platforms and Infrastructure for Urban Planning

Big data analytics rely heavily on robust platforms that can handle large-scale data processing. Ajah and Nweke [33] highlight the importance of platforms like Hadoop, MapReduce, and Spark in managing urban data. These platforms allow for distributed computing, enabling the analysis of data in parallel across multiple nodes, which is critical for handling the sheer volume of data generated in cities, some examples of these platforms are:

- Hadoop Ecosystem: Used in managing data from traffic sensors, public transportation systems, and environmental monitors. Its ability to process large volumes of structured and unstructured data makes it suitable for city-scale analysis.

- Spark: A particularly effective for real-time analytics, Spark can be used in emergency response systems, where live data is analyzed to coordinate quick responses to incidents such as traffic accidents or natural disasters [33].

Implementing big data platforms often requires significant infrastructure investments. Urban planners need to collaborate with IT departments and data scientists to ensure proper integration and functionality of these systems [33].

Predictive and Prescriptive Analytics for Urban Management

Predictive analytics uses statistical algorithms and machine learning techniques to identify the likelihood of future outcomes based on historical data. In contrast, prescriptive analytics suggest possible courses of action and evaluate their potential outcomes.

According to Wu, predictive analytics is increasingly applied in urban sustainability efforts, such as optimizing energy use in buildings or predicting traffic patterns to reduce emissions [34]. We have 2 types of predictions to apply to Urban Planning:

- Predictive Models: These models are used in planning smart cities by predicting demand for resources such as water and electricity, helping to allocate resources more efficiently.
- Prescriptive Analytics: Employed in land-use planning to simulate the impact of different zoning regulations on future urban development.

The primary challenge lies in aligning short-term predictive models with long-term urban policy goals. Planners must balance the immediate insights provided by real-time data with the slower processes of structural urban change.

Geospatial Analytics and Citizen Reporting in Smart Cities

Geospatial data analytics is a crucial component in urban planning, allowing planners to visualize and analyze spatial relationships across different urban phenomena, such as population density, infrastructure development, and land use. These analytics tools are vital for tasks like zoning, transportation planning, and environmental monitoring.

Kopáčková and Libalová [28] highlight the role of citizen reporting platforms, such as WebGIS and mobile applications, that allow citizens to report non-emergency issues. This data can be aggregated and analyzed to identify recurring problems in specific urban areas.

- Spatial Pattern Detection: Geospatial analytics can be used to detect patterns in traffic accidents or urban decay, enabling planners to intervene proactively.
- Citizen-Driven Data: Reports from platforms like WebGIS provide local governments with actionable insights, such as identifying areas with frequent infrastructure breakdowns or public safety concerns [28].

One significant issue is the integration of citizen-generated data with formal urban planning processes. Data quality and consistency can vary, making it necessary to develop sophisticated data validation mechanisms [28].

Big Data-Driven Urban Sustainability

Big data plays a key role in ensuring urban sustainability by supporting smart transport, waste management, energy efficiency, and environmental conservation. Wu emphasize how big data analytics can help urban managers make informed decisions about sustainable resource use and urban resilience [34]. On that note, we have two examples:

- Smart Energy Grids: Big data analytics can optimize energy consumption in urban areas by monitoring demand patterns and suggesting efficiency measures.
- Waste Management: Real-time data from sensors in waste bins can be used to optimize collection routes, reducing costs and environmental impact [34].

One of the main challenges is the effective use of big data for long-term urban sustainability. Planners need to develop systems that not only respond to immediate issues but also account for broader, systemic urban changes [34].

Data analytics has become indispensable in modern urban planning, enabling cities to optimize resources, improve citizen engagement, and ensure long-term sustainability. However, the successful implementation of these techniques requires overcoming significant challenges related to data integration, infrastructure, and ethical considerations. As urban environments continue to grow in complexity, the role of machine learning, big data platforms, and citizen participation will become increasingly central to effective urban management.

2.6.2. Applications of business intelligence tools in urban governance

Business Intelligence (BI) tools are increasingly being applied in urban governance to improve decision-making, enhance service delivery, and optimize the management of urban infrastructure. This section examines key applications of BI tools in urban contexts, focusing on the integration of big data analytics and geospatial metrics. It draws upon insights from both business analytics literature and case studies in urban planning to illustrate how these tools are leveraged for effective governance.

Big Data and Business Analytics in Urban Governance

BI tools help manage and analyze large volumes of data to support decision-making in urban governance. As outlined by Ajah and Nweke, BI frameworks often incorporate big data platforms such as Hadoop, Spark, and NoSQL databases, which facilitate real-time analytics, visualization, and reporting [33].

In urban governance, these tools are used to process data from various sources, such as sensors, citizen reports, and public services, allowing for descriptive, predictive, and prescriptive analytics. Descriptive analytics help summarize past urban phenomena, while predictive analytics can forecast trends, and prescriptive analytics suggests actionable insights for decision-makers. Types of applications:

- Resource Allocation: BI tools help cities optimize the allocation of resources, such as energy, water, and waste management services. Predictive models can forecast peak demand periods, allowing cities to manage utilities more efficiently.
- Real-Time Monitoring: City administrations can monitor critical urban services, such as transportation networks or emergency response systems, in real-time. This allows for faster responses to disruptions, thereby improving service delivery.
- Policy Evaluation: Using big data analytics, cities can evaluate the effectiveness of policies, such as zoning laws or sustainability initiatives. This helps decision-makers fine-tune regulations and strategies based on data-driven insights.

Geosocial Media Metrics and Crowd-Sourcing in Smart Cities

Geosocial media, such as data from platforms like Twitter and Facebook, offer valuable insights into citizen behavior and public sentiment. As explored by Zook, these metrics can be used to track how residents engage with urban spaces and to inform governance decisions [35]. For example, crowd-sourced reports of traffic congestion, infrastructure damage, or environmental issues can be collected and analyzed to provide a real-time snapshot of urban conditions. Types of applications in Governance:

- Smart City Governance: Geosocial media metrics help urban planners understand how people use public spaces and services. This data can reveal trends, such as areas with high foot traffic or frequent service disruptions, enabling targeted interventions.
- Public Sentiment Analysis: Social media data can be used to gauge public opinion on municipal issues, such as new development projects or changes in public services. This feedback can guide policy adjustments and improve citizen engagement.
- Crowd-Sourced Data for Infrastructure: Cities can crowd-source data on infrastructure issues, such as broken streetlights or potholes, which helps prioritize repairs based on public reports. This approach enhances the responsiveness and transparency of urban service delivery.

While geosocial media data offers rich insights, the author warns against over-reliance on such data, as they may not always represent the entire population and could reinforce biases towards more affluent or tech-savvy groups. Effective governance must ensure the inclusion of diverse citizen voices in decision-making processes [35].

Case Study: City Vitality through Four Pillars of Activity

The case study of Seattle, as presented by Griffin, demonstrates how BI tools were applied to measure and enhance the city's vitality using four strategic pillars: Live, Work, Shop, and Play [36]. These pillars represented key aspects of urban life, and metrics were developed to track progress in each area. Data sources included population statistics, employment data, and retail sales information. By integrating these metrics, the Downtown Seattle Association (DSA) was able to monitor the city's growth and prioritize interventions in areas requiring improvement [37].

The Urban Vitality metrics allowed the DSA to evaluate Seattle's urban health and identify gaps where public services or infrastructure investments were needed. For example, if employment rates in certain districts lagged, the city could introduce programs to stimulate business development in those areas [36].

In the areas of sustainability and growth, BI tools were also used to assess the sustainability of urban growth. Metrics related to energy consumption and environmental quality helped the city ensure that its development was both economically viable and environmentally responsible.

Visual Analytics and Citizen Complaints, CitymisVis

Hubert [38] provides an example of how BI tools can be used to manage citizen reports and complaints through the CitymisVis platform. This tool allows municipalities to visually analyze geolocated citizen requests and complaints, providing valuable insights into recurring urban problems. One of such examples was the implementation of using heatmaps and clustering techniques. CitymisVis helps cities identify which geographic areas are most affected by specific issues, such as traffic congestion or public lighting failures. This data can guide municipal authorities in prioritizing interventions, improving service delivery, and reducing response times.

Similar to geosocial media, citizen-generated data can present challenges in terms of data consistency and accuracy. Effective implementation requires robust data validation mechanisms and continuous citizen engagement to ensure that the data reflects real urban needs.

Business Intelligence tools are critical for modern urban governance, providing cities with the ability to make data-driven decisions, monitor service performance, and engage with citizens. Through the use of big data platforms, geosocial media metrics, and visual analytics tools, cities can optimize resource allocation, improve service delivery, and enhance citizen participation. However, challenges remain, including the need for more inclusive data sources and the proper integration of BI tools with existing urban infrastructure. As cities continue to grow, the use of BI in urban governance will be essential for creating smart, sustainable, and resilient urban environments.

2.6.3. Challenges in the implementation of data-driven governance

Data-driven governance, while promising significant advancements in urban management, faces a number of technical, conceptual, and ethical challenges. This section explores these challenges, drawing insights from the literature on smart urbanism and big data in governance. The implementation of real-time data-driven systems in cities is complex, involving issues related to technological infrastructure, governance frameworks, and citizen participation.

Technical Challenges in Real-Time Data-Driven Governance

The increasing use of pervasive and ubiquitous computing in smart cities generates vast amounts of real-time data, requiring sophisticated data management systems. Kitchin [39] emphasizes that urban governance increasingly depends on real-time data, but the infrastructure required for data collection, storage, and analysis is often inadequate. Cities must invest in systems that can handle big data’s high volume, velocity, and variety while ensuring interoperability between different systems. Many cities struggle with integrating data from various sources, such as sensors, geospatial data, and social media, into a unified platform. The lack of standardized protocols for data sharing across departments exacerbates this issue.

As cities become increasingly dependent on digital infrastructures for governance, they are also vulnerable to technical failures and cybersecurity threats. The systems used for real-time urban management may contain bugs, become outdated quickly, or be vulnerable to hacking, which could disrupt essential services like traffic management or public safety monitoring. Challenge: Ensuring the robustness and security of these systems requires continuous investment in maintenance, updates, and cybersecurity, which can be resource-intensive for municipalities.

The Politics of Big Urban Data

While data-driven governance promises efficient and transparent decision-making, it also risks sidelining broader democratic processes. As noted by Kitchin, technocratic governance can prioritize data metrics over citizen needs, leading to governance that is more responsive to data flows than to actual public concerns [39].

A reliance on big data for decision-making can marginalize non-quantifiable aspects of urban life, such as social justice and community well-being. Urban policies may become overly focused on what is measurable, rather than addressing deeper, more complex issues.

Many smart city initiatives involve public-private partnerships where private companies provide technology and expertise for data collection and analysis. While this can lead to innovation, it also raises concerns about the corporatization of urban governance and the risk of technological lock-ins, where cities become dependent on proprietary systems from a single vendor.

These partnerships may limit cities' ability to control their data, as private companies often prioritize profit over public interest. Furthermore, technological lock-ins can hinder future adaptability if new systems or vendors cannot be easily integrated.

Ethical and Social Challenges of Big Data in Urban Governance

Metrics derived from geosocial media and other big data sources can shape policy decisions in ways that may inadvertently reinforce social inequalities. Zook [35] highlights that the use of geosocial media in urban governance can privilege certain groups over others, as data generated by wealthier, more tech-savvy citizens may dominate, leading to unequal representation in decision-making processes.

Ensuring equitable representation in data-driven governance is difficult, as the digital divide means that not all citizens have equal access to the technologies that generate urban data. Additionally, the prioritization of easily measurable metrics, such as traffic counts, over more complex social indicators can skew urban policies away from addressing issues like housing equity or community cohesion.

With the increasing use of sensors, cameras, and geospatial tracking in smart cities, concerns about citizen privacy are growing. Zook, discusses how citizens' activities, often unconsciously captured by sensors or social media, are turned into data points that cities use for governance. This raises ethical concerns about the extent to which citizens are being surveilled without their consent, and how this data is being used.

Balancing the benefits of real-time data collection with the protection of individual privacy is a major issue. Cities must develop transparent data governance policies that ensure citizens are aware of how their data is collected, stored, and used.

Organizational and Policy-Related Challenges

Wu [34] highlights that the use of big data technologies in urban sustainability faces significant challenges related to organizational and policy frameworks. While big data offers tools for improving urban sustainability—such as optimizing energy use and waste management—there are obstacles in adapting traditional governance structures to data-driven models.

Many cities lack the organizational capacity to implement and manage big data systems effectively. Policy frameworks often lag behind technological advancements, leading to a mismatch between the tools available and the regulations governing their use.

Another common issue is the existence of data silos within urban governance. Different departments may collect and analyze their own data independently, without sharing information with other departments. This limits the potential for integrated, city-wide data governance.

Breaking down these silos requires a concerted effort to foster interdepartmental collaboration and develop common data standards. Cities must also invest in data integration platforms that can support cross-departmental access to real-time data.

Implementing data-driven governance presents numerous challenges, both technical and ethical. Cities must invest in robust infrastructures capable of handling the scale and complexity of big data, while also ensuring that governance frameworks are inclusive, transparent, and responsive to all citizens. The reliance on metrics and real-time data, while offering potential benefits, also raises concerns about privacy, equity, and the corporatization of urban governance. As cities continue to embrace big data and smart technologies, careful attention must be given to mitigating these challenges in order to realize the full potential of data-driven urban governance.

2.7. Civic engagement through digital platforms

2.7.1. Impact of technology

Technology has transformed the way citizens engage with governance, enabling more dynamic and interactive participation in decision-making processes. Digital platforms and tools facilitate greater transparency, accessibility, and responsiveness in civic engagement, empowering citizens to influence urban policies and governance.

E-Deliberation and Enhanced Democratic Processes

E-deliberation, as explored by Tsakanikas, refers to the use of digital platforms to facilitate public dialogue and decision-making processes [40]. This form of engagement allows citizens to contribute to policy discussions, vote on issues, and shape public decisions in a more transparent and inclusive manner. The authors argue that smart cities require smart citizens—those who actively engage in digitally mediated governance to make informed and consensus-driven decisions. E-deliberation encourages collaboration, consensus-building, and more equitable representation of diverse views.

Impact on Citizen Participation: By creating spaces where citizens can participate in deliberative processes, digital platforms foster deeper engagement in governance. Citizens can propose ideas, provide feedback on policies, and influence outcomes through sustained dialogue, which is often missing in traditional face-to-face public forums.

Digital Tools for Participation in European Smart Cities

According to Muñoz, European smart cities have adopted various digital tools that enhance citizen participation in governance [41]. These tools range from e-participation platforms to social media and mobile apps, which allow citizens to engage with their local governments more easily. In particular, these tools are used for activities like reporting issues, sharing feedback, participating in urban planning, and discussing public policies.

The study highlights that many European cities have successfully integrated social media as a primary tool for public interaction, with platforms like Facebook and Twitter being widely used. Additionally, approximately 60% of smart cities analyzed in the study have developed official apps to improve public engagement. These platforms contribute to an open dialogue between the government and its citizens, encouraging transparency and collaboration.

Gamification and Citizen Engagement through M-Participation

Thiel [42] investigates the use of game elements in mobile participation (m-participation) apps. The study suggests that gamification can significantly enhance civic engagement by making participation more enjoyable and rewarding. Game elements such as leaderboards, points systems, and challenges motivate citizens to contribute more actively to governance processes.

Impact on Motivation: Gamification taps into both intrinsic and extrinsic motivations by offering rewards for participation, such as recognition and progress within the app. However, the study cautions that while game elements may encourage initial participation, sustained engagement requires more than just incentives—citizens need to feel that their contributions are being heard and valued by local authorities.

Open Data and Mobile Apps for Citizen Empowerment

Sandoval-Almazan [20] explores how open data and mobile apps have reshaped civic engagement by providing citizens with access to government datasets and digital platforms for interaction. Open government initiatives focus on empowering citizens by increasing transparency and facilitating collaboration between the public and government. This shift towards open data has led to the creation of over 1,500 mobile applications, many of which were developed by citizens themselves, demonstrating the potential for citizen-led innovation in solving public issues.

Impact on Governance: These apps allow for greater accountability and real-time feedback, enabling citizens to report issues, participate in public consultations, and track the status of government initiatives. The use of open data thus creates an ecosystem of participation, where government, private companies, and citizens collaborate to enhance public services and governance.

The integration of digital platforms into governance has had a profound impact on citizen participation, offering new avenues for engagement through e-deliberation, gamification, and open data initiatives. These technologies empower citizens by providing them with tools to voice their opinions, engage in public discussions, and influence policy decisions. However, for these platforms to be effective in the long term, it is crucial for governments to ensure that citizens feel heard and that their contributions are reflected in governance outcomes.

2.7.2. Challenges and opportunities in digital civic engagement

Digital platforms have become essential in enabling civic engagement, but they also present a range of challenges and opportunities that need to be addressed to enhance their effectiveness. This section explores both the obstacles and potential presented by the integration of digital tools in civic participation, particularly in the context of smart cities and urban governance.

Martinez-Mosquera [43] highlights that while IoT and ICT infrastructures are crucial for smart urban governance, they require significant investment in both technical and social systems to work effectively. Developing regions, in particular, face challenges in establishing the necessary infrastructure to support data-driven governance. The complexities of integrating IoT devices for real-time monitoring of urban activities, such as traffic and public services, present hurdles in data collection, processing, and management.

Many citizens are unaware of how to effectively use these technologies for civic engagement, leading to underutilization of IoT-enabled platforms. In addition, data privacy concerns and lack of trust in government handling of personal data limit the widespread adoption of such systems.

E-Participation in Portugal: Evaluating Government Platforms

Cerioli [44] discusses the barriers to e-participation initiatives, focusing on issues such as the digital divide, where certain demographic groups are unable to access or effectively use digital platforms for civic engagement. This divide is particularly evident in rural and low-income populations. Furthermore, there are difficulties in fostering meaningful collaboration between governments and citizens, as many e-participation platforms fail to reach the critical mass required for impactful citizen involvement.

Another major challenge is governmental resistance to change, as traditional bureaucratic systems may be slow to integrate digital solutions. Even when digital platforms are available, there may be limited follow-through in terms of actually incorporating citizen input into decision-making processes.

Opportunities in Gamified Civic Engagement

Thiel [42] explores how gamification can be both a challenge and an opportunity in civic engagement. On one hand, adding game elements like leader boards, points, and rewards can increase participation by making engagement more enjoyable. However, gamified systems may also introduce issues related to overemphasis on competition rather than collaboration, and there is a risk that citizens participate for rewards rather than out of genuine interest in civic matters.

The opportunity lies in using game design principles to sustain interest and motivate continuous participation. By rewarding meaningful contributions rather than simple actions, gamification can lead to more active and informed citizenry, particularly among younger demographics who are more likely to engage with digital tools.

Design Thinking in Digital Engagement: Collaboration Approaches

Yadav [27] emphasizes the importance of design-thinking approaches in the creation of digital civic platforms. One major challenge in this area is ensuring that digital tools are inclusive and cater to diverse user groups. A key opportunity lies in applying user-centered design methodologies to ensure that digital platforms are accessible, intuitive, and responsive to the needs of all citizens, regardless of their technological proficiency or access.

These platforms should encourage co-creation and collaboration, allowing citizens not only to report issues but also to propose solutions and participate in decision-making. This fosters a more inclusive form of civic engagement where governments and citizens work together to shape the future of their cities.

Digital civic engagement presents both challenges and opportunities for urban governance. While the integration of IoT, gamification, and e-participation platforms can enhance citizen involvement, obstacles such as technical barriers, social infrastructure, and limited governmental responsiveness must be addressed. By leveraging design thinking and focusing on inclusive, user-centered platforms, cities can tap into the full potential of digital tools to foster more meaningful and widespread civic participation.

2.7.3. The role of citizen-generated data in urban decision-making

Citizen-generated data has become a pivotal resource in contemporary urban governance, transforming how cities make decisions and address urban challenges. This section explores the impact of citizen-generated data, drawing insights from various sources that emphasize the potential, challenges, and applications of this data in urban decision-making.

Non-Emergency Reporting Systems as a Form of E-Participation

Non-emergency incident reporting systems have emerged as critical tools in smart city initiatives, providing platforms where citizens can report local issues such as infrastructure damage, environmental hazards, and other non-critical urban problems. According to Fedotova, these systems are a form of e-participation that allows citizens to directly contribute data to local governments [45]. These platforms, such as 311 services in many cities, create a direct channel for public engagement, enabling urban authorities to respond to civic issues more efficiently and effectively.

Data generated from citizen reports informs municipal decision-making processes by providing real-time insights into urban challenges. These platforms not only serve as monitoring tools but also offer data that can be used for trend analysis and forecasting, helping cities allocate resources where they are most needed. Moreover, the availability of real-time data fosters greater accountability and transparency, as citizens can track the status of their complaints.

Social Media and IoT in Developing Countries: Ecuador Case Study

The use of social media and Internet of Things (IoT) technologies to gather citizen-generated data is especially transformative in developing countries, where traditional data collection methods may be limited. In Ecuador, social media platforms have become a key source of urban data, allowing local governments to tap into crowdsourced information for urban planning and management. Suleimany [46] discusses how Ecuadorian cities are using IoT to collect data on urban phenomena like traffic flow, environmental conditions, and public services, integrating this data into urban governance systems.

- The use of IoT and citizen-generated data in Ecuador demonstrates the potential for these technologies to overcome infrastructural challenges in developing countries. IoT sensors combined with citizen input via social media allow cities to collect real-time data on various urban systems, which in turn supports more informed decision-making. This approach also enhances citizen engagement by giving residents a more active role in monitoring and improving their urban environments.

Blockchain-Based Incentives for Citizen Participation: Ethereum and Civic Currency

Oschinsky [47] proposes an innovative approach to incentivizing citizen participation through blockchain-based civic currencies. This method encourages citizens to generate valuable urban data by offering rewards through decentralized platforms like Ethereum. Blockchain technology provides a transparent, immutable ledger for tracking citizen contributions, ensuring that all participants are recognized and rewarded for their engagement in civic activities.

By leveraging blockchain, cities can create a trustworthy system for managing citizen-generated data. The integration of civic currencies encourages higher participation rates and generates more comprehensive datasets that urban planners and policymakers can use to make informed decisions. Blockchain also adds a layer of transparency and security, addressing concerns about data manipulation or misuse.

Citizen-generated data has emerged as a crucial element in urban decision-making, empowering local governments with real-time, crowdsourced information to address pressing urban issues. From non-emergency reporting systems to the use of IoT and social media in developing countries, this data fosters more responsive, transparent, and inclusive urban governance. As innovative approaches like blockchain-based incentives gain traction, the role of citizens in shaping urban policies is likely to expand, further enhancing the integration of citizen input into urban decision-making processes. However, the effective use of this data requires robust systems for data validation, integration, and analysis to ensure its long-term viability and impact on urban governance.

CHAPTER 3

Research Methodology

3.1. Research Design

The research design adopts the Cross-Industry Standard Process for Data Mining (CRISP-DM) methodology to develop an analytical tool addressing the primary research question: "How can an analytical tool be developed to effectively process and analyze civic complaints data from the 'Na Minha Rua' platform to identify patterns and support evidence-based urban governance decisions?"

CRISP-DM was selected for five fundamental strengths. First, its structured development framework provides an organized approach for handling datasets from the 'Na Minha Rua' platform while supporting systematic development of visualization components. This structured approach offers a foundation for data processing and visualization design.

Second, the methodology's iterative development approach supports progressive refinement of visualization components. This iterative process enables dashboard enhancement based on emerging requirements and changing visualization needs.

Third, CRISP-DM's business-oriented focus aligns with urban governance documentation, supporting the development of practical visualization capabilities. This alignment helps ensure that visualization components address documented operational requirements.

Fourth, the methodology's inherent flexibility accommodates both technical development and visualization design needs. This adaptability supports the integration of diverse visualization approaches and enables dashboard modifications for different urban management contexts.

Finally, CRISP-DM's technical integration capabilities support the combination of multiple technologies, specifically Python and Power BI, while enabling modular component development. This integration framework supports the development of scalable visualization components.

This methodological foundation provides a structured approach for developing a visualization dashboard that could help bridge the gap between urban complaint data collection and pattern recognition. The approach enables systematic development while maintaining adaptability to different visualization requirements.

3.2. CRISP-DM Phase 1: Business Understanding

The business understanding phase establishes the foundation for developing a visualization dashboard for the ’Na Minha Rua’ platform [48], [49]. This platform serves as an interface between citizens and the Lisbon municipal government, generating an extensive dataset of urban issues from 2018 to 2024. Understanding the platform’s context through available documentation is crucial for developing an appropriate visualization solution.

Platform Context and Requirements

The ’Na Minha Rua’ application enables citizens to interact with urban governance in Lisbon. Through citizen participation and reporting processes, the platform accumulates data that could support urban management practices. The proposed dashboard therefore aims to address both data visualization needs and support the platform’s documented objectives of response time monitoring, operational transparency, and decision-making support.

Based on municipal documentation, three distinct operational levels were identified: Câmara Municipal de Lisboa (CML), Junta de Freguesia (JF), and External Entities, each with specific roles in urban management.

Organizational Context

Document analysis revealed three key operational tiers within the urban governance structure. At the municipal level, CML operates through specialized directorates handling specific urban domains, with documented interdepartmental workflows for coordinated responses [50]. The Junta de Freguesia (JF) functions as local administrative units with geographical responsibilities. External Entities are documented as supporting organizations with specialized roles in the municipal system.

Business Requirements Analysis

Analysis Through analysis of CML documentation, four primary business requirements were identified. Performance monitoring requirements include the visualization of active complaints, service workload distribution, and resolution timing. Resource management requirements focus on departmental capacity visualization and workload distribution representation.

Spatial analysis requirements highlight the need for visualizing geographic distribution of incidents and territory-based performance patterns. Temporal analysis requirements emphasize historical trend visualization and seasonal pattern display capabilities.

Business Success Criteria

The proposed success criteria framework encompasses three areas. Operational visualization focuses on response times, resource utilization, and complaint status representation. Strategic planning visualization supports maintenance planning and resource optimization display. System capabilities include transparency in data representation and clear visualization of operational patterns

Risk Assessment

The analysis identified several potential challenges for dashboard development. Technical risks include data quality limitations and visualization accuracy constraints. Implementation risks encompass potential system integration challenges and data processing limitations

Through analysis of available documentation, requirements for visualization capabilities that could support both operational and strategic objectives in urban governance were identified. This understanding provides direction for subsequent development phases while acknowledging system constraints and limitations.

3.3. CRISP-DM Phase 2: Data Understanding

The data understanding phase involved comprehensive analysis of multiple data sources from the 'Na Minha Rua' platform, spanning from 2018 to 2024 [49]. This phase revealed significant limitations in data availability and highlighted important gaps between collected and provided information.

Data Source Overview and Limitations

The analysis utilized seven distinct data sources, representing different periods in the platform's evolution. The primary dataset comprised six Excel files covering 2018 through 2023, while a supplementary CSV file contained 2024 data. Given Lisbon's population of approximately 545,142 residents, the total of 774,072 complaints over six years (2018-2023) suggests limited platform adoption by citizens, averaging about 129,012 complaints per year or 0.24 complaints per resident annually. This relatively low engagement rate indicates potential gaps in urban issue reporting.

Data Availability Constraints

Important discrepancies exist between the data collected by the application and the data provided for analysis. While the platform collects rich contextual information including:

- Incident photographs providing visual documentation.
- Reference points entered as free text by users.
- Detailed issue descriptions in free text format.

- User comments and feedback These valuable data elements were not included in the provided datasets, limiting the depth of possible analysis.

Data Structure Evolution

The initial dataset structure (2018-2023) captured basic aspects of urban complaints through key variables. Temporal information was recorded through registration dates (dt_registo), enabling chronological analysis. Spatial data included administrative boundaries (parish) and geographical coordinates (Subsection_Longitude and Latitude_Subsection). Complaint categorization used a hierarchical structure with general areas (area) and specific types (type).

The 2024 dataset introduced additional operational variables including unique identifiers (id), status fields (status and dt_status), and responsible service attribution (servico_rep). However, it still excluded the richer contextual data collected by the platform.

Data Volume and Coverage

While the combined historical dataset encompassed 774,072 complaints (2018-2023), and the 2024 dataset contained 765,769 records, these numbers should be considered in context. For a city of Lisbon's size and complexity, this volume suggests potentially significant underreporting of urban issues, possibly due to:

- Limited citizen awareness of the platform.
- Barriers to platform access or use.
- Preference for alternative reporting methods.
- Varying adoption rates across different city areas.

Temporal and Spatial Representation

The temporal span (2018-2024) enables basic trend analysis, though limited citizen engagement may affect pattern reliability. Spatial data supports geographical analysis through parish-level information and coordinates, but the relatively low complaint volume may result in incomplete coverage of urban areas.

Data Quality Considerations

Initial assessment revealed several quality limitations:

- Evolution in data structure between historical and recent datasets.
- Absence of unique identifiers in earlier data.
- Missing contextual information (images, descriptions, reference points).
- Potential sampling bias due to limited platform adoption.

- Incomplete representation of actual urban issues due to low reporting rates.

The understanding gained through this phase reveals significant limitations in data availability and completeness. While the provided data allows for basic analysis, the exclusion of rich contextual data collected by the platform and limited citizen engagement constrains the depth and reliability of potential insights. These limitations fundamentally affect subsequent analysis approaches and the interpretation of results.

3.4. CRISP-DM Phase 3: Data Preparation

The modeling phase implemented a comprehensive analytical framework through a multi-stage approach, combining Python-based data processing with Power BI visualization capabilities. This hybrid approach enabled both sophisticated data manipulation and accessible visualization of urban complaint patterns.

Data Processing Framework

The initial modeling stage established a sequential data processing framework implemented in Python. This framework addressed the complexity of handling multiple data sources while ensuring consistency in analytical outputs. The processing sequence began with systematic loading of annual datasets, progressing through standardization procedures to create a unified analytical base.

Feature Engineering Framework

The model incorporated several engineered features to enhance analytical capabilities. Temporal enrichment introduced calendar-based features, including holiday periods, seasonal markers, and standardized time units from weekly to yearly aggregations. Spatial enhancement implemented a dual-level geographic representation, combining precise complaint locations with clustered representations for different analysis scales.

Categorical Standardization Model

A hierarchical classification model was developed to standardize complaint categories across the organizational structure. This model aligned complaint types with municipal administrative units, creating logical groupings based on the Lisbon City Council’s organizational structure. The classification framework supported both detailed operational tracking and high-level strategic analysis.

Spatial Analysis Model

The spatial modeling component implemented a dual-approach framework. The first level maintained precise geographic coordinates for detailed operational analysis, while the second level introduced clustered representations for strategic overview. This approach enabled both drill-down capability for specific complaint investigation and aggregated views for pattern recognition.

Integration Architecture

The integration model established a structured approach to combining multiple data sources while preserving critical operational information. This architecture utilized left outer join methodology, prioritizing the retention of status tracking and temporal resolution data. The model maintained referential integrity through systematic foreign key implementation across fact and dimension tables.

Performance Metrics Framework

A comprehensive metrics framework was developed to support operational monitoring and strategic analysis. This framework included standardized calculations for active complaint tracking, service workload assessment, and resolution time analysis. The metrics model supported both real-time operational monitoring and historical performance analysis.

Dimensional Modeling

The analytical framework implemented a dimensional model optimized for urban complaint analysis. This structure organizes data across core dimensions including time, geography, administrative units, and complaint categories. The dimensional framework supported flexible analysis across different organizational perspectives while maintaining data consistency.

Multilingual Support Model

If needed, the implementation included a translation framework supporting both Portuguese and English interfaces. This model enabled consistent analytical representation across language preferences while maintaining standardized categorical classifications and metrics calculations.

Data Categorization Framework

The model implemented a structured categorization framework across eight core urban management areas, from environmental issues to public safety concerns. This framework supported both broad pattern analysis and detailed investigation within specific urban management domains while maintaining consistent analytical approaches across categories.

Through these modeling components, the implementation created a robust analytical framework capable of processing complex urban complaint data while supporting accessible insight generation. The combination of sophisticated data processing and structured visualization frameworks enables both operational monitoring and strategic analysis of urban complaints.

3.5. CRISP-DM Phase 4: Modeling

The modeling phase focuses on developing analytical capabilities that address the complex requirements of urban complaint management across multiple organizational levels. This phase implemented a multi-layered analytical approach designed to support both operational and strategic decision-making processes within Lisbon's urban governance framework.

Service Performance Analysis Model

The primary analytical model centers on service performance measurement, incorporating multiple dimensions of complaint management. The model processes historical complaint data to generate comprehensive performance metrics, including resolution rates, average response times, and service workload distributions. This analytical framework enables the evaluation of service efficiency across different administrative units while accounting for varying operational contexts and resource constraints.

Temporal Pattern Recognition

The temporal analysis model examines complaint patterns across different time scales, from daily fluctuations to long-term trends spanning multiple years. This model incorporates seasonal decomposition techniques to identify recurring patterns in urban issues, enabling more accurate resource planning and allocation. By analyzing historical data from 2018 onwards, the model provides insights into evolving urban challenges and helps predict future service demands.

Spatial Distribution Analysis

The spatial analysis component employs two distinct modeling approaches to understand the geographic distribution of urban complaints. The first approach utilizes spatial clustering techniques to identify areas with high complaint concentrations, supporting strategic resource allocation and preventive maintenance planning. The second approach focuses on precise location mapping, enabling detailed analysis of specific urban areas and supporting tactical response planning.

Workload Distribution Model

A specialized analytical model was developed to understand and optimize workload distribution across different municipal directorates and service units. This model analyzes active complaints, service capacity, and resolution times to provide insights into resource utilization and operational efficiency. The approach accounts for the distinct operational parameters of different organizational units while maintaining a coherent analytical framework.

Integration Framework

The modeling phase implemented an integration framework that ensures seamless interaction between different analytical components. This framework enables cross-dimensional analysis by combining temporal, spatial, and organizational aspects of urban complaints. The integrated approach supports comprehensive understanding of urban issues while maintaining analytical consistency across different organizational levels.

Performance Monitoring System

A systematic performance monitoring model was developed to track key operational indicators across all service levels. This model processes real-time data to generate updated performance metrics, enabling continuous monitoring of service delivery effectiveness. The approach incorporates multiple performance dimensions, from individual case tracking to aggregate service level assessment.

Model Validation Approach

The validation process incorporated multiple stages to ensure analytical reliability. Historical data was used to validate temporal pattern recognition accuracy, while spatial analysis models were validated through comparison with known urban issue hotspots. The workload distribution model underwent validation through comparison with actual service delivery patterns and resource utilization data.

3.6. CRISP-DM Phase 5: Evaluation

The evaluation phase proposes an assessment framework for the visualization dashboard's capabilities using historical data from the 'Na Minha Rua' platform. The proposed evaluation approach considers the different types of urban issues and varying data volumes present in the historical dataset.

Technical evaluation focused on testing the data processing components using historical datasets of different sizes. The dashboard processed both large datasets representing primary service areas and smaller datasets from specialized services, demonstrating the proposed framework's potential to handle varying data volumes while maintaining consistent visualization performance.

The core visualization components, including spatial representation, temporal pattern display, and performance metric visualization, were tested with historical data to assess their functionality. The dashboard design allows for viewing different metrics and data representations, maintaining a consistent visual structure while accommodating different data exploration needs.

Testing with historical 'Na Minha Rua' platform data demonstrated the dashboard's compatibility with existing data structures. The evaluation confirmed the visualization framework's ability to process and display the available data types, though actual integration would require further validation in an operational context.

The evaluation process identified potential areas for future enhancement of the visualization capabilities. While the current design provides general visualization features, the framework could be expanded to include additional visualization components based on specific operational requirements.

This evaluation approach suggests that the proposed dashboard provides a foundation for urban complaints visualization, though further assessment would be needed in an actual operational environment. The framework maintains flexibility for future enhancements while providing basic visualization capabilities for urban service data.

3.7. CRISP-DM Phase 6: Deployment

The deployment phase outlines potential steps for future implementation of the visualization dashboard in Lisbon's urban governance context. While the proposed dashboard provides fundamental visualization capabilities, its value would lie in serving as a starting point for future development and customization based on operational needs.

The proposed deployment approach could begin with a pilot phase to understand practical requirements in greater depth. This initial phase would focus on testing basic visualization capabilities and identifying potential areas for enhancement. Such an approach would view the dashboard not as a final solution, but as a foundation for iterative development.

Through potential implementation across different urban management areas, from Urban Hygiene to Environmental Management, the dashboard could reveal additional visualization needs not apparent in the initial design. Each operational area's specific context might require different visualization approaches or data presentation methods.

Future development could include:

- Refinement of visualization components based on operational feedback
- Additional data representation options for different urban issues.
- Customized dashboard views for specific operational areas.
- Enhanced data exploration capabilities.
- Integration capabilities with existing systems.

The visualization framework could potentially evolve to include:

- Advanced data visualization options.
- Customized reporting layouts.
- Enhanced pattern display capabilities.
- Additional data representation methods.
- Expanded visual exploration features.

A systematic approach to future enhancement could include:

- Regular assessment of visualization effectiveness.
- Identification of new data representation needs.
- Prioritization of visualization feature development.
- Integration of new data sources.
- Expansion of display capabilities.

While the current design provides basic visualization capabilities, future developments could address specific operational needs. This might include specialized visualization modules for different urban management areas or custom display options for specific data types.

The proposed deployment approach suggests how the visualization dashboard could evolve from its current basic framework into a more comprehensive visualization tool. Such evolution would depend on practical implementation experience and operational requirements identified during actual use.

CHAPTER 4

Overview of Dashboard Implementation

4.1. Overview

The analytical dashboard employs a hierarchical navigation structure that systematically reveals insights across organizational levels through specialized visualization components and analytical tools. This multi-tiered approach supports decision-making at varying operational scales while maintaining coherent data presentation.

The home view establishes a comprehensive overview through three primary service categories, with the CML section at its core, as presented in Figure 3. This section presents standardized municipal performance metrics, including active complaint volumes, service workload percentages, and daily operational load measurements. The interface extends parallel visualization components to both the JF section and external entities, facilitating direct operational pattern comparison while maintaining consistent measurement methodologies.

At the organizational level, selecting specific services reveals a second tier of analysis focused on municipal directorates, as presented in Figure 4, Figure 5 and Figure 6. This level preserves visualization consistency while providing directorate-specific context through standardized performance indicators, comparative metrics, operational load measurements, and service efficiency assessments.

The department-specific dashboard, exemplified by the Environmental Directorate implementation, offers detailed analysis through comprehensive visualization components. The performance panel integrates active case tracking, resolution rates, processing time metrics, and daily intake monitoring. This granular view enables thorough operational assessment while maintaining connection to broader organizational contexts, as presented in the figures from Figure 7 to Figure 15.

Geographical analysis implements dual mapping functionality, combining strategic clustered representations for pattern analysis with precise location mapping for incident management. Both views incorporate interactive exploration capabilities through zoom and selection tools, enabling detailed spatial investigation of urban issues, as presented in figures from Figure 16 to Figure 25.

The temporal analysis framework encompasses historical trend visualization, seasonal pattern recognition, period-over-period comparisons, and timeline-based pattern analysis. These tools provide comprehensive temporal context for urban complaint patterns and operational responses.

Interactive control elements enhance user interaction through temporal range selection, departmental filtering, category classification, status monitoring, and geographic area definition. These controls enable focused analysis of specific operational aspects while maintaining broader contextual awareness.

The dashboard emphasizes intuitive navigation through clear hierarchical progression, consistent analytical frameworks, and maintained context during detailed analysis. This integration extends across all levels, incorporating performance metrics, temporal pattern analysis, spatial distribution visualization, and operational status tracking into a cohesive analytical system.

This comprehensive implementation creates a unified platform for urban complaint analysis, supporting both strategic oversight and detailed operational management. The system's integrated approach ensures consistent analytical capabilities across organizational levels while maintaining flexibility for specific departmental needs.

CHAPTER 5

Conclusion

5.1. Reflection on research objectives and questions

This research sets out to answer the primary question: "How can an analytical tool be developed to effectively process and visualize civic complaints data from the 'Na Minha Rua' platform to support pattern recognition in urban governance?" The research outcomes can be examined through the lens of each objective

The first objective **O1** called for proposing a comprehensive visualization dashboard for civic complaints data. This objective was addressed through the development of a dashboard design that processes data from the 'Na Minha Rua' platform and presents it through visual components. The proposed framework includes capabilities for displaying spatial and temporal patterns, presenting statistical information through visual elements, and supporting data exploration for different planning horizons.

The second objective **O2** focused on developing specific visualization components. This was approached through the creation of mapping interfaces that display geographical distribution of reported issues, and the development of visualization components for historical data representation. These components enable users to explore spatial patterns and temporal trends in the complaint data through visual interfaces.

The third objective **O3** aimed to design a framework for visual data representation. This was addressed through the development of visualization approaches for complaint data, including components for presenting service delivery metrics and supporting data-informed decision making. The framework provides a foundation for exploring urban complaints data through visual interfaces while maintaining consistency in data representation.

The research addressed its primary question by proposing approaches for processing and visualizing civic complaints data. The developed dashboard demonstrates how visualization techniques, combined with systematic data processing, can support pattern recognition in urban governance data.

This reflection shows that while the objectives guided the development of visualization capabilities, further validation would be needed to assess their effectiveness in operational contexts. The research provides a foundation for future work in urban complaints visualization and data representation in governance contexts.

5.2. Significance of the study

The proposed visualization dashboard for 'Na Minha Rua' data represents a contribution to urban governance analytics, exploring the potential of data visualization in urban complaint management while contributing to smart city research. The study's significance spans multiple dimensions.

Technical Innovation

The study contributes to urban analytics by proposing an approach for integrating diverse visualization methods into a cohesive dashboard design. The proposed processing and visualization framework for handling large-scale urban complaints data (over seven hundred thousand records) explores approaches for developing accessible visualization tools. The combination of Python-based processing with Power BI visualization capabilities suggests a model for developing urban data visualization tools that could bridge technical capabilities with practical needs.

The proposed framework explores approaches for supporting data-informed decision-making in municipal operations through visualization. This approach could enhance visibility of service performance patterns while supporting evidence-based resource allocation considerations.

Knowledge Transfer Potential

The documented development process provides a reference for future smart city visualization projects. The modular design approach and visualization framework offer templates that could be adapted across different urban contexts. The research provides a structured approach to developing urban complaint visualization tools that could inform future municipal initiatives.

Potential Societal Impact

The research proposes approaches that could contribute to urban service delivery through enhanced data visibility and pattern recognition capabilities. The visualization framework's transparency features could support citizen-centered governance by making urban service patterns more visible. The proposed approaches could contribute to advancing data-informed urban governance practices.

Organizational Considerations

The proposed integration of different operational needs into a unified visualization framework suggests possibilities for standardized yet flexible approaches to urban data visualization. The framework's design considers varying operational scales, from high-volume services to specialized units, exploring approaches that could maintain departmental autonomy while providing consistent visualization capabilities.

Theoretical Contribution

The study contributes to theoretical understanding by proposing approaches for integrating visualization methods into urban governance frameworks. This exploration of visualization approaches in smart city development enhances our understanding of potential paths for data-informed urban management.

The study's significance lies in its proposed technical approaches, framework development for future urban governance visualization tools, and contribution to smart city research literature. Through this multi-dimensional approach, the research provides insights for future urban visualization initiatives while suggesting models for smart city development. The significance of this research has been recognized through the publication of "Urban Issue Reporting Applications Towards Government 2.0" at the 8th International Symposium on Multidisciplinary Studies and Innovative Technologies, supported by Tokat Gaziosmanpasa University and the Turkish Section of the IEEE.

5.3. Limitations and lessons learned

The development of the 'Na Minha Rua' visualization dashboard revealed several significant limitations that provide important insights for future urban analytics initiatives.

Data Availability and Quality Limitations

The most fundamental limitation relates to data availability and citizen engagement with the platform. Given Lisbon's population of approximately 544,851 residents (as of 2021), the volume of collected complaints suggests limited citizen adoption of the platform. This relatively low engagement affects the comprehensiveness of urban issue reporting and potentially creates blind spots in urban problem identification. Additionally, significant discrepancies were observed between the data available for this research and the actual data collected in the application, suggesting potential gaps in data access and completeness.

Critical Data Structure Limitations

The dataset structure presented significant constraints, particularly the absence of unique identifiers for individual complaints in earlier records. This fundamental limitation impacts the ability to track complaint lifecycles effectively. Without unique identifiers, distinguishing between new and existing complaints proves challenging, complicating pattern recognition efforts. The later introduction of ID variables highlighted how this structural limitation affects data analysis capabilities.

Data Quality and Consistency Challenges

Historical data consistency presented another significant limitation. Variations in data collection methods across years created substantial challenges for longitudinal analysis. Categorical classifications showed inconsistencies over time, complicating trend identification and pattern recognition. These inconsistencies, combined with gaps in operational metrics across different periods, limit the ability to conduct comprehensive historical analysis.

Platform Adoption and User Satisfaction

A significant limitation identified through user feedback analysis is the platform's limited appeal to citizens, as evidenced by app store ratings in the Text Mining Analysis of 'Na Minha Rua' App Reviews, available publicly on the site https://github.com/joaomesoares/97787-joao-soares-MSIAD-2024. The AppleApp Store rating of 1.4 and Google Play Store rating of 2.5 indicate substantial user dissatisfaction. Further sentiment analysis using advanced natural language processing (RoBERTa) revealed potentially even lower satisfaction levels, with overall sentiment-based ratings of 1.93 (Google Play Store: 2.10, Apple App Store: 1.71).

This analysis also identified key problematic areas that limit the platform's effectiveness:

- Access and authentication issues.
- Technical limitations in photo attachment and GPS functionality.
- Inadequate issue resolution tracking.
- User interface challenges.
- Insufficient customer support responsiveness.

These findings suggest that beyond the data availability and stakeholder validation limitations discussed above, the platform faces significant user adoption challenges that could affect the quality and quantity of collected data.

Stakeholder Validation Limitations

A critical limitation of this research is the lack of stakeholder validation. The requirements and design choices were based solely on documentation analysis without direct input or validation from municipal stakeholders. This absence of stakeholder engagement means that the proposed visualization approaches have not been validated against actual operational needs or user preferences. The lack of direct communication with potential users limits our understanding of specific departmental requirements and use cases.

Requirements Definition Constraints

The reliance on document analysis for requirements definition, without direct stakeholder communication, presents significant limitations. While municipal documentation provided structural insights, the absence of direct stakeholder input means that specific operational needs, user preferences, and practical constraints may not be fully addressed in the dashboard design. This limitation potentially affects the practical utility of the proposed visualization approaches.

Technical Design Constraints

The proposed technical architecture reveals limitations in several areas. The visualization framework shows constraints in handling simultaneous display of multiple spatial dimensions and complex visualizations. These technical limitations affect the implementation of sophisticated pattern recognition displays and restrict the integration of diverse data sources.

Development Process Insights

The process highlighted the importance of comprehensive initial data assessment and documentation analysis. However, the absence of stakeholder engagement throughout the development process limits the validation of design decisions and requirement interpretations. These insights suggest that future implementations should prioritize both thorough data analysis and active stakeholder involvement.

Documentation Importance

The research emphasized the importance of systematic documentation of both limitations and proposed solutions. This documentation process supports knowledge transfer and helps identify potential challenges for future implementations. The value of creating comprehensive records of technical constraints and design decisions became evident throughout the development process.

Through these limitations and lessons, the research provides insights for future urban analytics initiatives. The experience highlights the complexities involved in developing visualization tools for urban governance while identifying crucial areas requiring attention in similar future projects.

5.4. Future research directions

The implementation of the ‘Na Minha Rua’ analytical tool has identified several promising directions for future research and development. These directions focus on expanding analytical capabilities, enhancing operational effectiveness, and advancing urban governance practices.

Expanded Data Collection

Collaboration with the Lisbon City Council presents immediate opportunities for data enrichment. Access to user-submitted images of occurrences would provide crucial visual context for reported issues, enabling more accurate assessment of problem severity and required responses. Similarly, obtaining detailed reference points and user descriptions would enhance spatial analysis accuracy and contextual understanding. This expanded dataset would support more nuanced analysis of urban issues and enable more precise resource allocation decisions.

Priority Framework Development

A critical research direction involves working with municipal departments to develop standardized priority classification systems. This research would analyze historical patterns and operational constraints to create evidence-based priority frameworks for different occurrence types. Establishing expected response times for each case type represents another vital area for investigation, requiring analysis of historical resolution patterns and operational capabilities to set realistic service delivery targets.

Department-Specific Analytics

Future research should explore the development of specialized analytical modules tailored to each department's unique operational context. This involves studying departmental workflows, identifying specific performance indicators, and creating customized visualization approaches aligned with different decision-making processes.

Pattern Recognition Advancement

Research into advanced pattern recognition capabilities could focus on identifying complex relationships between urban issues, temporal patterns, and spatial distributions. This direction would involve developing sophisticated algorithms capable of detecting subtle patterns that might indicate emerging urban challenges.

Predictive Modeling Integration

Development of predictive analytics capabilities represents a significant research opportunity. This would involve investigating machine learning approaches for forecasting complaint volumes, identifying potential problem areas, and anticipating resource needs, transforming urban management from reactive to proactive approaches.

Real-Time Processing Enhancement

Investigation into enhanced real-time monitoring capabilities presents another valuable research direction. This would explore methods for faster data processing, development of early warning systems, and implementation of automated alert mechanisms for emerging issues.

Municipal Systems Integration

Research into methods for integrating the analytical tool with other municipal systems represents an important direction. This includes exploring data exchange protocols and developing standardized interfaces for cross-system communication.

Data Structure Standardization

Investigation into standardized data structures could facilitate better integration of different data sources while maintaining analytical capabilities. This research would focus on developing flexible yet consistent approaches to data organization and management. Through these research directions, the analytical tool could evolve to better serve urban governance needs while contributing to the broader field of urban analytics. These pathways for future development would not only enhance operational effectiveness but also advance our understanding of data-driven urban management approaches.

References

[1] “naminharuaLX GOPI Gestão e Pedidos de Intervenção de Ocorrências em Lisboa.” Accessed: Sep. 22, 2024. [Online]. Available: https://naminharualx.cm-lisboa.pt/

[2] “CRISP-DM for Data Science: Strengths, Weaknesses and Potential Next Steps | IEEE Conference Publication | IEEE Xplore.” Accessed: Oct. 30, 2024. [Online]. Available: https://ieeexplore.ieee.org/document/9671634

[3] “What is CRISP DM? - Data Science Process Alliance.” Accessed: Oct. 30, 2024. [Online]. Available: https://www.datascience-pm.com/crisp-dm-2/

[4] M. J. Page *et al.*, “The PRISMA 2020 statement: an updated guideline for reporting systematic reviews,” *BMJ*, vol. 372, p. n71, Mar. 2021, doi: 10.1136/bmj.n71.

[5] “Scopus preview - Scopus - Welcome to Scopus.” Accessed: Oct. 30, 2024. [Online]. Available: https://www.scopus.com/home.uri

[6] “Clarivate.” Accessed: Oct. 30, 2024. [Online]. Available: https://access.clarivate.com/login?app=wos&alternative=true&shibShireURL=https:%2F%2Fwww.webofknowledge.com%2F%3Fauth%3DShibboleth&shibReturnURL=https:%2F%2Fwww.webofknowledge.com%2F&roaming=true

[7] J. Yang, T. Lee, and W. Zhang, “Smart Cities in China: A Brief Overview,” *IT PROFESSIONAL*, vol. 23, no. 3, pp. 89–94, May 2021, doi: 10.1109/MITP.2020.2993946.

[8] D. Ludlow and ACM, “Smart City: Challenges and Opportunities- Experiences from European Smart Cities Projects,” in *University of West England*, 2017, pp. 165–165. doi: 10.1145/3147234.3148090.

[9] “smarticipate – Opening up the smart city.” Accessed: Oct. 30, 2024. [Online]. Available: https://www.smarticipate.eu/

[10] “urbanApi: Urban planning tools and intelligence for integrated urban governance - Projects | UWE Bristol.” Accessed: Oct. 30, 2024. [Online]. Available: https://www.uwe.ac.uk/research/centres-and-groups/spe/projects/urbanapi

[11] “URBIS | arquitectura | urbanismo | engenharias.” Accessed: Oct. 30, 2024. [Online]. Available: https://urbis.pt/web/

[12] “The DECUMANUS Project,” Decumanus. Accessed: Oct. 30, 2024. [Online]. Available: http://decumanus.cat/en/

[13] J. Kandt and M. Batty, “Smart cities, big data and urban policy: Towards urban analytics for the long run,” *Cities*, vol. 109, 2021, doi: 10.1016/j.cities.2020.102992.

[14] I. Sarker, “Smart City Data Science: Towards data-driven smart cities with open research issues,” *INTERNET OF THINGS*, vol. 19, Aug. 2022, doi: 10.1016/j.iot.2022.100528.

[15] C. Sharma, I. Batra, S. Sharma, A. Malik, A. Hosen, and I. Ra, “Predicting Trends and Research Patterns of Smart Cities: A Semi-Automatic Review Using Latent Dirichlet Allocation (LDA),” *IEEE ACCESS*, vol. 10, pp. 121080–121095, 2022, doi: 10.1109/ACCESS.2022.3214310.

[16] N. Monios, N. Peladarinos, V. Cheimaras, P. Papageorgas, and D. Piromalis, “A Thorough Review and Comparison of Commercial and Open-Source IoT Platforms for Smart City Applications,” *ELECTRONICS*, vol. 13, no. 8, Apr. 2024, doi: 10.3390/electronics13081465.

[17] K. Desouza and A. Bhagwatwar, “Citizen Apps to Solve Complex Urban Problems,” *Journal of Urban Technology*, vol. 19, Jul. 2012, doi: 10.1080/10630732.2012.673056.

[18] Y. Yüksekdağ, “Commodification, datafication and smart cities: An ethical exploration,” *J. Urban Aff.*, 2024, doi: 10.1080/07352166.2024.2309290.

[19] L. Hagen, H. Yi, S. Pietri, and T. Keller, “Processes, Potential Benefits, and Limitations of Big Data Analytics: A Case Analysis of 311 Data from City of Miami,” in *State University System of Florida*, Y. Chen, F. Salem, and A. Zuiderwijk, Eds., 2019, pp. 1–10. doi: 10.1145/3325112.3325212.

[20] R. Sandoval-Almazan, J. R. Gil-Garcia, L. F. Luna-Reyes, D. E. Luna, and Y. Rojas-Romero, “Open government 2.0: citizen empowerment through open data, web and mobile apps,” in *Proceedings of the 6th International Conference on Theory and Practice of Electronic Governance*, Albany New York USA: ACM, Oct. 2012, pp. 30–33. doi: 10.1145/2463728.2463735.

[21] F. Gamboa, M. A. Malamud, A. G. Maguitman, and C. I. Chesñevar, “Citymis OpTree: Intelligent Citizen Management Using Sentiment Analysis and Opinion Trees,” in *Proceedings of the 9th International Conference on Theory and Practice of Electronic Governance*, Montevideo Uruguay: ACM, Mar. 2016, pp. 250–253. doi: 10.1145/2910019.2910040.

[22] T. Nam and T. A. Pardo, “Exploring 311-driven changes in city government,” in *18th Amer. Conf. Inf. Sys. 2012, AMCIS 2012*, 2012, pp. 2534–2546. [Online]. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84877871656&partnerID=40&md5=632def6faf85c5ceb0eab659478083de

[23] “FixMyStreet,” FixMyStreet. Accessed: Sep. 22, 2024. [Online]. Available: https://www.fixmystreet.com/

[24] J. Soares and C. Coutinho, “Urban Issue Reporting Applications Towards Government 2.0”.

[25] S. Cheng, S. Ganapati, G. Narasimhan, and F. B. Yusuf, "A machine learning-based analysis of 311 requests in the Miami-Dade County," *Growth Change*, vol. 53, no. 4, pp. 1627–1645, 2022, doi: 10.1111/grow.12578.

[26] A. Dumrewal, A. Basu, S. Atreja, P. Mohapatra, P. Aggarwal, and G. B. Dasgupta, "CitiCafe: Conversation-based intelligent platform for citizen engagement," in *ACM Int. Conf. Proc. Ser.*, Association for Computing Machinery, 2018, pp. 180–189. doi: 10.1145/3152494.3152511.

[27] K. Yadav *et al.*, "Human sensors: Case-study of open-ended community sensing in developing regions," in *IEEE Int. Conf. Pervasive Comput. Commun. Workshops, PerCom Workshops*, 2013, pp. 389–392. doi: 10.1109/PerComW.2013.6529523.

[28] H. Kopackova, P. Libalova, and IEEE, "Citizen reporting as the form of e-participation in smart cities," in *University of Pardubice*, 2019. doi: 10.23919/cisti.2019.8760931.

[29] Z. Dong, X. Lv, Z. Zhang, and X. Li, "Subject extraction method of urban complaint data," in *Beijing Information Science & Technology University*, X. Wu, T. Ozsu, J. Hendler, and R. Lu, Eds., 2017, pp. 179–182. doi: 10.1109/ICBK.2017.11.

[30] C. Wang, G. Chen, and Y. Liang, "Spatiotemporal Evolution and Influencing Factors of Urban Industry in Modern China (1840-1949): A Case Study of Nanjing," *ISPRS INTERNATIONAL JOURNAL OF GEO-INFORMATION*, vol. 13, no. 5, May 2024, doi: 10.3390/ijgi13050144.

[31] B. Du, Y. Wang, J. He, W. Li, and X. Chen, "Spatio-temporal characteristics and obstacle factors of the urban-rural integration of china's shrinking cities in the context of sustainable development," *Sustainability*, vol. 13, no. 8, 2021, doi: 10.3390/su13084203.

[32] I. Nti, J. Quarcoo, J. Aning, and G. Fosu, "A Mini-Review of Machine Learning in Big Data Analytics: Applications, Challenges, and Prospects," *BIG DATA MINING AND ANALYTICS*, vol. 5, no. 2, pp. 81–97, Jun. 2022, doi: 10.26599/BDMA.2021.9020028.

[33] I. Ajah and H. Nweke, "Big Data and Business Analytics: Trends, Platforms, Success Factors and Applications," *BIG DATA AND COGNITIVE COMPUTING*, vol. 3, no. 2, Jun. 2019, doi: 10.3390/bdcc3020032.

[34] W.-N. Wu, "Determinants of citizen-generated data in a smart city: Analysis of 311 system user behavior," *Sustainable Cities Soc.*, vol. 59, 2020, doi: 10.1016/j.scs.2020.102167.

[35] M. Zook, "Crowd-sourcing the smart city: Using big geosocial media metrics in urban governance," *BIG DATA & SOCIETY*, vol. 4, no. 1, pp. 1–13, May 2017, doi: 10.1177/2053951717694384.

[36] M. Griffin *et al.*, "A case study: Analyzing city vitality with four pillars of activity - Live, work, shop, and play," *Big Data*, vol. 4, no. 1, pp. 60–66, 2016, doi: 10.1089/big.2015.0043.

[37] "Downtown Seattle Association." Accessed: Oct. 30, 2024. [Online]. Available: https://downtownseattle.org/

[38] R. B. Hubert, A. G. Maguitman, C. I. Chesñevar, M. A. Malamud, and M. Management, "CitymisVis: A Tool for the visual analysis and exploration of citizen requests and complaints," presented at the ACM International Conference Proceeding Series, 2017, pp. 22–25. doi: 10.1145/3047273.3047320.

[39] R. Kitchin, "The real-time city? Big data and smart urbanism," *GeoJournal*, vol. 79, no. 1, pp. 1–14, 2014, doi: 10.1007/s10708-013-9516-8.

[40] V. Tsakanikas, G. Rokkou, and V. Triantafyllou, "Toward E-Deliberation 2.0," 2022, pp. 229–246. doi: 10.1007/978-3-030-97818-1_14.

[41] L. Muñoz, M. Bolívar, and ACM, "Tools Used by Citizens for Participation in European Smart Cities," in *University of Granada*, A. Zuiderwijk and C. Hinnant, Eds., 2018, pp. 783–784. doi: 10.1145/3209281.3225220.

[42] S. Thiel, U. Lehner, and ACM, "Exploring the effects of game elements in m-participation," presented at the BRITISH HCI 2015, 2015, pp. 65–73. doi: 10.1145/2783446.2783587.

[43] D. Martinez-Mosquera, L. Recalde, and C. Tipantuna, "Building Cognitive Cities in Developing Countries: Ecuador Case Study," in *Escuela Politecnica Nacional Ecuador*, C. Vaca, D. Riofrio, J. Pincay, and L. Teran, Eds., 2023, pp. 115–120. doi: 10.1109/ICEDEG58167.2023.10121914.

[44] M. Cerioli and M. Ribaudo, "Civic Participation Powered by Ethereum: a Proposal," in *University of Genoa*, S. Marr and W. Cazzola, Eds., 2019. doi: 10.1145/3328433.3328449.

[45] O. Fedotova, L. Teixeira, and H. Alvelos, "E-participation in Portugal: evaluation of government electronic platforms," *Procedia Technology*, vol. 5, pp. 152–161, Jan. 2012, doi: 10.1016/j.protcy.2012.09.017.

[46] M. Suleimany, "Smart Urban Management and IoT; Paradigm of E-Governance and Technologies in Developing Communities," in *Proc. Int. Conf. Internet Things Appl., IoT*, Institute of Electrical and Electronics Engineers Inc., 2021. doi: 10.1109/IoT52625.2021.9469713.

[47] F. Oschinsky, H. Klein, and B. Niehaves, "Invite everyone to the table, but not to every course. How Design-Thinking collaboration can be implemented in smart cities to design digital urban services How Design-Thinking collaboration can be implemented in smart cities to design digital services," *ELECTRONIC MARKETS*, vol. 32, no. 4, pp. 1925–1941, Dec. 2022, doi: 10.1007/s12525-022-00567-7.

[48] “Lisboa.pt - Website oficial do Município.” Accessed: Oct. 30, 2024. [Online]. Available: https://www.lisboa.pt/

[49] “LxDataLab,” LISBOA ABERTA. Accessed: Sep. 22, 2024. [Online]. Available: https://lisboaaberta.cm-lisboa.pt/index.php/pt/lx-data-lab/apresentacao

[50] “Organização, Composição Social e Funcionamento Câmara Municipal de Lisboa.” Accessed: Oct. 30, 2024. [Online]. Available: https://transparencia.lisboa.pt/organizacao-e-governacao

Appendix A: Research Queries and Keywords

Theme 1: Data-driven urban governance

- Evolution of urban management practices
- Concepts of smart cities and data-driven decision making
- Ethical considerations in using citizen-generated data

Data-Driven Urban Governance Keywords: "data-driven urban governance", "smart cities", "urban data analytics", "ethical data use in cities"

Scopus Query:

- TITLE-ABS-KEY(("data-driven urban governance" OR "urban data analytics" OR "smart cities") AND ("ethical data use" OR "citizen-generated data"))
  - o TITLE-ABS-KEY(("data-driven urban governance" OR "urban data analytics" OR "smart cities") AND ("ethical data use" OR "citizen-generated data")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"SOCI")) AND (LIMIT-TO (LANGUAGE,"English"))
- TITLE-ABS-KEY(("urban management" AND "smart cities") AND ("data governance" OR "ethical data use"))
  - o TITLE-ABS-KEY(("urban management" AND "smart cities") AND ("data governance" OR "ethical data use")) AND (LIMIT-TO (SUBJAREA,"SOCI")) AND (LIMIT-TO (LANGUAGE,"English"))
- TITLE-ABS-KEY(("smart city" OR "urban governance") AND ("data-driven" AND "urban analytics" OR "ethics"))
  - o TITLE-ABS-KEY(("smart city" OR "urban governance") AND ("data-driven" AND "urban analytics" OR "ethics")) AND (LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"COMP")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SRCTYPE,"j") OR LIMIT-TO (SRCTYPE,"p"))

Web of Science Query:

- TS=("data-driven urban governance" OR "smart cities" OR "urban data analytics") AND TS=("ethical data use" OR "citizen-generated data")
- TS=("urban governance" AND "smart cities") OR TS=("evolution of urban management" OR "ethics in data")
  - o TS=("urban governance" AND "smart cities") OR TS=("evolution of urban management" OR "ethics in data") and English (Languages) and 2015 or 2014 or 2013 or 2012

(Exclude – Publication Years) and Computer Science Information Systems (Web of Science Categories)

• TS=("smart cities" OR"data-driven governance" OR "government 2.0") OR TS=("urban management practices" OR "citizen data ethics")

o TS=("smart cities" OR"data-driven governance") OR TS=("government 2.0") AND TS=("urban management practices" OR "citizen data ethics") and Computer Science Information Systems (Web of Science Categories) and Computer Science Information Systems (Web of Science Categories) and English or Portuguese (Languages) and Computer Science Information Systems (Web of Science Categories) and 2024 or 2023 or 2022 or 2021 or 2020 (Publication Years) and 4.13.807 Internet Of Things (Citation Topics Micro) and Review Article or Early Access (Document Types)

Theme 2: Urban Complaint Management Systems

• Overview of traditional and digital complaint management approaches

• Case studies of similar platforms worldwide

• Effectiveness and limitations of digital complaint systems

Urban Complaint Management Systems Keywords: "urban complaint management", "citizen reporting systems", "311 services", "311 Espaços do Cidadão", "digital urban services"

Scopus Query:

• TITLE-ABS-KEY(("Civic Complaint" OR "Urban Complaint") OR ("digital urban services"))

o TITLE-ABS-KEY(("Civic Complaint" OR "Urban Complaint") OR ("digital urban services")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"DECI")) AND (LIMIT-TO (LANGUAGE,"English"))

• TITLE-ABS-KEY(("urban complaints" OR "311 services") AND ("effectiveness" OR "limitations"))

o TITLE-ABS-KEY(("urban complaints" OR "311 services") AND ("effectiveness" OR "limitations")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"DECI") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI"))

Web of Science Query:

• TS=("Civic Complaint" OR "Urban Complaint") OR TS=("digital urban services")

• TS=("urban complaints" OR "311 services" OR "311 request") AND TS=("effectiveness" OR "limitations")

Theme 3: Spatial and Temporal Analysis in Urban Studies

• Theories and methods in urban spatial analysis

• Temporal patterns in urban phenomena

• Integration of spatial and temporal dimensions in urban studies

Spatial and Temporal Analysis in Urban Studies Keywords: "spatial analysis urban", "temporal patterns cities", "GIS urban studies", "spatiotemporal urban analysis"

Scopus Query:

• TITLE-ABS-KEY(("spatial analysis" AND "urban studies") AND ("temporal patterns" OR "GIS"))

o TITLE-ABS-KEY(("spatial analysis" AND "urban studies") AND ("temporal patterns" OR "GIS")) AND (LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"ENVI")) AND (LIMIT-TO (LANGUAGE,"English"))

• TITLE-ABS-KEY(("spatiotemporal urban analysis" OR "spatial patterns") AND ("urban studies" AND "GIS"))

o TITLE-ABS-KEY(("spatiotemporal urban analysis" OR "spatial patterns") AND ("urban studies" AND "GIS")) AND (LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"SOCI")) AND (LIMIT-TO (LANGUAGE,"English"))

• TITLE-ABS-KEY(("spatial analysis" AND "temporal patterns") AND ("urban areas" OR "urban studies"))

o TITLE-ABS-KEY(("spatial analysis" AND "temporal patterns") AND ("urban areas" OR "urban studies")) AND (LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"COMP")) AND (LIMIT-TO (LANGUAGE,"Portuguese") OR LIMIT-TO (LANGUAGE,"English"))

Web of Science Query:

• TS=("spatial analysis" OR "temporal patterns") AND TS=("urban studies" AND "GIS")

o TS=("spatial analysis" OR "temporal patterns") AND TS=("urban studies" AND "GIS") and 2014 or 1997 (Exclude – Publication Years) and English (Languages)

• TS=("spatiotemporal urban analysis" OR "spatial analysis") AND TS=("urban theory" OR "spatial dimensions") o TS=("spatiotemporal urban analysis" OR "spatial analysis") AND TS=("urban theory" OR "spatial dimensions") and 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 or 2007 or 2005 or 2002 (Exclude – Publication Years) and English (Languages) and Urban Studies or Regional Urban Planning or Computer Science Information Systems (Web of Science Categories)

• TS=("urban studies" OR "spatiotemporal patterns") AND TS=("GIS" OR "temporal analysis")

- TS=("urban studies" OR "spatiotemporal patterns") AND TS=("GIS" OR "temporal analysis") and 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2008 or 2007 or 2006 or 2005 or 2002 or 2000 or 1998 or 1997 or 1995 or 1994 or 1993 (Exclude – Publication Years) and English (Languages) and Computer Science Information Systems (Web of Science Categories)

Theme 4: Data Analytics in Urban Planning

• Overview of data analytics techniques relevant to urban planning

• Applications of business intelligence tools in urban governance

• Challenges in implementing data-driven governance

Data Analytics in Urban Planning Keywords: "urban planning analytics", "business intelligence urban governance", "big data city planning", "predictive analytics urban"

Scopus Query:

• TITLE-ABS-KEY(("urban planning analytics" OR "data analytics") AND ("urban governance"))

o TITLE-ABS-KEY(("urban planning analytics" OR "data analytics") AND ("urban governance")) AND (LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"COMP")) AND (LIMIT-TO (LANGUAGE,"English"))

• TITLE-ABS-KEY(("big data" AND "city planning") AND ("predictive analytics" OR "urban management"))

o TITLE-ABS-KEY(("big data" AND "city planning") AND ("predictive analytics" OR "urban management")) AND PUBYEAR > 2015 AND PUBYEAR < 2021 AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"DECI")) AND (LIMIT-TO (LANGUAGE,"English"))

- TITLE-ABS-KEY(("urban governance" AND "data analytics") AND ("challenges" OR "business intelligence"))
  - o TITLE-ABS-KEY(("urban governance" AND "data analytics") AND ("challenges" OR "business intelligence")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI")) AND (LIMIT-TO (LANGUAGE,"English"))

Web of Science Query:

- TS=("urban planning analytics" OR "data analytics" OR "predictive analytics") AND TS=("urban governance" OR "business intelligence")
  - o TS=("urban planning analytics" OR "data analytics" OR "predictive analytics") AND TS=("urban governance" OR "business intelligence") and 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 or 2007 or 2005 (Exclude – Publication Years) and Portuguese or English (Languages) and Computer Science Information Systems (Web of Science Categories) and Review Article or Early Access (Document Types)
- TS=("big data" AND "city planning") AND TS=("urban governance" OR "data-driven challenges")

Theme 5: Civic Engagement through Digital Platforms

- Impact of technology on citizen participation
- Challenges and opportunities in digital civic engagement
- The role of citizen-generated data in urban decision-making

Civic Engagement through Digital Platforms Keywords: "digital civic engagement", "e-participation urban", "citizen-generated urban data", "smart city participation"

Scopus Query:

- TITLE-ABS-KEY(("digital civic engagement" OR "e-participation") AND ("urban governance" AND "smart cities"))
  - o TITLE-ABS-KEY(("digital civic engagement" OR "e-participation") AND ("urban governance" AND "smart cities")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI")) AND (LIMIT-TO (LANGUAGE,"English"))
- TITLE-ABS-KEY(("citizen-generated data" OR "civic engagement") AND ("smart cities" AND "digital platforms"))

o TITLE-ABS-KEY(("citizen-generated data" OR "civic engagement") AND ("smart cities" AND "digital platforms")) AND (LIMIT-TO (SUBJAREA,"COMP") OR LIMIT-TO (SUBJAREA,"SOCI")) AND (LIMIT-TO (LANGUAGE,"English"))

• TITLE-ABS-KEY(("digital platforms" OR "civic engagement") AND ("urban governance" AND "e-participation"))

o TITLE-ABS-KEY(("digital platforms" OR "civic engagement") AND ("urban governance" AND "e-participation")) AND (LIMIT-TO (SUBJAREA,"COMP")) AND (LIMIT-TO (LANGUAGE,"English"))

Web of Science Query:

• TS=("digital civic engagement" OR "e-participation") AND TS=("smart cities" OR "urban governance")

o TS=("digital civic engagement" OR "e-participation") AND TS=("smart cities" OR "urban governance") and 2015 or 2004 (Exclude – Publication Years) and English or Portuguese (Languages) and Social Sciences Interdisciplinary or Computer Science Information Systems (Web of Science Categories)

• TS=("citizen-generated data" OR "civic participation") AND TS=("digital platforms" OR "smart cities")

o TS=("citizen-generated data" OR "civic participation") AND TS=("digital platforms" OR "smart cities") and 2013 or 2014 (Exclude – Publication Years) and English (Languages) and Enriched Cited References

• TS=("digital platforms" OR "civic engagement") AND TS=("urban governance" AND "e-participation")

Appendix B: Urban Complaint Management Dashboard - Interface Documentation

This appendix presents the look & feel of the developed proposal for Urban Complaint Management Dashboard.

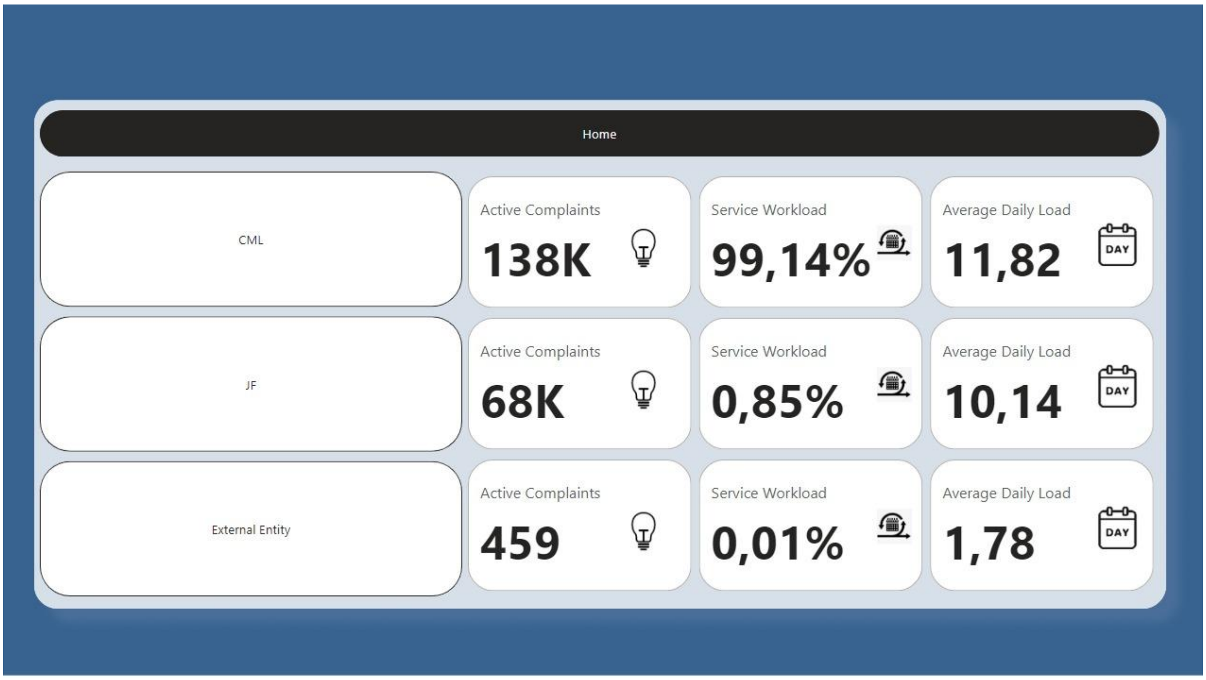

Figure 3- Municipal Service Monitoring Dashboard - Organizational Overview - A streamlined homepage display showing key performance metrics across three organizational units (CML, JF, and External Entity), tracking active complaints, service workload percentages.

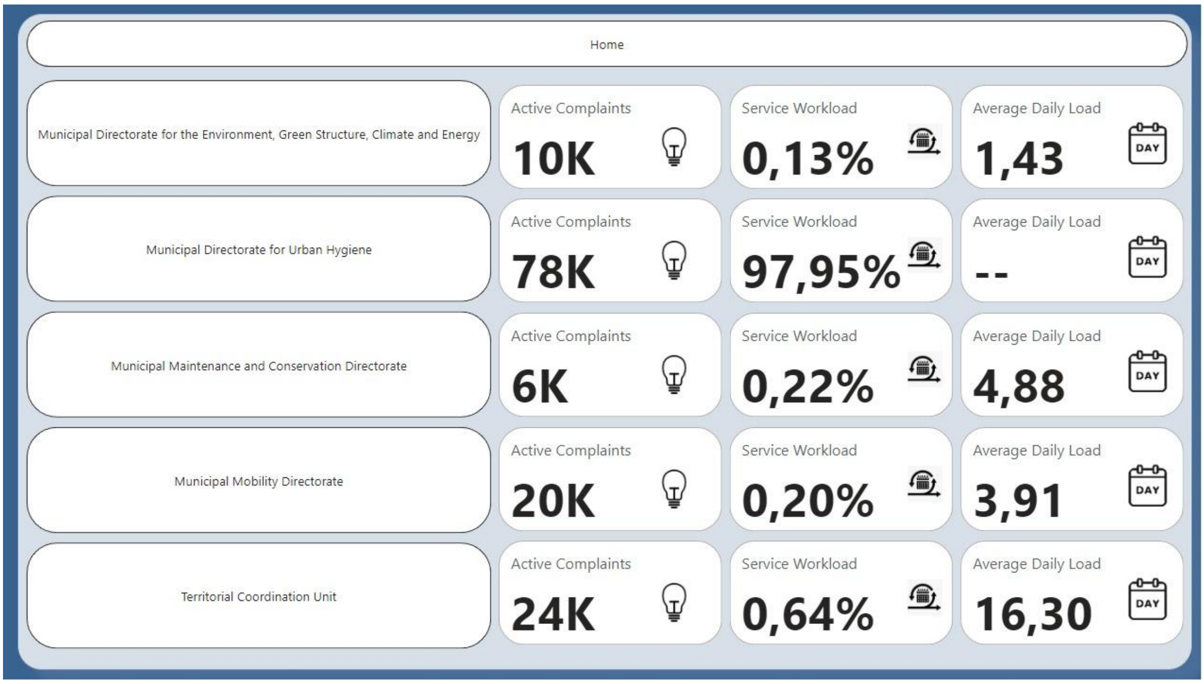

Figure 4- Municipal Services Performance Dashboard - A detailed breakdown of key municipal service areas showing active complaints, workload percentages, and daily processing rates across five major directorates.

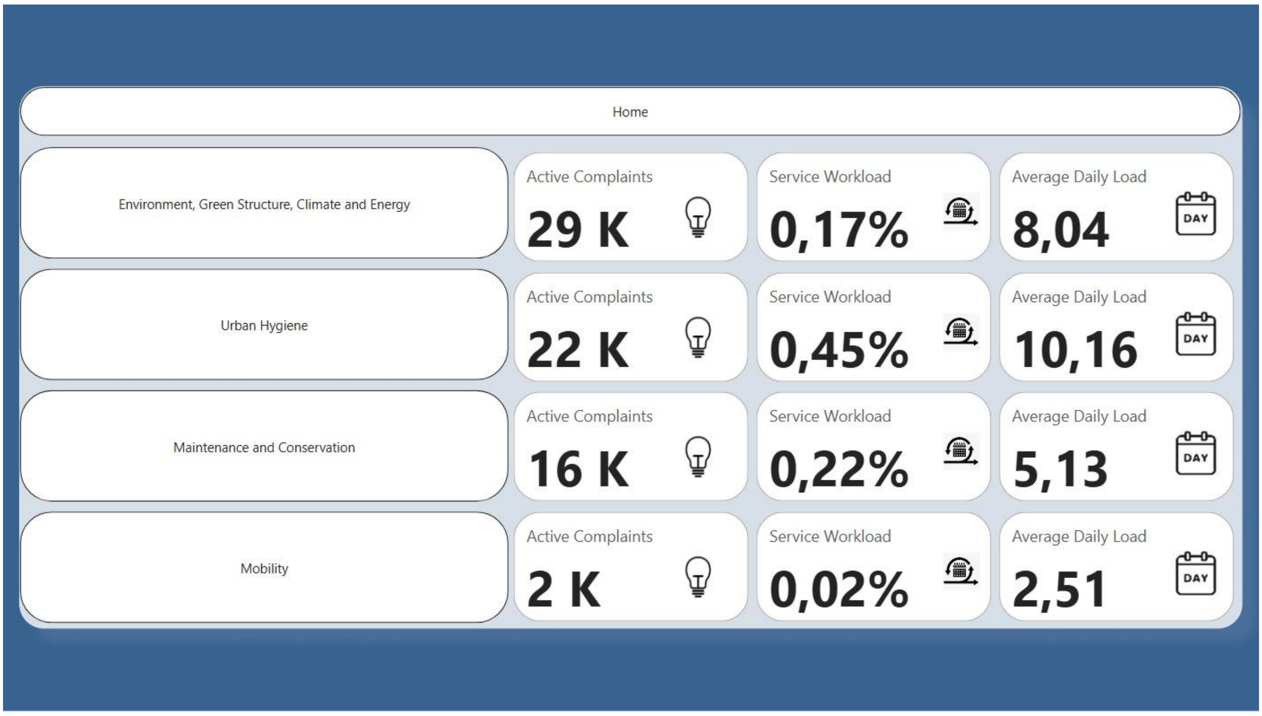

Figure 5- Parish Councils Services Performance Dashboard - A detailed view of operational metrics across four key parish service areas.

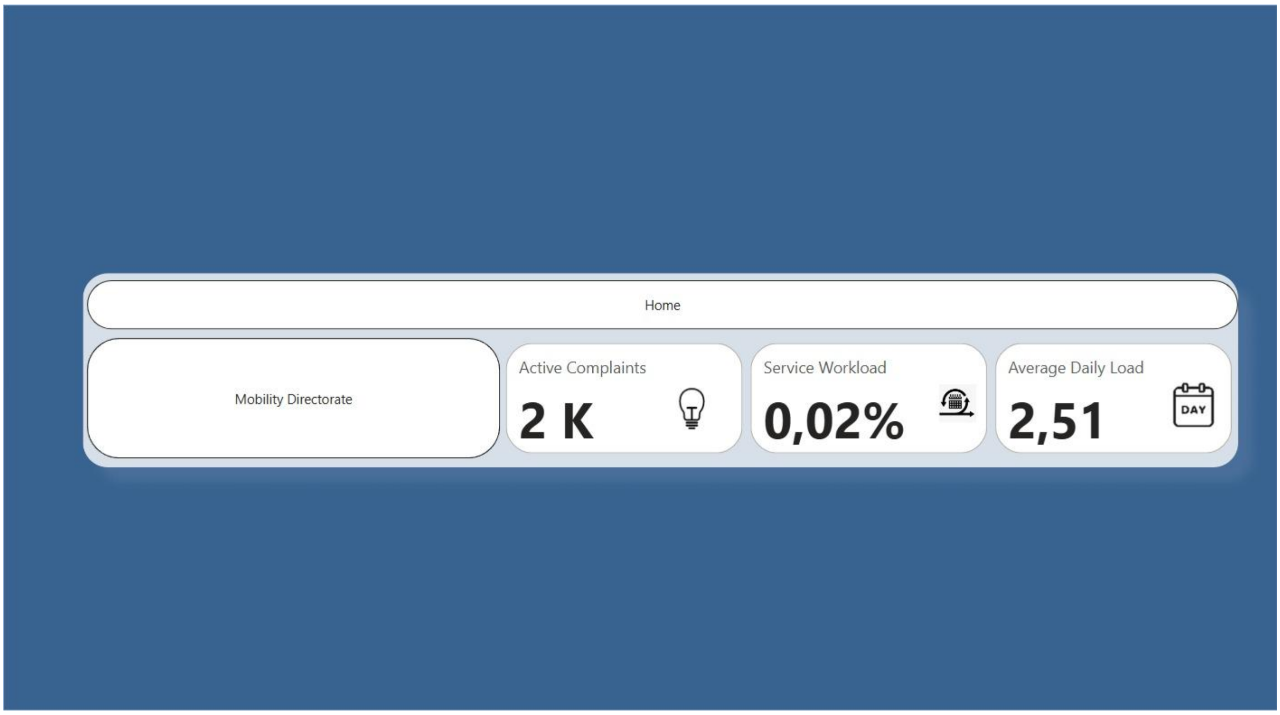

Figure 6- External Entity Service Performance Dashboard - A focused view of the Mobility Directorate's operational metrics as an external entity.

Figure 7- Environmental Directorate Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

Figure 8- Urban Hygiene Directorate Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

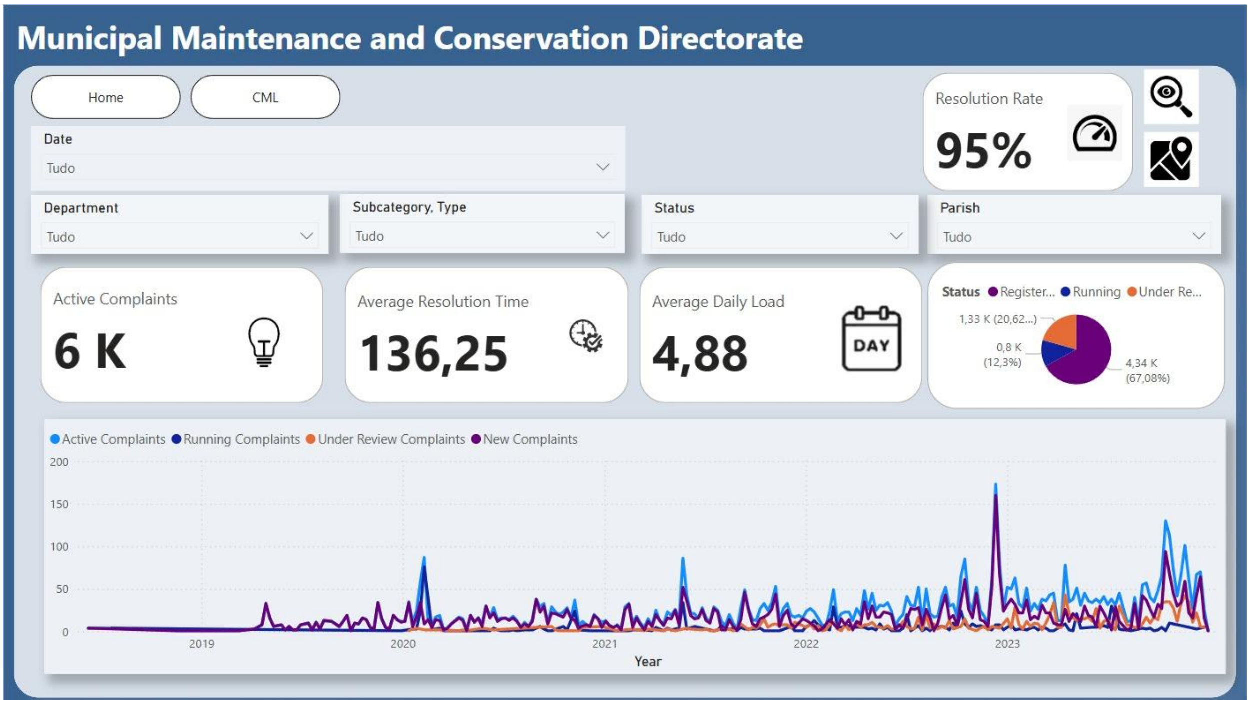

Figure 9- Maintenance and Conservation Directorate Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

Figure 10- Mobility Directorate Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

Figure 11- Territorial Coordination Unit Directorate Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

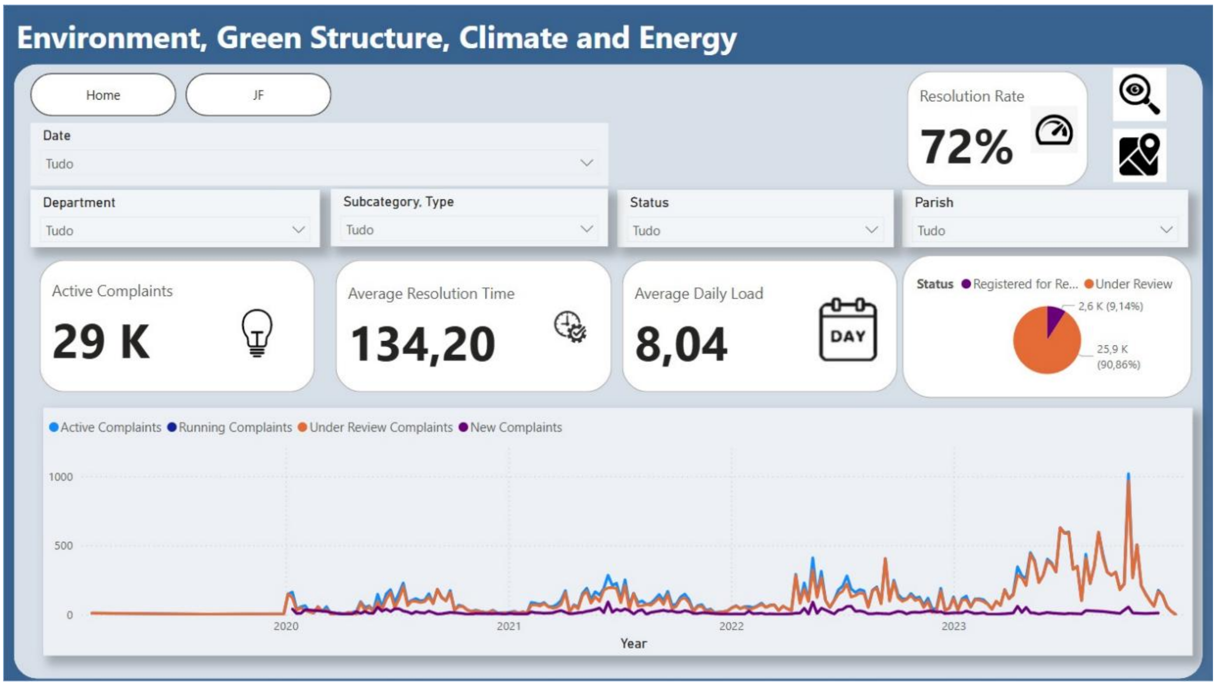

Figure 12- Environment Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicator.

Figure 13- Urban Hygiene Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

Figure 14- Maintenance and Conservation Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

Figure 15- Mobility Directorate Analytics Dashboard - A comprehensive visualization interface for environmental services management, featuring interactive filters for date, department, subcategory, status, and parish-level analysis, complemented by performance indicators and temporal trend visualization.

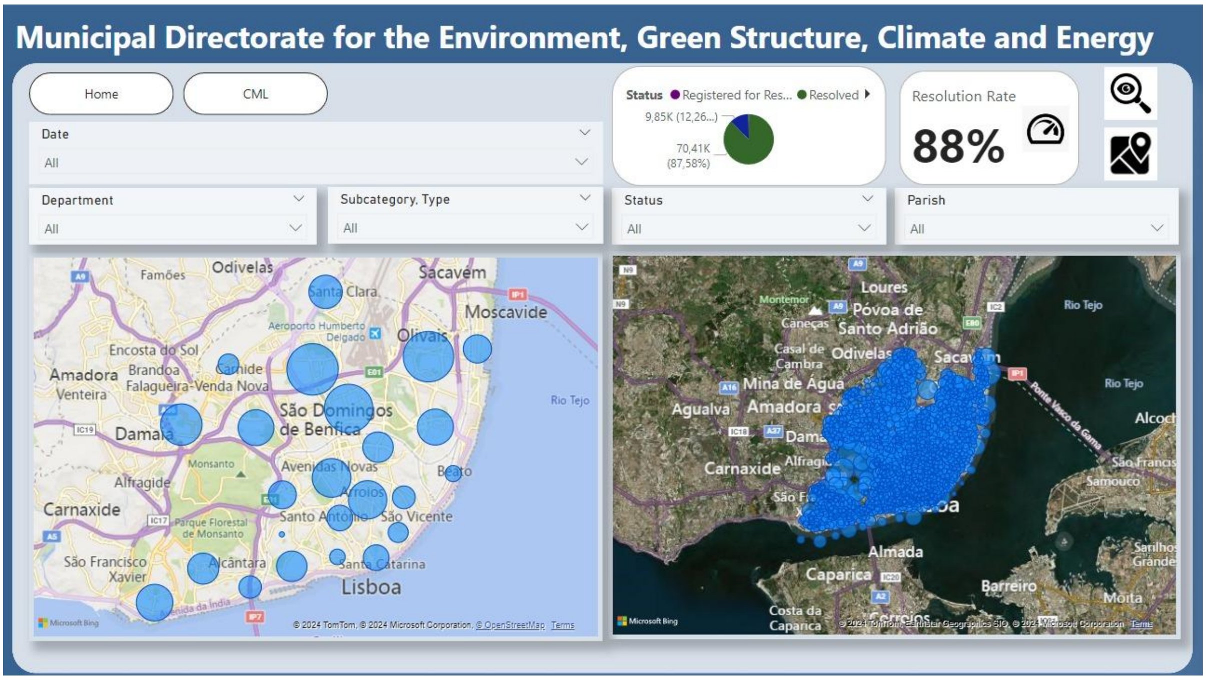

Figure 16- Environmental Directorate Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

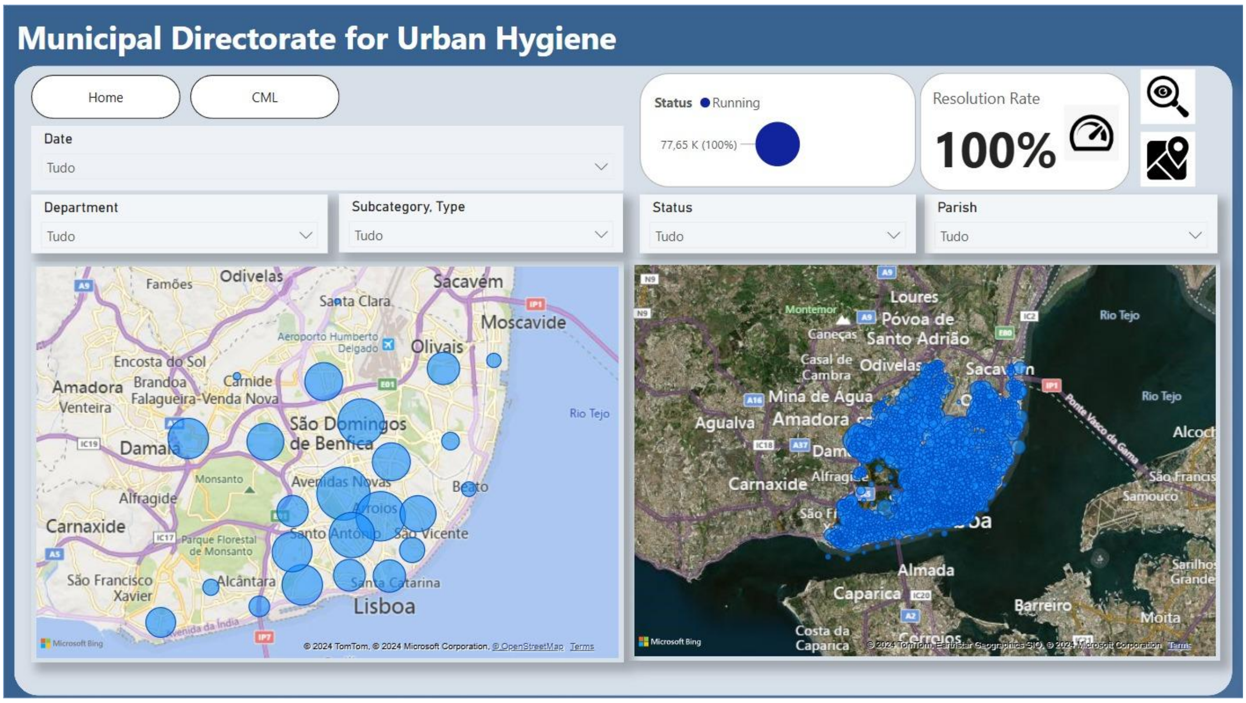

Figure 17- Urban Hygiene Directorate Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

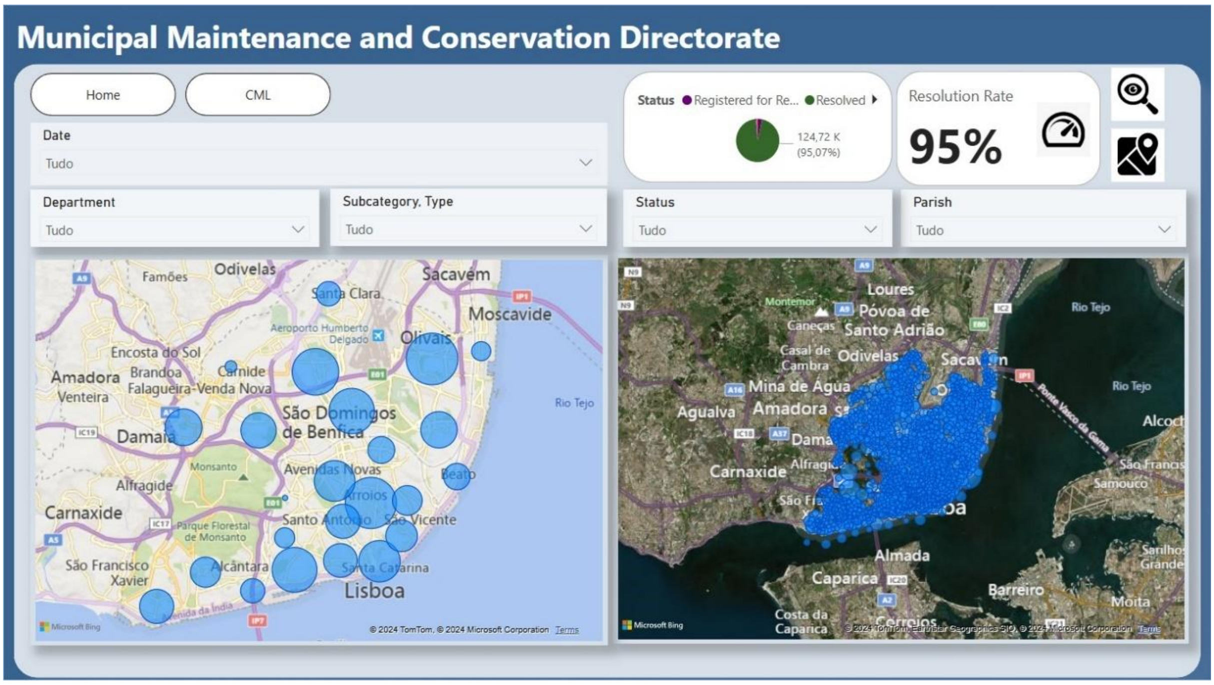

Figure 18- Maintenance and Conservation Directorate Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

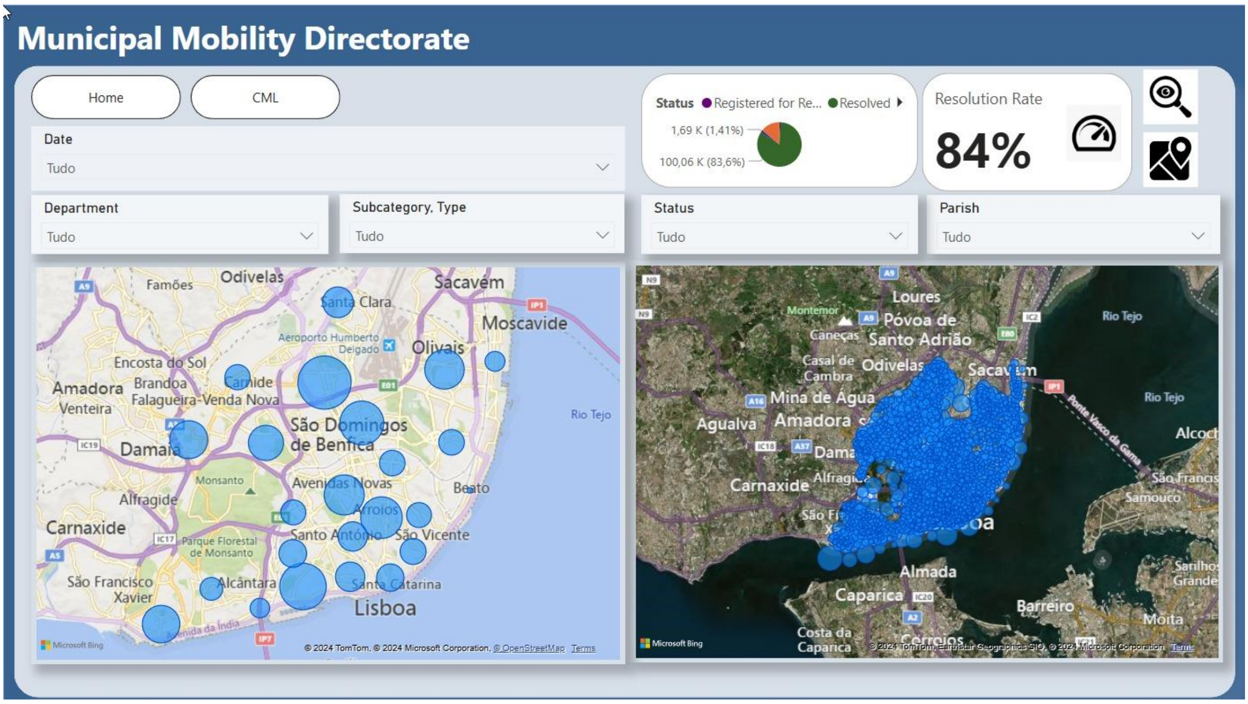

Figure 19- Mobility Directorate Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

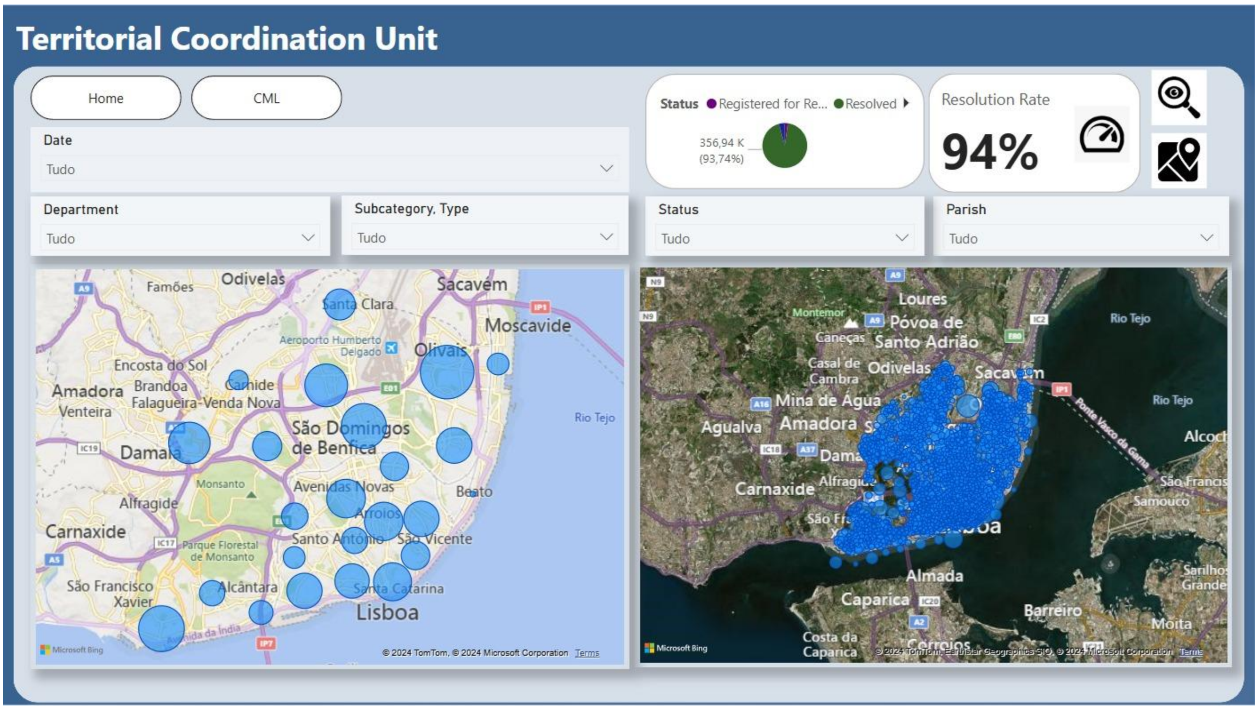

Figure 20 - Territorial Coordination Unit Directorate Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

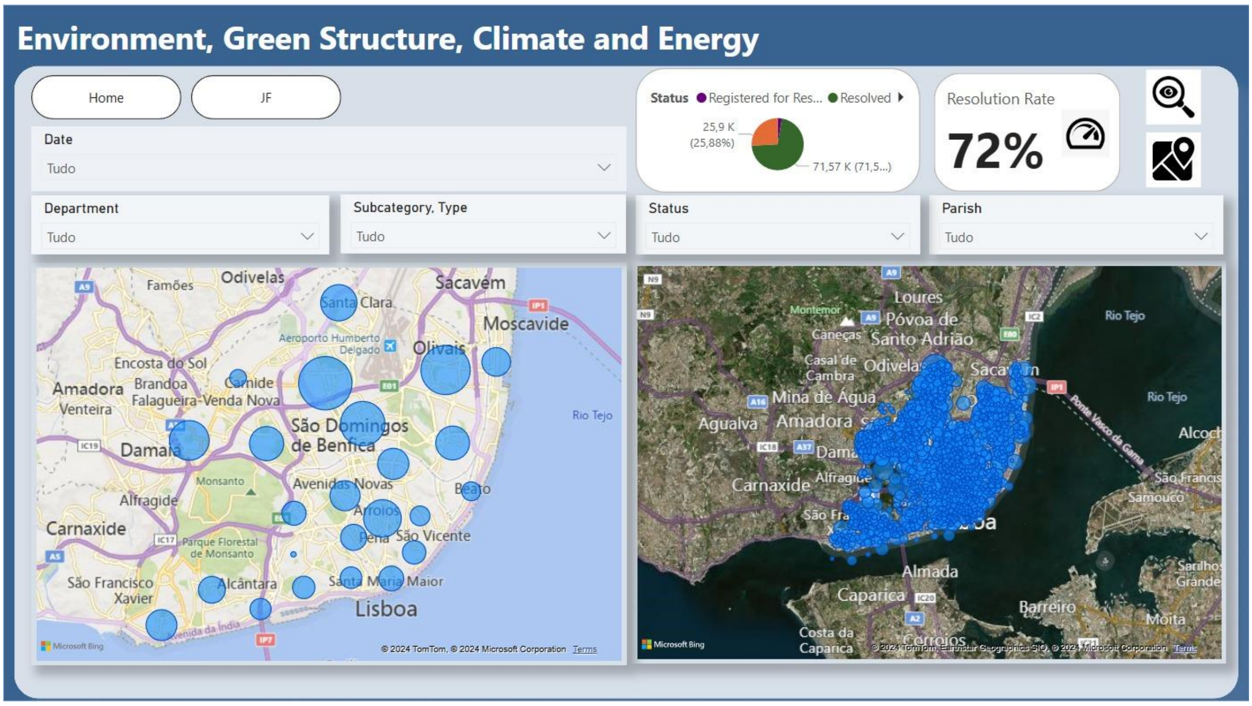

Figure 21- Environmental Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

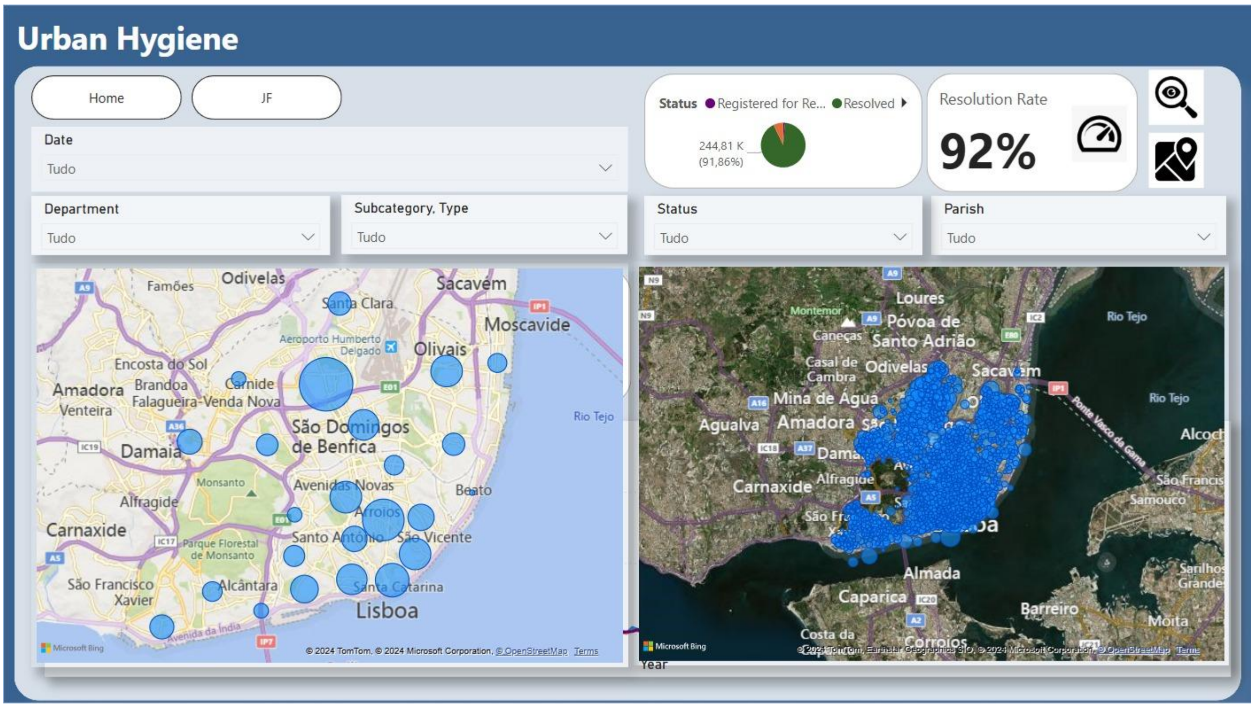

Figure 22- Urban Hygiene Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

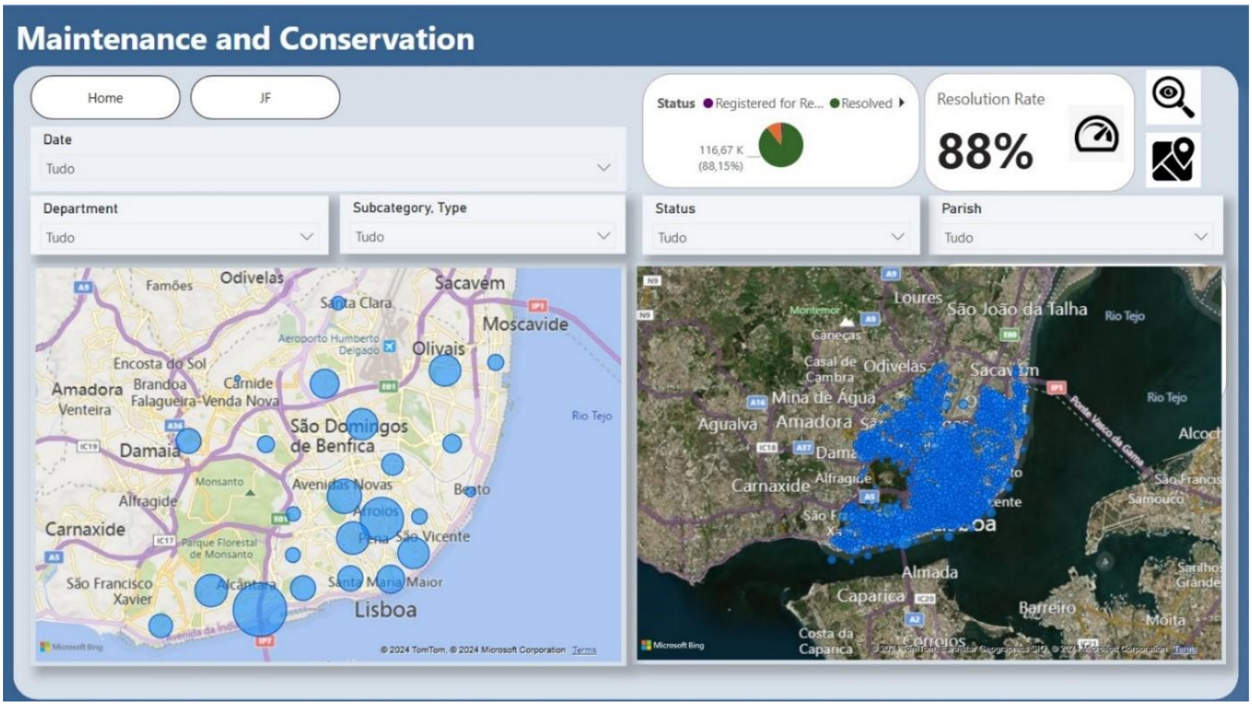

Figure 23- Maintenance and Conservation Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

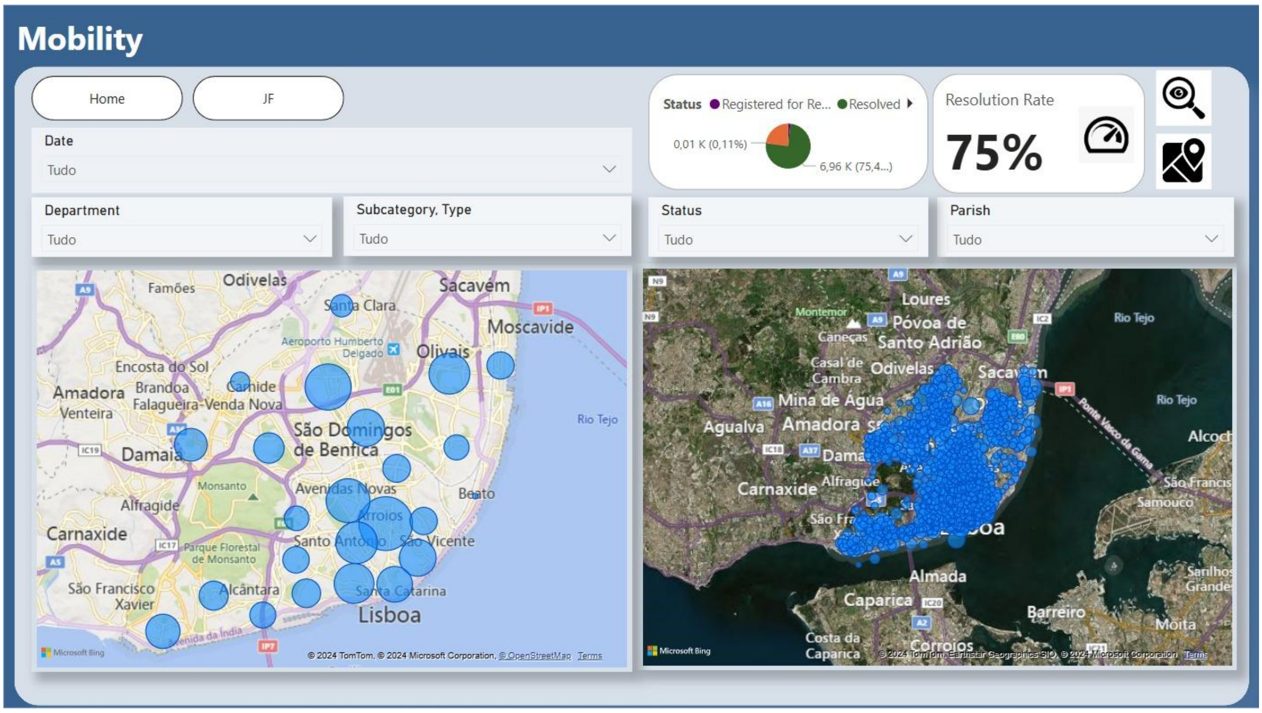

Figure 24- Mobility Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.

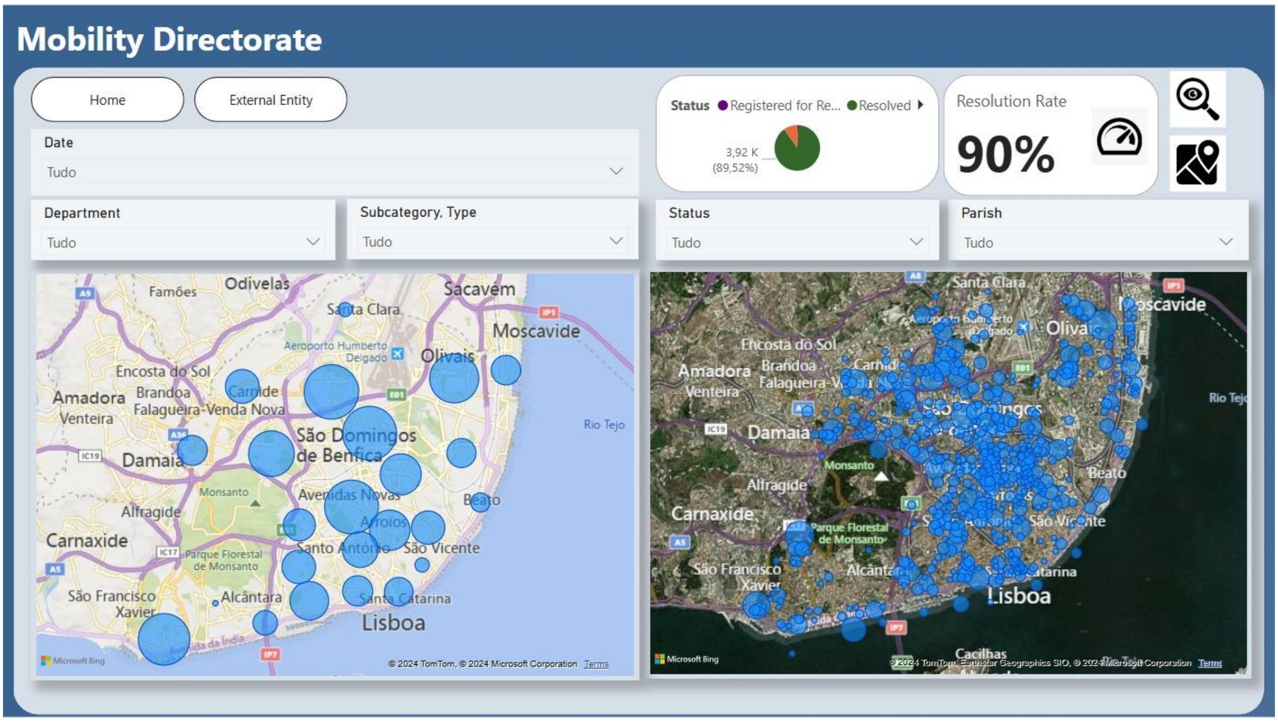

Figure 25- Mobility Directorate Spatial Analysis - A side-by-side map interface displaying urban environmental complaints through both clustered view (left) and point density distribution (right) across Lisbon's metropolitan area, with interactive filters for comprehensive spatial analysis.