# Leveraging Large Language Models for Automated Assessment and Mapping in Participatory Urban Planning

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**Abstract**

This research introduces an innovative platform designed to enhance citizen engagement in urban planning and management by integrating emerging technologies such as Artificial Intelligence (AI), Large Language Models (LLMs), and chatbots. Traditional Public Participation Geographic Information Systems (PPGIS) often face challenges in effectively capturing and analyzing citizen input. This platform addresses these limitations by enabling users to articulate urban issues or ideas in natural language, which are then processed through AI-driven Natural Language Processing (NLP) techniques to identify key elements such as location, issue type, and intensity. Furthermore, the platform facilitates interactive dialogues, allowing citizens to inquire about perspectives from other community members, thereby fostering a dynamic exchange of views. In the absence of an initial user base, a dataset comprising 2,000 tweets related to Montreal's public transportation was curated. An LLM was fine-tuned using this data, equipping the model to respond to queries concerning Montreal's public transportation system. The findings demonstrate the feasibility of leveraging AI and LLMs to create a responsive and interactive platform that not only streamlines data collection but also enriches the participatory planning process. This approach has the potential to transform urban governance by making it more inclusive and data driven.

## 1. Introduction

PPGIS involve utilizing Geographic Information Systems (GIS) to enhance public engagement in policymaking processes and to leverage GIS technology in advancing the objectives of non-governmental organizations, grassroots movements, and community-based organizations (Sieber, 2006).

PPGIS are crucial in spatial planning as they enable enhanced public participation and collaboration among various stakeholders. In spatial planning, stakeholders often bring differing levels of knowledge and assumptions based on their individual experiences, which can result in conflicting views on desirable planning outcomes. PPGIS facilitates this process by improving access to information and fostering collaboration among planners, stakeholders, and the public. By providing a platform for distributed collaboration, PPGIS allows stakeholders to learn about the potential outcomes of their preferences, leading to more informed and consensus-driven planning decisions. This collective learning and engagement help align spatial planning with the needs and preferences of the community, making it more inclusive and effective (Simão et al., 2009). Public participation is proving to be highly effective tools in addressing complex urban challenges by integrating citizen input into spatial planning processes. As demonstrated in a recent study conducted in a rural German municipality, the PPGIS scenario approach facilitated meaningful discussions among stakeholders and citizens regarding land-use decisions for renewable energy projects (Rösch and Fakharizadehshirazi, 2025). By enabling participants to visualize and assess various scenarios, the approach enhanced mutual understanding and supported consensus-building, even under strict land-use constraints. This participatory method not only improved the transparency and legitimacy of decision-making but also ensured that diverse community values were considered, leading to more equitable and acceptable outcomes. Such applications of

PPGIS underscore the importance of citizen engagement in urban planning, highlighting how inclusive participation can lead to more informed, just, and sustainable urban solutions.

Geo-questionnaires, the most common method of data collection in PPGIS, often face challenges such as low engagement rates and participant fatigue, making it crucial to explore potential alternatives (Czepkiewicz et al., 2017). Structured surveys can be time-consuming and monotonous, leading to reduced participation. Additionally, many citizens may prefer to express their opinions in more convenient formats, such as text messages, voice notes, or other informal means, rather than adhering to rigid survey structures. Additionally, to enhance citizen participation, as highlighted by Maptionnaire[1], it is essential to transform these platforms into interactive systems where individuals can not only contribute data but also access and benefit from the insights generated. These limitations can hinder the effectiveness of PPGIS in capturing diverse community perspectives.

To address these challenges, recent advancements in AI, particularly in NLP and LLMs, offer promising solutions. NLP has emerged as a crucial pillar in the development of smart cities, enabling improved communication, information flow, and decision-making across domains such as healthcare, education, and civic engagement (Tyagi and Bhushan, 2023). These technologies enable the extraction and analysis of insights from unstructured data, allowing citizens to contribute their opinions in natural language formats.

Recent empirical studies have further demonstrated the potential of LLM agents in smart city management, where multi-agent architectures integrating Retrieval-Augmented Generation (RAG) and local urban information systems significantly improve decision support accuracy and citizen–planner interaction (Kalyuzhnaya et al., 2025).

In this context, a proposed web service facilitates plain text data collection, allowing citizens to express their concerns or suggestions freely. Although the platform is not yet publicly available, initial analysis has been conducted using publicly available textual data from Canadian citizens on Twitter.

This development aims to create a chatbot that provides valuable insights for both citizens and urban planners, enhancing the participatory planning process by making it more inclusive and responsive to community needs. This chatbot enables both citizens and urban planners to ask a wide range of questions, with responses generated from the perspective of citizens. For instance, a city manager could ask what the main issues in public transportation are from the citizens' point of view. By creating an interactive platform where citizens are not only data providers but also active users. As such, we assume that participation and engagement rates can be significantly increased.

## 2. Literature Review

PPGIS has expanded over recent years, emphasizing their potential to democratize spatial planning. However, several recurring limitations continue to constrain their effectiveness. Through multiple studies, issues of temporality, engagement decline, and data quality emerge as persistent challenges. Hasanzadeh (2022) links declining participation rates to temporal and analytical constraints in PPGIS datasets, while Chelli et al. (2025) similarly demonstrate that citizens' preferences vary over time, revealing the absence of mechanisms for continuous data capture. Collectively, these findings suggest that existing PPGIS frameworks inadequately represent dynamic, long-term public interests.

A second line of research points to limitations in the design and interactivity of digital participation tools. Kajosaari et al. (2025) observed that current online PPGIS practices remain largely dependent on map- and survey-based participation, which restricts expression to static spatial representations. Likewise, Hitchins (2018) showed that the usability of Geoweb interfaces directly influences both user satisfaction and data reliability, highlighting the importance of interface design in shaping participation outcomes. Despite these advancements, most systems still lack mechanisms for open-ended, conversational engagement that reflect how citizens naturally express spatial experiences.

Challenges in data accuracy and analytical efficiency also remain central in PPGIS research. Brown et al. (2015) reported that citizen-generated data, while spatially informative, often suffer from low completeness and positional accuracy, particularly in peripheral areas. Fagerholm et al. (2021) attempted to address the analytical side of this problem by proposing a structured “Explore–Explain–Predict” framework for participatory data modeling. Yet, both studies depend on manual analysis, leaving significant gaps in scalability and automation.

Recent attempts to modernize participatory systems have sought to integrate citizen-generated content with intelligent processing methods. Zali et al. (2025) exemplified this approach through a social-media-enhanced PPGIS platform

[1] https://www.maptionnaire.com/

that captured community insights on pedestrian safety and mobility. Their system successfully linked participatory mapping with routing algorithms but remained limited by its reliance on pre-structured input formats and the absence of real-time, adaptive feedback. These examples illustrate that, despite methodological progress, current PPGIS applications still operate as static data collection tools rather than dynamic systems of dialogue and learning.

To overcome these barriers, researchers have begun exploring the integration of AI, NLP, and LLMs in participatory and spatial contexts. These technologies allow citizens to communicate using natural language, enabling automated interpretation, classification, and spatialization of text-based input. For instance, GeoGPT demonstrates how LLMs can reason semantically and execute geospatial workflows autonomously, illustrating their potential to enhance both accessibility and analytical precision in GIS environments(Zhang et al., 2024).

Building on this paradigm, Mansourian and Oucheikh (2024) developed ChatGeoAI, which employs a Llama 2-based model within the PyQGIS environment to translate user queries into executable scripts. By combining entity recognition and ontology mapping, their framework enables non-expert users to perform geospatial analysis without programming skills, thereby reducing the technical barrier to GIS engagement. Similarly, Quan and Lee (2025) integrated ChatGPT into a Participatory Planning Support System (PPSS) that employs multi-agent collaboration to facilitate dialogue and co-creation among stakeholders. Their platform enhanced communication and creativity in a simulated Seoul urban regeneration project, showing how conversational AI can strengthen collective decision-making.

In the domain of smart city management, Kalyuzhnaya et al. (2025) demonstrated that LLM-based multi-agent systems augmented with RAG can process complex urban queries with up to 99% accuracy. By integrating urban databases and service APIs, their architecture accelerated decision-making while maintaining contextual accuracy, positioning LLM agents as reliable decision-support tools. Similarly, Hang Rong et al. (2025) benchmarked LLMs and NLP models against qualitative methods for analyzing citizen sentiment. Their findings confirm that LLMs substantially improve efficiency and interpretability in public comment analysis, although human oversight remains essential to ensure fairness and mitigate bias.

Although PPGIS platforms have the potential to play a pivotal role in urban management and guide cities toward sustainable development, they still face notable challenges such as data temporality and quality issues. Recent advancements in AI, NLP, and intelligent agents demonstrate strong capabilities in addressing similar challenges across other domains. Building on this, the present study proposes a framework that integrates these emerging technologies with PPGIS to pave the way toward the next generation of intelligent, adaptive urban participation platforms.

## 3. Methodology

We propose a platform that aims to enhance public participation in data generation by combining user-friendly interfaces with AI-driven analytics. Citizen messages are collected through a web interface, stored in PostgreSQL/PostGIS, and processed via Apache Airflow pipelines. NLP techniques, including Named Entity Recognition (Jehangir et al., 2023) and reverse geocoding (Sabzali Yameqani and Alesheikh, 2019), extract spatial information and enrich the dataset for visualization on an interactive map. To support dialogue, the system integrates Retrieval-Augmented Generation with a fine-tuned LLM accessed through an external API. A chatbot built on this architecture enables citizens and planners to query community contributions in natural language.

Transformers are a type of neural network architecture designed to process and understand sequences of data—such as language—by using a mechanism called self-attention, which allows the model to identify relationships between words regardless of their position in a sentence. Unlike older architectures like RNNs or LSTMs that processed text step-by-step, Transformers analyze all words in parallel, making them far more efficient and able to learn richer contextual patterns. This scalability and ability to capture deep semantic meaning are what make Transformers the foundation of modern LLMs. They enable LLMs to understand context, generate coherent text, translate languages, answer questions, and perform many other language-driven tasks with human-like proficiency (Vaswani et al., 2017). Building on this foundation, LLMs were developed by pre-training at massive scale over large corpora and subsequently fine-tuning or prompt-based adapting for domain-specific tasks (Zhuang et al., 2025). To overcome limitations of static knowledge and domain mismatch in LLMs, RAG methods have been employed; these combine external knowledge retrieval with generative output to enhance accuracy and relevance (Lewis et al., n.d.). Finally, AI agent systems are reviewed, in which LLMs and RAG pipelines are embedded within autonomous frameworks that plan, utilize tools, manage workflows, and interact; such multi-agent designs have recently been demonstrated in smart-city and planning contexts (Minaee et al., 2025).

By Making data generation easier for citizens and offering them meaningful analysis of their input can significantly enhance sustained engagement. When contributions can be made through intuitive interfaces rather than technical tools, the barrier to entry is lowered and more people are able to participate. Providing analysis-based feedback for example visualizations of how citizen submissions map into planning data, helps participants feel their input is valued and visible. This aligns with participation-theory research which shows that closing the feedback loop and communicating how citizen input has been used are key to maintaining trust and interest over time (*OECD Guidelines for Citizen Participation Processes*, 2022). In this platform, by combining a user-friendly submission interface, automated spatial tagging and NLP, and natural-language query capabilities via a chatbot, the system enables both easy contribution and responsive feedback. This dual approach is expected to boost participation rates and convert one-time contributors into ongoing collaborators.

### 3.1. System Architecture Overview

The proposed platform has been designed to advance PPGIS by making them more interactive and user-friendly. The system is composed of several key components. First, a user interface (UI) was developed to collect messages from citizens. These inputs are stored in a PostgreSQL database and processed through data pipelines implemented using Apache Airflow. Since this system currently has no active users, the input data was drawn from the study Transportation in Montreal Tweets[2], which collected transportation-related data from Twitter. Within these pipelines, AI-based NLP techniques are applied to analyze the content. During the Extract–Transform–Load (ETL) process, additional fields such as geographic location are appended. Specifically, Named Entity Recognition (NER) techniques are employed to detect place references within the text, which are then converted into precise latitude and longitude coordinates through reverse geocoding. The enriched dataset is subsequently stored again in PostgreSQL, where it can be visualized on an interactive map.

A second component of the platform enables both citizens and urban planners to engage in conversational interactions with the processed data. To achieve this, the textual data are prepared for fine-tuning on a LLM using RAG techniques. An API connection to an external LLM provider is established, and a chatbot is built on top of the fine-tuned model. This chatbot allows users to pose questions about their city and receive responses grounded in the information previously contributed by other community members. Figure 1 illustrates the overall workflow of the platform.

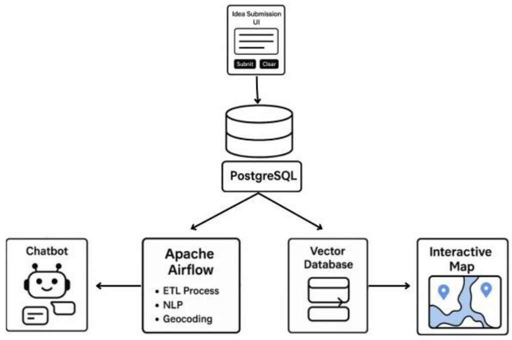


Figure 1. System Architecture Overview

**3.1.1 Database Layer:** The database layer is built on PostgreSQL, extended with the PostGIS module to provide native support for spatial data types and operations. This setup allows efficient storage, indexing, and querying of both textual and geospatial information. Citizen inputs collected through the user interface are first stored as raw text records. During preprocessing, NLP enriches these entries by extracting location references via Named Entity Recognition, which are then resolved into geographic coordinates through reverse geocoding. The resulting coordinates are stored in PostGIS geometry fields, creating a structured repository of geolocated citizen contributions.

In addition to the relational database, a vector database is maintained to support RAG. Large pre-trained language models encode factual knowledge in their parameters but often lack mechanisms for precise retrieval and updating of information; RAG addresses this limitation by combining pre-trained sequence-to-sequence generators with differentiable retrieval systems, thereby improving factual accuracy and contextual understanding.

Text entries are transformed into embeddings using pretrained language models, and these high-dimensional vectors are indexed for similarity search. When a user submits a query through the chatbot, the system retrieves semantically related citizen inputs from the vector store and supplies them to the LLM as contextual evidence. This dual-layer design relational for structured spatial data and vector-based for semantic retrieval ensures that the platform can serve both interactive mapping and conversational intelligence with consistency.

**3.1.2. Backend Layer:** The back-end layer was implemented in Python using the Flask microframework, selected for its lightweight design and flexibility in developing web services. This layer operates as the central

[2]https://ngci.encs.concordia.ca/ckan/dataset/transportation-in-montreal-tweets

controller of the platform, coordinating communication between the user interfaces, the database, and the AI components. A set of REST APIs was designed to manage the core functionalities, including submission of citizen messages, retrieval of processed geospatial data for visualization, and interaction with the chatbot.

For data ingestion, the back-end receives inputs from the Idea Submission Page and stores them in PostgreSQL/PostGIS through secure API endpoints. For data visualization, the map interface queries the back-end, which retrieves geocoded records from the database and serves them to the Leaflet-based front-end as structured GeoJSON. For conversational interactions, the chatbot interface communicates with a dedicated endpoint. Upon receiving a query, the back-end first consults the vector database to retrieve semantically similar embeddings, then forwards both the retrieved context and the user’s question to the Large Language Model (LLM) via an external API connection. The LLM’s response is subsequently relayed through the Flask server to the chatbot interface.

This modular design ensures scalability and maintainability: each component data management, mapping, and conversational intelligence can be extended or replaced independently while maintaining consistent communication through the back-end service layer.

**3.1.3. Frontend Layer:** The front-end layer was developed with HTML, CSS, and JavaScript to ensure simplicity and accessibility. It includes three main interfaces: (1) an Idea Submission Page where citizens can share their inputs, (2) an Interactive Map Page that visualizes geocoded messages as spatial markers, and (3) a Chatbot Page that enables natural language queries. Together, these interfaces provide users with intuitive ways to contribute information, explore spatial data, and engage in dialogue.

**3.1.4. Data Engineering and Workflow Management:** Data preprocessing and workflow orchestration are managed using Apache Airflow, which automates the ETL process. Raw citizen messages submitted through the interface are first stored in PostgreSQL. Within the pipeline, Natural Language Processing techniques are applied to extract key information such as locations, which are then geocoded into latitude and longitude. The enriched records are written back into the database for visualization and retrieval. In parallel, text data are transformed into embeddings and indexed in a vector database to support Retrieval-Augmented Generation for the chatbot. This automated workflow ensures consistency, scalability, and timely integration of new citizen inputs across the platform.

## 4. Result

The platform is composed of four main pages. The first page is the welcome page, which serves as an entry point for citizens. It provides a brief introduction to the purpose and functionality of the web service, explains how users can interact with it, and guides them toward the subsequent sections of the platform. In addition to offering clear navigation, the welcome page helps establish trust by clarifying the platform’s objectives and ensuring that users understand its relevance. This introductory step is crucial for encouraging engagement and facilitating a smooth transition to the other pages of the system. Figure 2 presents a screenshot of the welcome page.

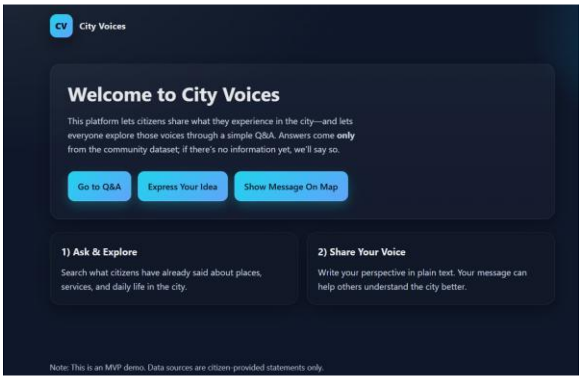


Figure 2. Welcome page of the City Voices platform.

Subsequently, by clicking on the *Express Your Idea* button, citizens are directed to a dedicated page that enables them to communicate their thoughts and suggestions directly through the platform. The main objective of this page is to provide a straightforward and accessible channel for participation, ensuring that every user can contribute without barriers. To achieve this, the page has been designed in the simplest possible form, avoiding unnecessary complexity in layout or functionality. Users are not required to enter additional personal information or complete lengthy forms; instead, they can focus solely on expressing their ideas. This design choice minimizes confusion, reduces cognitive load, and encourages higher levels of engagement by making the process quick, intuitive, and user-friendly. Such simplicity is particularly important for reaching a wider range of citizens, including those who may be less familiar with digital platforms. Figure 3 illustrates the Express Your Idea page.

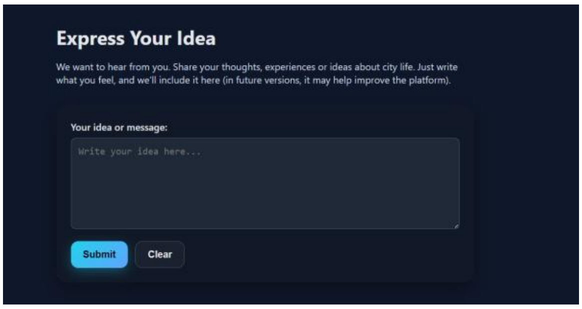


Figure 3. Express Your Idea Page

Another section of the platform is the analysis page, where the geocoded data is visualized on an interactive map. This page provides users with the ability to explore the spatial distribution of the collected information in a clear and intuitive manner. The purpose of this page is to offer a GIS-based perspective that can be valuable both for citizens, who can view and interpret the shared content geographically, and for urban planners, who can use the mapped data to better understand patterns and trends. In particular, the map allows users to locate and examine individual tweets directly within their spatial context, bridging the gap between public input and urban analysis. Figure 4 presents the representation of the analysis page.

Figure 4. Data visualization on map

The final page of the platform is the Q&A section, which features an intelligent chatbot designed to facilitate direct interaction with users. This chatbot is developed using a RAG framework, enabling it to combine the strengths of large language models with context-specific information retrieval. By integrating the OpenAI Router API, the system is capable of understanding natural human language and responding in a conversational manner. This design ensures that users can communicate with the platform intuitively, without requiring technical expertise or specialized input formats. The chatbot’s core functionality is to provide an accessible and interactive medium for citizens to ask questions and receive meaningful responses.

Beyond its general language capabilities, the chatbot has been fine-tuned with information gathered directly from citizens through the platform. Using RAG techniques, it retrieves relevant pieces of citizen-generated data and incorporates them into its responses, ensuring that the answers reflect real community perspectives. This approach not only enhances the accuracy of the chatbot’s responses but also grounds them in lived experiences and local knowledge. As a result, the system does more than just provide generic information; it delivers contextually rich answers that capture the priorities, concerns, and viewpoints of the public. In this way, the Q&A page strengthens the feedback loop between citizens and planners, supporting more informed decision-making and fostering a participatory approach to urban development. Figure 5 illustrates the Q&A page.

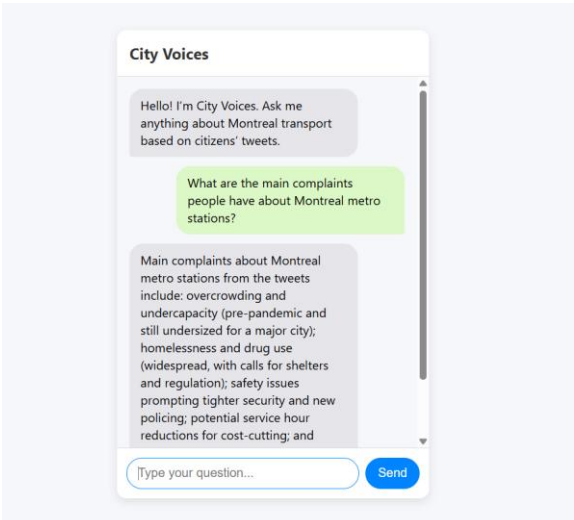


Figure 5. How the Chatbot Works

## 5. Conclusion

In conclusion, the primary purpose of this platform is to simplify the process of data generation for citizens by making it more user-friendly and accessible. The system is designed so that citizens only need to provide their input in the most convenient format, while the subsequent stages of analysis and data extraction are handled automatically through AI algorithms. This approach minimizes barriers to participation and ensures that valuable insights can be gathered with minimal effort from users. The current research has focused mainly on text-based inputs, demonstrating the feasibility of collecting and analyzing written data from the public. However, there is significant potential to expand this framework by incorporating additional modalities such as images or voice recordings. Allowing citizens to contribute data in multiple formats would not only enrich the dataset but also make the platform more inclusive. Such extensions could strengthen the adaptability and real-world applicability of the system.

Another major focus of this research has been the development of the chatbot section, which currently provides AI-driven responses grounded in citizen-generated content. While this functionality already offers valuable interaction, future improvements could enable the chatbot to function as a more advanced AI agent. Specifically, it could be designed to perform spatial analysis directly on the collected data in response to user commands. This capability would represent a significant step forward, as it would empower citizens and planners alike to query, analyze, and visualize complex spatial relationships in real time. By integrating natural language processing with GIS-based analytical functions, the system could bridge the gap between public input and technical urban analysis. Such advancements would enhance the platform’s role as both a participatory tool and a decision-support system. Ultimately, this would contribute to creating smarter, more responsive, and more citizen-centered urban planning processes.

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