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Towards an Integrated Smart City Platform: A Prototype for Enhancing Urban Services

Assis Tanji
Moroccan School of Engineering Sciences (EMSI)
Casablanca, Morocco
a.tanjji@gmail.com

Mohamed Essaaidi
Moroccan School of Engineering Sciences (EMSI)
Casablanca, Morocco
essaaidi@ieee.org

Ghezlane Halhoul Merabet
Smart Systems Laboratory (SSL) ENSIAS, Mohammed V University
Rabat, Morocco
ghezlane.merabet@um5s.net.ma

Abstract—**Smart cities are complex systems that leverage digital transformation to generate and utilize substantial amounts of data from diverse sources, such as social media, citizen interactions, sensors, cameras, and Internet of Things devices, among others. This data can be used to enhance the quality of life for citizens by informing better decisions about urban services and resource management. However, this requires effective visualization and analysis of this data through user-friendly interfaces, such as *dashboards*. This paper endeavors to elucidate the concept of smart cities by providing a comprehensive definition and proposing a prototype for a smart city dashboard that displays data collected from sensors, IoT devices, and cameras. Our dashboard addresses key challenges in urban service management by effectively overseeing four critical aspects: weather conditions, air quality, and noise levels; and provides stakeholders with valuable insights into the city's dynamics. Our prototype contributes to the creation of more livable, sustainable, and efficient urban environments by harnessing the power of data-driven insights.**

Keywords—Smart Cities; Data Visualization; Dashboards; Urban Service Management; Data-Driven Insights

I. INTRODUCTION

The world is experiencing rapid urbanization, with more than half of the population living in cities. By 2050, this number is expected to increase to 75%. According to V. Arana [1], In response to this impending challenge, authorities have turned to the analysis of urban data, derived from citizens, surveys, and observations, to generate actionable insights [2]. This approach has given birth to the concept of the 'smart city', a model that leverages technology to enhance urban efficiency, sustainability, and the overall quality of life for its inhabitants. Thus, a smart city, represents a synergistic collaboration between humans and technology, with the shared objective of fostering a more sustainable urban environment and improving the quality of life, thereby augmenting the efficiency of citizens using technology.

In recent times, the proliferation of sensors and cameras has led to an exponential increase in data availability. However, the real-time collection, processing, and utilization of this data to inform the design, operation, and governance of urban systems pose a significant challenge. This highlights the critical need for dashboards that can equip city authorities with profound insights and support real-time decision-making. Despite the crucial role of urban service management, there is a conspicuous research gap in this field. This paper endeavors to bridge this gap by proposing a prototype of a dashboard capable of effectively managing urban services in a city such as waste management, weather conditions, air quality, and noise levels. The proposed dashboard, characterized by itshigh performance through real-time data processing, analysis, and visualization, encompasses a majority of urban services, setting it apart from most existing dashboards.

The primary objective of this work is to explore the potential of urban data in improving sustainability and quality of life in smart cities. This is achieved, by developing and evaluating a prototype of a smart city platform that integrates various dashboards to manage different urban services. The remainder of this paper is organized as follows: Section II provides a comprehensive review of existing work related to smart city dashboards. Section III delves into the platform's architecture, while Section IV discusses the data processing mechanisms within the platform. Subsequently, Section V presents the development of Zenata City's Dashboard, and finally, Section VI concludes the paper, offering insights into the future directions and implications of the platform.

II. REALTED WORK

City dashboards are interactive urban tools designed to support different levels of decision-making for various stakeholders-, such as analysts, policymakers, politicians, and citizens [3]–[5]. They enable the visualization and exploration of city-specific data, as well as the participation and engagement of citizens in decision-making in urban governance. Several smart city dashboards have been developed to address different urban challenges, such as traffic, public transportation, weather, and air quality

[6],[7]. However, few of them provide a comprehensive and integrated view of all smart city services. In this paper, we focus on the design and evaluation of such dashboards, which can leverage real-time, diverse, and accessible data from multiple sources, such as sensors, cameras, and other channels, to enhance the understanding and management of city dynamics. We conducted a structured literature review to identify the existing smart city dashboards that offer a holistic perspective of urban services, and to analyze their strengths and weaknesses. The results of our review are summarized in Table I.

We found that most of the existing dashboards have some common features, such as real-time processing, easy content accessibility, and a diverse range of data sources. However, we also identified some limitations, such as the lack of user personalization, citizen participation, alerting mechanisms, and coverage of essential urban services, such as waste management, traffic, lighting, and transport. Among the reviewed dashboards, only the Dublin Dashboard provides an integrated view of various smart city services, but it still suffers from some of the aforementioned drawbacks.

TABLE I. TABLE 1. EXAMINATION OF EXISTING SMART CITY DASHBOARDS.

Dashboard	**key Attributes**
Dublin Dashboard [2],[8], [9]	• Pull real-time and administrative data from a variety of sources. • Easy access to content. • Real-time services: Airport arrivals and departures, Bus Passenger Information, weathers, air quality and water monitoring Information, number of free car spaces.
Skopje Dashboard [10]	• Friendly user interfaces and accurate data. • Real-time reporting on infrastructure conditions. • Predicting and preventing problems. • Two-way communications between government and people. • Data sources: sensor networks, social networks, news, blogs, and Internet of Things (IoT).
London City Dashboard [11]–[13]	• Simple Design of the Dashboard. • Collect data using web scraping technology from: British Broadcasting Corporation, London School of Economics, Port of London Authority, Department for Environment, Food and Rural Affairs, OpenStreetMap, ScotRail, Twitter • Uses of APIs.
CityEye Dashboard [14]	• Foster dialogue between users and urban service providers. • Real-time data from: Sensors, GPS, Citizens, social media.
Amsterdam City Dashboard [15]	• Customized Dashboard for Each User. • The Dashboard Offers Two Primary Data Presentation Modes: Map View, Partition View • Real-Time Display: City wide statistics on transportation, environment, economy, community, culture, and security.
Dubai Personal Dashboard [16]	• Ensuring Residents and Visitors stay Informed and Connected by Visualizing Data. • Support Personalized Information. • Data Sources Include Public, Private, and social media. • Utilizing MyID Service for Dashboard Login.
Search-the-City Dashboard [17]	• Leveraging Diverse Data Sources, Including Sensors, Cameras, Social Streams, User-Generated Content, and Information Provided by City Authorities. • Presenting Data in an Easily Accessible Format. • The Dashboard's Structure Consists of Two Key Components: a Search Layer and a Visualization Framework.
Bandung Dashboard [18]	• Identifying Issues and Proposing Solutions. • Utilizing TCP/IP Internet Connection to Minimize Energy Consumption.
Sydney City Dashboard [19], [20]	• Aggregating Real-Time Open Data Feeds: Sensors, Cameras, News, and Twitter. • Using 'React Widget' which communicates with the back end. • Integration of Google Analytics for Insights. • Employing Google GTFS Technology for Seamless Communication and Data Retrieval.

Based on our review, we propose a novel smart city dashboard prototype that aims to overcome the limitations of the existing dashboards and to provide a more comprehensive and effective platform for urban management and governance. Our prototype incorporates the following features: (1) user personalization, which allows users to customize the dashboard according to their preferences and needs; (2) citizen participation, which enables users to provide feedback and opinions on urban issues and solutions; (3) alerting mechanisms, which notify users and authorities of any problems or emergencies in the city; and (4) coverage of essential urban services, which includes not only weather and air quality, but also waste management, traffic, lighting, and transport.

III. ZSMART DASHBOARD: AN OVERVIEW

The prototype is designed to supervise a broad spectrum of Zenata's services, encompassing weather, air quality, waste management, and noise levels. It also integrates an alarm system to swiftly address any city-related issues. These operations are predicated on the processing, analysis, and visualization of data derived from diverse resources within Zenata. The platform's objective is to equip Zenata's planning authorities in Zenata with profound insights into the city, thereby facilitating its evolution into a smarter, more environmentally friendly, and more comfortable urban space. This transformation, can potentially attract investment to this burgeoning city and align with its envisioned status as an environmentally conscious and pleasant place to live.

Our platform offers several key advantages compared to the existing smart city dashboards listed in Table I. Unlike the Dublin Dashboard and London City Dashboard, which rely on periodic data updates, our design utilizes a real-time data streaming model. This model receives sensor data directly and continuously with concurrent data backup. This allows for quicker response times and more informed decision-making regarding city issues.

Secondly, we are actively integrating Artificial Intelligence (AI) across various services. This goes beyond functionalities like real-time reporting on infrastructure conditions (e.g., Skopje Dashboard) by enabling predictive actions. For instance, in green space management, AI will monitor humidity and forecast optimal watering times, reducing water usage. We plan to expand our AI integration and services to encompass areas like traffic management (currently absent in most dashboards) and building utilities management (not a focus in many existing dashboards). Additionally, social media integration is planned, fostering dialogue between users and urban service providers (similar to CityEye Dashboard but potentially offering a more comprehensive approach).

Finally, as the first smart city platform in Morocco and Africa, our design underscores the region's commitment to smart city initiatives. This pioneering approach positions the platform to be a leader in implementing these innovative functionalities within a developing region.

A. *Platform Architecture*

The Zenata Dashboard is a comprehensive web platform comprising several web pages, designed to visualize and display data for the city of Zenata from various sources. This data undergoes real-time processing and analysis, ensuring the delivery of accurate insights. The system is based on the Model-View-Controller (MVC) architectural pattern, as illustrated in Figure 1. The data initially transitions from sensors to the file system, where it undergoes processing and analysis before being ready for storage in the database. Subsequently, the stored data is presented in graphical formats (Chart.js) using a JavaScript library. The front-end architecture relies on HTML and CSS in conjunction with JavaScript. On the back end, the system utilizes the Python-based Django framework, functioning as a controller responsible for processing data and establishing connections with the User Interface (UI).

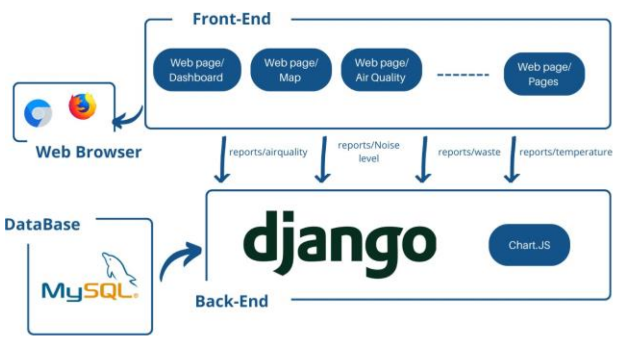


Figure 1. The Overview of the "ZSMART" Platform.

B. *Data Acquisition Framework*

As previously mentioned, the data is processed in real-time and sourced from various channels such as sensors, IoT devices, mobile applications, and social media. Initially, this data is stored in the file system. Simultaneously, in real-time, it undergoes cleaning, pre-processing, and analysis to ensure its quality and usability for integration into our platform.

Data cleaning involves removing inconsistencies, handling missing values, correcting errors, and standardizing the format of the collected data. The data points with missing values were eliminated from the dataset. By discarding these instances, we aimed to ensure the integrity and reliability of the remaining data for our analysis and subsequent modeling processes.

Pre-processing techniques are applied to transform the data into a suitable format for further analysis, which may include normalization, feature scaling, or feature engineering.

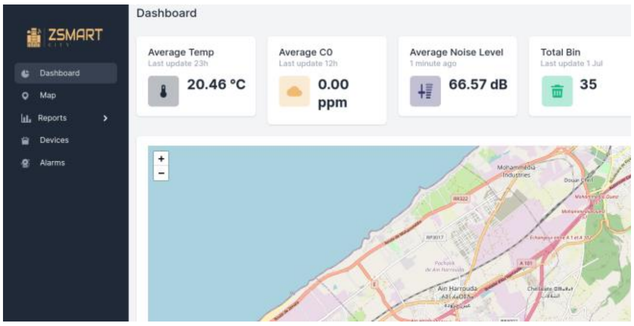
The last phase is Exploratory Data Analysis (EDA), conducted to gain insights into the dataset's characteristics, un- cover patterns, identify outliers, and understand the relationships between variables. By visualizing the data and applying statistical techniques, we can extract meaningful information and make informed decisions during subsequent stages of the project.

Once the data cleaning, pre-processing, and EDA steps are completed, the data is ready to be stored in the database for further utilization in our smart city platform.

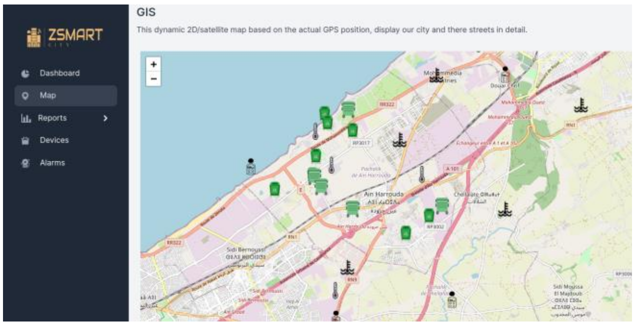
C. *Prototype*

The Zenata Platform relies on real-time data to establish interactive communication with both citizens and authorities, as illustrated in Figures (2a) to (2e). It comprises eight distinct web pages, namely:

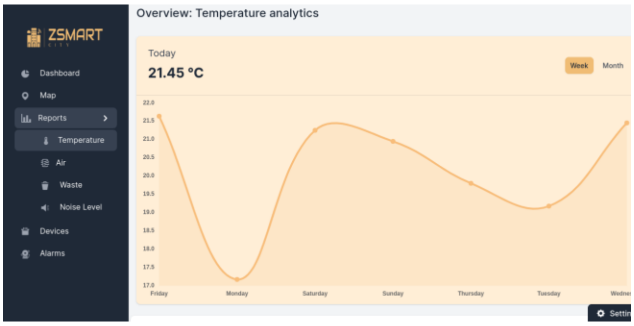
1) **Dashboard Page:** This serves as the platform's main interface, showcasing essential metrics and the latest sensors-derived values. The metrics include temperature, air quality, waste levels, and noise levels (Cf. Figure 2a).
2) **Map View:** This page displays the city's geographical location and all deployed sensors, featuring a filter option for selecting specific sensor types. Clicking on a sensor reveals its identifier (Cf. Figure 2b).
3) **Reports Section:** This section comprises a list of key metrics that the platform prioritizes, namely: Temperature, Air Quality, Waste, and Noise level. These metrics serve as the foundational indicators for a smart city.
4) **Temperature Page:** This page Includes a weekly chart depicting average temperature values for each day, a monthly chart for average temperature values, and a table providing detailed information about all temperaturesensors (Cf. Figure 2c).
5) **Air Quality Page:** This page features a daily chart illustrating the variation of ozone gas and carbon monoxide levels, along with monthly values for ozone gas, carbon monoxide, and particulate matter. Similar to the Temperature page, it includes a comprehensive tableabout all the Air sensors (Cf. Figure 2d).



a. Main Dashboard Page

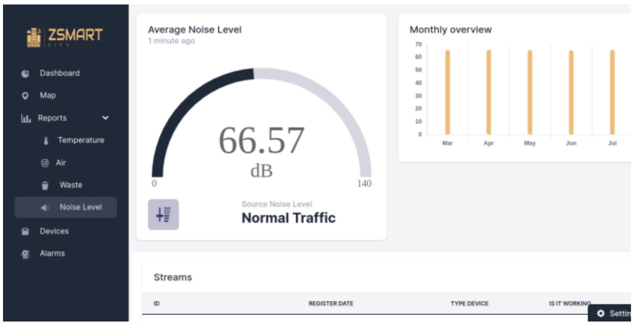


b. Map Page

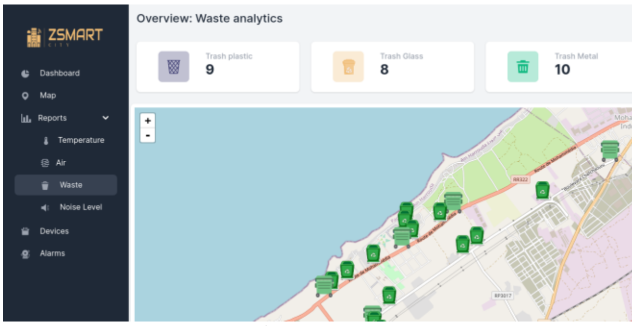


c. Temperature Page

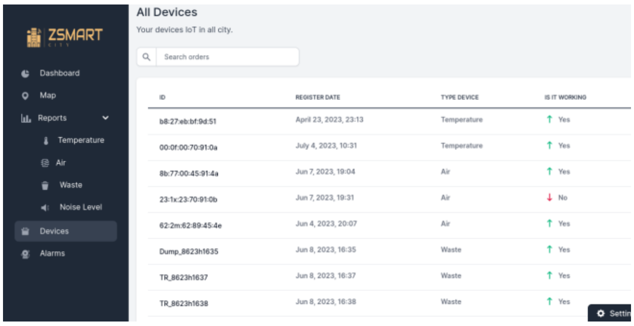
d. Air Quality Page



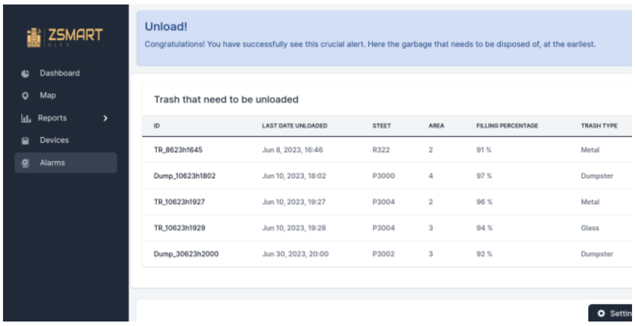
e. Noise Levels Page



f. Waste Page



g. Devices Page



h. Alarms Page

Figure 2. Various screenshots were captured from the Zeneta Platform's web interface.

6) **Noise Level Page:** This page is divided into three sections, featuring a graph of daily average noise levels, a gauge chart displaying average noise levels per minute,and a table providing detailed insights into noise sensors(Cf. Figure 2e).
7) **Waste Page:** This page presents three cards at the top displaying quantities of Plastic, Glass, and Metal trash. The middle section features a map showing the locations of all trash sensors, accompanied by latitude and longitude coordinates. Additionally, two charts illustrate the percentage breakdown of different trash types in dumpsters and an overview of total city trash distribution. The Fig.2 offers comprehensive information about allwaste sensors (Cf. Figure 2f).
8) **Devices Page:** This page includes a sizable table with detailed information about all sensors, covering registration date, sensor type, and status, providing a comprehensive overview of all city sensors (Cf. Figure 2g).

9) **Alarms Page:** This page showcases two critical elements, listing IoT devices requiring maintenance and displaying waste that needs prompt disposal (Cf. Figure 2h).

IV. Conclusion and Future Work

As the quest for building smarter cities persists, it becomes increasingly imperative for city authorities, researchers, and technology providers to engage in collaborative efforts and knowledge sharing to fully harness the potential access of smart city platforms. This paper makes a significant contribution to this collective endeavor by proposing a prototype platform specifically designed to empower Zenata authorities to manage urban services, thereby enhancing the city's quality of life and sustainability. However, this endeavor is not devoid of challenges, including data scarcity and difficulties in specific case studies due to limited collaboration with local authorities. This work represents an ongoing process, underscoring the need for continual development. Future iterations should extend to include additional urban services such as traffic management, public transport coordination, parking management, water monitoring, and street lighting. Moreover, it is crucial to create a space for citizen engagement, where residents can express their opinions and actively participate in decision-making processes. is crucial.

Additionally, the work aspires to integrate more artificial intelligence, particularly machine learning, into the platform. This includes predictive capabilities and automated decision-making to proactively address issues. Furthermore, there is a vision to enrich data sources by incorporating social media as an additional resource, thereby facilitating a more comprehensive understanding of the urban landscape. This paper, therefore, serves as a stepping stone towards the realization of smarter, more sustainable cities.

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