Public Participation, Spatially-Informed Artificial Intelligence and Territorial Planning: Integrating GIS, Text Mining and Clustering for the Analysis of Stakeholder Preferences

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Abstract. The increasing complexity of territorial planning processes, particularly in the context of large-scale infrastructure projects, calls for the integration of participatory approaches, spatial analysis and advanced computational techniques. This paper proposes a comprehensive methodological framework that combines public participation, Geographic Information Systems (GIS), text mining, clustering algorithms, and AI-based analytical techniques within a structured and transparent workflow for the systematic analysis of stakeholder contributions. A central contribution of this work lies in the explicit incorporation of spatial variables into the analysis of stakeholder preferences, with particular attention to the relationship between geographical proximity and expressed sentiment. Based on developed theoretical paradigms such as spatial behavior theory, distance-decay models, and Not In My Back Yard (NIMBY) dynamics, the study explores how distance from an intervention impact on the strength and direction of stakeholder positions.

The proposed approach transforms unstructured textual data obtained by participatory processes into structured indicators of territorial consensus and dissent. These indicators provide a solid analytical foundation for understanding spatial patterns of conflict and support in complex planning environments. To achieve a thorough understanding of territorial transformation processes and their perception by stakeholders and locals, a case-study approach is adopted. The in-depth analysis implemented of the Paderno Bridge enables the implementation of a series of examinations aimed at investigating the relationships between public opinion, stakeholder positions, and decision-making processes.

Keywords: Public Participation · Clustering Analysis · Stakeholder Analysis · Geographic Information Systems (GIS) · Natural Language Processing (NLP) · Participatory Planning

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1 Introduction

In the last decades, territorial planning has experienced a deep transformation, changing from a predominantly technocratic and expert-driven practice toward more inclusive and participatory models. This evolution has been particularly evident in the management of major infrastructure projects, where decision-making processes are characterized by a multiplicity of stakeholders, including public entities, local communities, economic operators, and civil society.

In such contexts, participatory mechanisms, such as public consultations, debates, and formal submissions, produce significant number of qualitative data. These contributions often reflect highly heterogeneous standpoints, ranging from technical observations to strongly articulated positions of support or opposition. While, on one hand these inputs are relevant for guaranteeing democratic legitimacy and for the enhancement of the quality of decisions, on the other hand they constitute significant analytical challenges due to their unstructured nature.

Simultaneously, decision-support frameworks, specifically those based on multi-criteria approaches, require structured and comparable information. Thus, a crucial methodological gap arises on how to systematically transform qualitative stakeholder contributions into quantitative or semi-quantitative indicators that can be integrated into decision-making processes.

Nevertheless, recent advances in Artificial Intelligence (AI), particularly in deep learning-based Natural Language Processing (NLP) and the emergence of Large Language Models (LLMs), offer encouraging solutions to this challenge. In particular, the extraction of significant patterns from large corpora of textual data is allowed by text mining and representation learning techniques, while clustering methods enables the identification of groups of stakeholders sharing similar positions. Still, the spatial embeddedness of stakeholder preferences represents a critical dimension often overlooked in such analyses. Indeed, it is necessary to consider that stakeholders are not abstract entities, since they are located in space and thus influenced by spatial factors and dynamics. Municipalities, associations, and committees operate within specific territorial contexts, and their perceptions are influenced by their geographical proximity to the intervention. This introduces a spatial dimension that is central to understanding the distribution of consensus and dissent.

This paper addresses this gap by proposing an integrated framework that combines participatory data analysis with spatial modeling, by investigating the hypothesis that distance from the intervention influences stakeholder sentiment, drawing on the well-established concept of the distance-decay effect.

2 Objectives

The necessity to involve stakeholders in decisional processes inherent territorial interventions, specifically those concerning infrastructures, has developed from a generic indication to a legal constraint. In this sense, the Economic Appraisal Vademecum highlights the relevance of considering the effects on those stakeholders that are indirectly affected by governance policies [1]. In particular, the Stakeholders Engagement (SE) is

prescribed as a fundamental step in the choices-making process to support the project decision aimed at determining part of the society's gains from the investment. In Italy, these indications are the basis of Public Debate, that is an obligatory procedure imposed by the Procurement Code with the objective of guaranteed transparency and stakeholders' participation, both private and public [2]. These impositions reinforce the fundamental principles of participatory planning: *i)* the population possesses a type of unstructured knowledge complementary to that of a technical-specialist type; *ii)* the success of a territorial transformation intervention requires the involvement of the population. The various challenges undoubtedly involve the participation of numerous actors, who are concerned in different ways by the social, economic, and environmental effects generated. Starting from this premise, the present work aims to provide a methodological approach that can support complex decision-making processes by enhancing the information derived from participatory procedures.

3 Theoretical Framework

The recorded difficulties in sustainable urban governance are mainly due to the heterogeneous nature of the societal domains and by the variety of the prospectives of the multiple actors involved concerned by the social, economic and environmental impacts [3]. In this sense, the integration of public opinion contributions represents, according to the recent academic literature [3–11], an effective tool to improve decision-making processes with respect to spatial planning. The theoretical foundation of participatory planning can be traced to two crucial works that conceptualize planning as a collaborative and communicative process [4, 5]. In this perspective, knowledge is co-produced through interaction among stakeholders, and planning outcomes emerge from negotiation rather than imposition. Moreover, involving multiple stakeholders in planning public land use has been considered promising in achieving better outcomes and increasing adaptability of social-ecological systems [6]. Additionally, the participation of citizens in the urban planification is recognized as key element in the requalification and revitalization projects [7]. The need to increase the population participation in the implementation of territorial transformation projects is also due by the imposition of legal requirements, community expectations and regulatory objectives. These requests, in fact, have led to the implementation of collaborative planning processes in solving urban problems [8]. It also possible to identify several benefits from public involvement in decision-making processes; it, in fact, allows to improve the effectiveness of projects; meet a growing demand for public participation, resolve conflicts, value knowledge, understanding and public awareness, manage resources more consciously, strengthen the local community, improve the decision-making process and better understand the needs of the real users of the project we intend to carry out [9]. In this sense, these approaches contribute to achieving the crucial objectives of inclusiveness, deliberation and consensus-building.

Although collaborative approaches are recognized as fundamental tools, their application is nevertheless characterized by some limits and issues [7, 9–11]. Specifically, the complexity of managing large-scale participatory processes increases when the number of actors and contributions rises significantly [4, 5]. In addition, contributions from the population are often restrained by lengthy and cumbersome bureaucratic procedures

for transmission to decision-making bodies. Also, requests for public opinion are often confined to a token procedure aimed at justifying decisions that have already been made [10]. Moreover, the limited awareness of social dynamics and structures by policymakers leads to a failure to recognize the heterogeneity of the population and to a flattening of the positions taken regarding the projects under consideration [11].

3.1 Spatial Behaviour and Distance-Decay

Some academic research highlights how the perspective of the population is closely linked to a range of factors, among which the perception of space emerges. The latter is a fundamental element as it shapes behaviors and affects how individuals relate and respond to spatial transformation interventions [12–14]. In line with these considerations, in the present study the spatial behaviour paradigm is considered as a key theoretical pillar. By examining how geographical factors influence human perceptions and decisions, it allows to deepen the comprehension of the public perspective. However, it is necessary to consider the distance-decay effect, which suggest that the intensity of interaction or perception decreases as distance increases. Specifically, in the context of urban governance, this principle has been widely observed in studies of environmental conflicts and infrastructure siting [15–19]. The distance-decay effect is indeed discussed as a fundamental feature of spatial economic processes, and therefore also of territorial planning, as spatial interactions decline with distance at different rates depending on the phenomenon considered [15]. Closely related is the concept of NIMBY (Not In My Backyard), which describes the tendency of local populations to oppose developments perceived as harmful when they are located nearby [20]. The NIMBY can also been considered as a political-economic conflict arising from the need to locate facilities that generate collective benefits but impose localized costs [21]. Such conflicts usually emerge when it comes to hazardous waste or nuclear facilities [22, 23] and wind energy technological innovation policies [24].

More recent research [25–27] extends these ideas through i) spatial econometrics, ii) geographically weighted models and iii) spatial decision support systems. For example, econometric methods have been used, specifically hedonic price model estimated with OLS and a Generalized Additive Model, to empirically analyze the NIMBY effect showing both distance-based and directional heterogeneity [25]. Accordingly, it has been shown that geographically weighted regression (GWR) is essential to capture spatial heterogeneity in the valuation of environmental amenities, revealing that their impact on housing prices varies significantly across space [26]. Moreover, a prototype Spatial Decision Support System (SUDSS) has been presented that integrates GIS and collaborative decision-making tools to support public participation in spatial planning problems, including conflicts such as NIMBY [27]. These approaches demonstrate that preferences are not spatially uniform but vary across space in systematic ways.

3.2 Toward Spatially-Informed Preference Analysis

The analysis and investigation models, discussed in the previous section, focused on the population spatial perception and on its effects on its perspective on the territorial transformations is a key starting point. In particular, the integration of spatial analysis with

textual data analysis represents an emerging research frontier [28]. While sentiment analysis has been widely applied in various domains, its integration with spatial variables has given rise to approaches that can be broadly defined as spatially-informed sentiment and preference analysis [29, 30]. This paradigm, by contextualizing the emerged opinions within a geographical framework, allows the identification of spatial patterns in attitudes and perceptions, thus going beyond the sole classification of the examined standpoints [31, 32]. For example, an approach that integrates spatial data with human emotional data with the objective to analyse how urban environments influence people sentiment has been proposed. Specifically, through the use of geolocated social media content and artificial intelligence techniques, physical characteristics of urban space have been associated to people's emotional responses, displaying that sentiment varies considerably according to the geographical context. In this sense, the study proves how the integration of spatial variables with collective perception data contributes to the development of a "spatially-informed" sentiment analysis [31]. Likewise, sentiment expressed on Twitter have been examined using geolocated data, combining sentiment analysis techniques with spatial and temporal methods to study how emotions are distributed across different locations. By using spatial indicators and mapping, it demonstrates that users' opinions and perceptions are not uniformly distributed; in fact, they vary forming distinct geographical patterns and local clusters related to place characteristics and social activities. In this sense, the study extends beyond simple sentiment classification, demonstrating how opinions can be interpreted within a geographical framework, in accordance with the idea of a spatially-informed sentiment analysis [32].

4 Methodological Approach

The analytical procedure followed a sequential and structured approach to text analysis, making use of NLP techniques supported by LLMs. Rather than relying on a fully automated or opaque process, each stage of the analysis was carried out in a controlled and explicit manner. The workflow included the extraction of key themes from the textual corpus, their subsequent organization through hierarchical clustering (represented by dendrograms), and finally a structured sentiment evaluation. Each step was subject to iterative checks and refinements to ensure consistency and methodological robustness. This approach allows the analytical process to remain transparent and interpretable, while still benefiting from the capabilities offered by advanced AI-based tools.

4.1 Text Processing and Representation

The analysis is based on textual documents derived from participatory processes (e.g., PDF submissions). These documents are first pre-processed through standard NLP procedures, including tokenization, stopword removal, and lemmatization. Following preprocessing, the textual corpus is transformed into numerical representations. In this study, both term-frequency-based approaches (e.g., TF-IDF) and embedding-based representations are considered, allowing documents to be mapped into a high-dimensional vector space suitable for further analysis.

The TF-IDF weighting scheme is defined as:

$$TF - IDF(t, d) = TF(t, d) \bullet \log\left(\frac{N}{DF(t)}\right)$$

This representation enables the identification of relevant terms within documents while reducing the impact of commonly occurring words.

4.2 Clustering Techniques

To identify groups of stakeholders with similar positions, clustering algorithms are applied. The K-means algorithm minimizes the within-cluster variance:

$$J = \sum_{i=1}^{k} \sum_{x \in C_i} \|x - \mu_i\|^2$$

4.3 Guided AI-Based Analysis

A key methodological aspect of the proposed approach lies in the guided use of AI-based techniques. Rather than relying on fully automated procedures, the analytical workflow is structured in a sequential and transparent manner, where each phase is explicitly defined and contributes to the overall interpretability of the results. The process include:

- the selection of appropriate text representation models (e.g., TF-IDF or embedding-based approaches),
- the application and comparison of clustering techniques,
- the interpretation of thematic and sentiment-related outputs in relation to planning issues.

This structured approach ensures that the analytical process remains transparent and interpretable, which is particularly relevant in planning contexts where the legitimacy of results depends on their clarity and traceability.

4.4 GIS Integration

Stakeholders were geolocated within a GIS environment by associating each actor—municipalities, committees, and associations—to their corresponding spatial reference (centroid or representative location). This process enabled the construction of a spatially explicit dataset linking stakeholder attributes to their geographical position. Subsequently, the distance between each stakeholder and the intervention site was calculated using proximity analysis tools, generating a continuous variable expressed in meters. This variable represents a key spatial metric used to investigate the relationship between territorial proximity and stakeholder positioning. The integration of GIS within the analytical framework allows for a multi-level spatial interpretation of participatory data. Specifically, it enables:

- the mapping of stakeholder distribution, highlighting the spatial configuration and density of actors involved in the participatory process;
- the identification of spatial clustering patterns, distinguishing between a core area of high stakeholder concentration and more peripheral zones;
- the interpretation of spatial gradients in stakeholder behavior, by linking geographical distance to qualitative evaluations expressed in the documents.

Rather than relying solely on descriptive mapping, the GIS component supports a structured spatial reading of the data, allowing the identification of territorial patterns in stakeholder engagement. This integration represents a crucial step in bridging qualitative participatory inputs with spatially grounded analytical perspectives, providing a more comprehensive understanding of how geographical context shapes stakeholder responses.

5 The Case Study

5.1 Description of the Intervention Area

The Paderno Bridge, also known as the San Michele Bridge or Röthlisberger Bridge, represents a major relevance infrastructure, particularly in light of the latest regional and European planning frameworks aimed at promoting transport networks and connectivity systems. The bridge is a relevant crossing over the Adda River, it is indeed characterized by a motor vehicle traffic (single lane with alternating flow), a regional railway line (single track), and cycling and pedestrian routes (including the Alpine foothills cycle path and the Adda cycle path). The bridge was constructed between 1887 and 1889 to connect the municipalities of Paderno d'Adda and Calusco d'Adda, it spans a segment of the Adda River characterized by significant elevation differences. From the historical point of view, the infrastructure falls into the broader and fundamental process of expansion and rationalization of the Lombard railway network in the second half of the nineteenth century. The expansion and enhancement of territorials' infrastructures was crucial to support the industrial development of the region. In the aftermath of the unification of Italy, the need to reorganize railway lines, earlier managed by different companies, became increasingly evident with the objective to improve connectivity between economically strategic areas and to promote the production and export of different goods. Within this context, the bridge shows the fundamental role of transport infrastructure in fostering economic integration between the two main productive areas of Milanese and Bergamo, while also representing a significant example of nineteenth-century technological progress in metal building engineering.

The construction of the bridge implicated the resolution of different complex technical challenges. The adopted design was indeed based on an innovative structural approach, aligning the project with contemporary European achievements in large-scale metal bridge construction. From a technical point of view, the bridge in made by an iron arch structure with riveted beams, extending over a total length of 266 m, with a central span of 150 m. The deck is divided in two functional levels: the upper one is dedicated to road traffic while the lower one to railway traffic. The structure rises approximately 85 m above the river level.

At present, the discrepancy between the bridge's structural capacity and the demands of modern traffic has necessitated the introduction of stringent traffic regulations, including speed limitations. However, such measures constitute only a partial response to emerging territorial needs. In particular, the inadequacy of the bridge in accommodating inter-municipal and regional traffic flows, as well as broader connectivity requirements, has prompted public authorities to explore alternative and more efficient strategies. These strategies aim not only to address infrastructural demands but also to preserve the historical and cultural value of the bridge, which is protected under Legislative Decree No. 42/2004. In response to the increasing pressure exerted on transport networks serving major urban hubs in the region (such as Milan, Monza, and Bergamo), the Ferrovie dello Stato Italiane Group has proposed a project to upgrade the Carnate–Ponte San Pietro railway line. Presented by Rete Ferroviaria Italiana (RFI) in July 2023, the project outlines three alternative design scenarios aimed at enhancing the crossing capacity of the railway system, currently recognized as a critical connection between the Brivio–Trezzo and Cisano Bergamasco–Capriate San Gervasio corridors.

The proposed intervention includes the enhancement of the Seregno/Monza–Bergamo transport corridor, a significant connection segment due to the high volume of commuter traffic, above all in the city of Seregno, which represent as a crucial interchange node with both the Milan–Chiasso line and the Ferrovie Nord network.

In particular, the project aims to achieve two purposes: on the one hand, it wants to guarantee the structural safety and the conservation of the existing bridge, preserving its historical, cultural, and landscape value. On the other hand, it aims to reduce traffic pressure through the enhancement of complementary infrastructure addressed at overcoming recent limitations. The overarching objective is to improve service performance along the Carnate–Ponte San Pietro line, thereby increasing new patterns of territorial use both within the directly affected area and across the broader connected regions.

The three proposed alternatives are defined as follows: Alternative 1 includes the construction of a single structure adjacent to the existing bridge, replicating its functional configuration, with road traffic on the upper level and railway traffic on the lower level (Fig. 1); Alternative 2 involves the development of a new railway alignment to the south of the existing route, combined with a road connection located to the north at a distance of approximately 3.5 km from the current crossing (Fig. 2); Alternative 3 represents a hybrid solution, combining elements of the previous scenarios, including a railway bridge closely aligned with the existing structure and a separate road bridge located approximately 3.5 km to the north, consistent with the spatial configuration defined in Alternative 2 (Fig. 3). Unlike Alternative 1, this scenario does not integrate road infrastructure within the railway bridge structure.

The comparative analysis of the three alternatives is aimed at identifying the most suitable option based on a set of explicitly defined criteria. In this sense, RFI's options analysis is a systematic and multidisciplinary evaluation process aimed at supporting the following implementation phases. In particular, the applied approach, instead of adopting unstructured techniques in the selection process, implements a more structured decision-making framework basing on predefined evaluation criteria, including environmental impact, economic sustainability, accessibility, and alignment with strategic international objectives. Within complex infrastructure projects, such as the case study,

this method enables the clear identification of trade-offs among the examined alternatives, contributing both to minimize the risk of ineffective decisions and to ensure that the final choice is drawn on a transparent and structured evaluation process. Consecutively, this approach influences the maximization of stakeholder value and develops long-term operational effectiveness.

Within this framework, the options analysis can be considered as a practical application of multi-criteria decision analysis methodologies applied in a complex decision-making context.



Fig. 1. Proposed intervention, alternative 1.

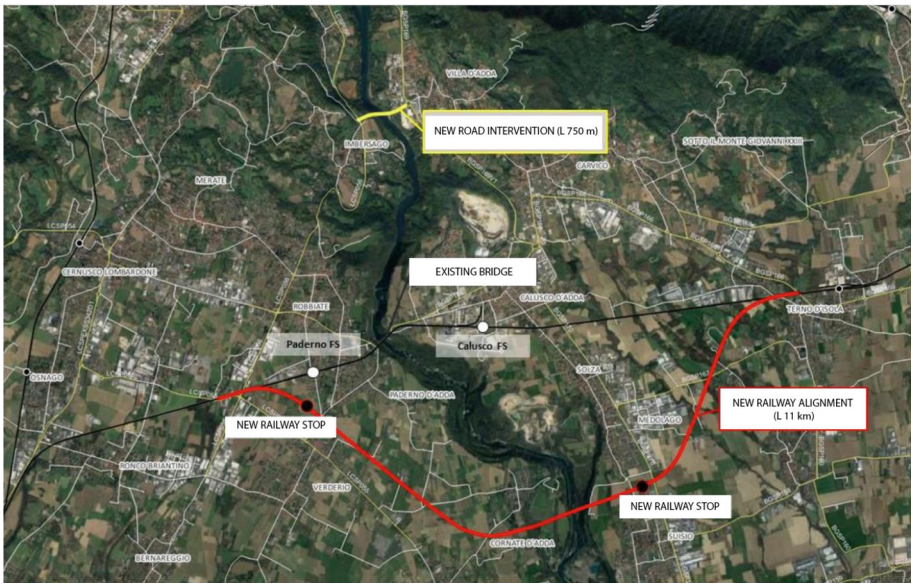

Fig. 2. Proposed intervention, alternative 2.

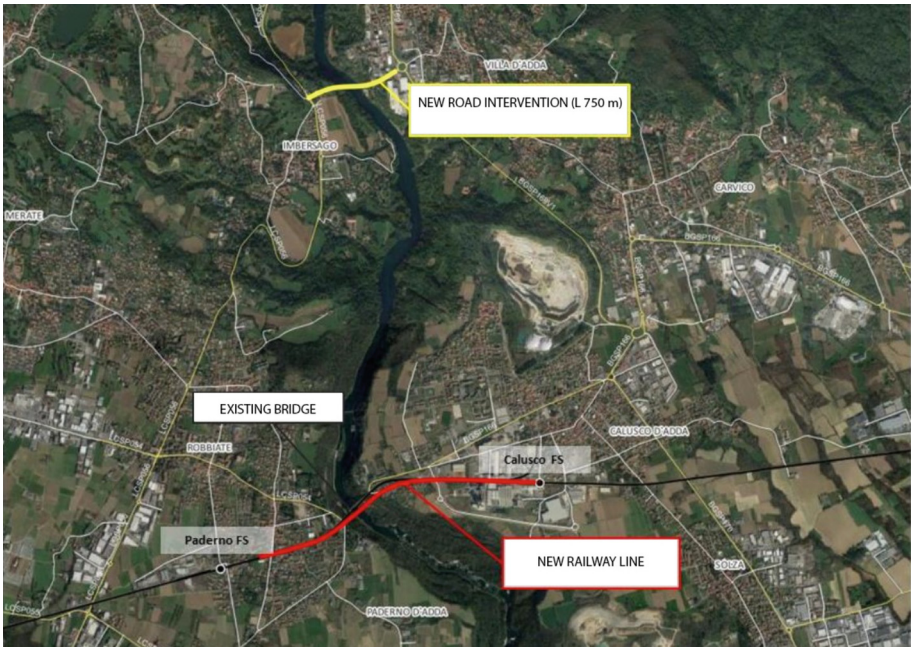

Fig. 3. Proposed intervention, alternative 3.

5.2 Application of the Methodological Approach

Spatial Distribution of Stakeholders

The spatial distribution of stakeholders (Fig. 4), derived from the calculated distances and administrative localization, reveals a clearly structured and multi-scalar configuration centered around the intervention area.

At the core, a highly concentrated local cluster emerges within a radius of approximately 0.8 km to 3 km, including municipalities such as Paderno d'Adda (≈0.8 km), Robbiate (≈1.3 km), Calusco d'Adda (≈2.1 km), Imbersago and Solza (≈2.8 km). This inner nucleus is further reinforced by the presence of local committees located at very short distances, indicating a strong territorial proximity to the project site.

A second spatial layer can be identified between approximately 3 km and 7 km, comprising municipalities such as Merate, Cernusco Lombardone, Osnago, Ronco Briantino, Aicurzio, Bernareggio, and Carnate. This intermediate ring reflects a broader area of territorial involvement, still closely connected to the intervention corridor but with a slightly reduced spatial centrality.

Beyond this, a peripheral and regional scale becomes evident, with stakeholders located at distances exceeding 10 km, including Trezzo sull'Adda (~9 km) and various associations and institutional actors extending up to 40 km (e.g., Lodi, Milano, Como). These actors define a more dispersed spatial pattern, extending the participatory process to a wider territorial context.

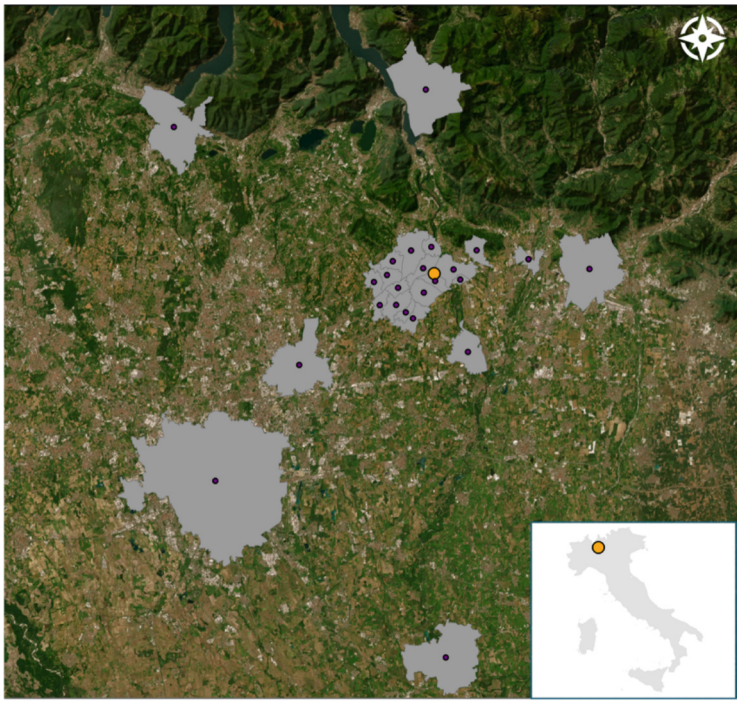

Fig. 4. Territorial distribution of municipalities contributing to the public debate.

Overall, the distribution delineates a concentric spatial structure, characterized by:

- a dense local core of municipalities and committees,
- an intermediate municipal belt,
- and a diffuse outer layer of regional stakeholders.

This configuration reflects a clear spatial gradient of stakeholder presence, transitioning from strong local concentration to broader regional dispersion.

AI-Assisted Structuring of Stakeholder Evaluations

In order to transform the unstructured textual contributions collected during the participatory process into a structured and comparable dataset, a Large Language Model (LLM) was employed as a support tool for qualitative synthesis and categorization. The LLM was used to systematically extract, organize, and standardize key information from each document, including stakeholder identity, institutional type, municipality, and evaluation of the three project scenarios.

Specifically, the model supported the construction of a synthetic table in which each contribution was codified according to: (i) the qualitative assessment of each scenario, (ii) an overall classification of the stakeholder's position, (iii) a set of representative keywords summarizing the main arguments, and (iv) a methodological note explaining the rationale behind the assigned judgment.

Importantly, the use of the LLM did not replace the interpretative role of the researcher. Instead, it operated within a guided and supervised framework, where outputs were iteratively reviewed, validated, and refined to ensure consistency, coherence, and adherence to the original content of the documents. This approach allowed for the efficient processing of a large textual corpus while maintaining transparency and interpretability in the analytical process.

The resulting table represents a structured synthesis of stakeholder position (Table 1).

Table 1. Synthesis of the stakeholder position obtained using the LLM approach (M = Municipality, BA = Business association, C = Committee, CA = Category association).

Stakeholder	Type	Scen.1	Scen.2	Scen.3	Overall Classification	Keywords
Aicurzio	M	Predom negative	Neutral	Neutral	Territorial critique	project disruption; territorial impact; line doubling
AIB Isola Bergamasca Association	BA	Neutral	Neutral	Neutral	Economic position	logistics mobility; enterprises
Bernareggio	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts; road congestion

(*continued*)

Table 1. (*continued*)

Stakeholder	Type	Scen.1	Scen.2	Scen.3	Overall Classification	Keywords
Calusco d'Adda	M	Moderately Positive	Neutral	Neutral	Conditional support	single bridge; direct connection; reduced impact; mobility continuity
Carnate	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts; road congestion
Cernusco Lombardone	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts; road congestion
Citizens Committee Ponti	C	Negative	Negative	Negative	Civic opposition	environmental damage; landscape degradation
New Mobility Isola Bergamasca Committee	C	Negative	Negative	Negative	Strategic opposition	ecological damage; lack of systemic vision; traffic dominance
Ponte e Monastero dei Verghi Committee	C	Negative	Negative	Negative	Environmental opposition	health impact; expropriation; hydrogeological risk; vibrations
Confagricoltura Como	CA	Neutral	Neutral	Neutral	Agricultural position	agricultural land impact
Confagricoltura Lecco	CA	Neutral	Neutral	Neutral	Agricultural position	agricultural land impact
Confagricoltura Lodi	CA	Neutral	Neutral	Neutral	Agricultural position	rural land protection
Confagricoltura Milano	CA	Neutral	Neutral	Neutral	Agricultural position	rural land protection
Confagricoltura Monza	CA	Neutral	Neutral	Neutral	Agricultural position	rural land protection
CONFAPI Lecco	CA	Neutral	Neutral	Neutral	Economic-technical position	productive activities; business mobility
Imbersago	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Lomagna	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts

(*continued*)

Table 1. (*continued*)

Stakeholder	Type	Scen.1	Scen.2	Scen.3	Overall Classification	Keywords
Merate	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Osnago	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Paderno d'Adda	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Robbiate	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Ronco Briantino	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Solza	M	Neutral	Neutral	Neutral	Technical observations	impact evaluation; sustainable mobility
Sotto il Monte Giovanni XXIII	M	Negative	Negative	Negative	Project opposition	multiple critical issues; no evident benefits
Sulbiate	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts
Trezzo sull'Adda	M	Predom negative	Neutral	Neutral	Institutional critique	road network issues; uncertainty in mobility
Verderio	M	Negative	Negative	Negative	Territorial opposition	traffic issues; severe impacts

6 Analysis of the Results

The integration between spatial data (distance from the intervention) and stakeholder evaluations reveals a clear and interpretable territorial pattern in the distribution of judgments. At the local scale, stakeholders located near the intervention—generally within a few kilometers—tend to express uniformly negative evaluations across all scenarios. Municipalities such as Paderno d'Adda, Robbiate, Imbersago, Merate, and the surrounding cluster show a strong alignment in their positions, consistently highlighting critical issues. This spatial concentration of negative judgments suggests that actors directly embedded in the area of impact perceive the project primarily through its immediate territorial consequences.

Moving to an intermediate spatial range, roughly between 5 and 10 km, the pattern becomes slightly more differentiated. While negative judgments still prevail, some stakeholders express less polarized or scenario-specific evaluations, as in the case of Aicurzio and Trezzo sull'Adda. This indicates a partial attenuation of opposition, where

the perceived impacts remain relevant but are less uniformly interpreted across all project alternatives.

At the regional scale, corresponding to distances exceedingly approximately 10–15 km, a clear shift in stakeholder positioning emerges. Actors located farther from the intervention—particularly sectoral and economic associations such as Confagricoltura and AIB—tend to adopt neutral or non-committal evaluations across all scenarios. Their contributions focus more on general or sector-specific considerations rather than direct territorial impacts.

Overall, the observed distribution highlights a spatial gradient in stakeholder judgments, characterized by:

- strong and homogeneous opposition in close proximity;
- moderate variability at intermediate distances;
- and increasing neutrality at greater distances.

This pattern suggests that the intensity and orientation of stakeholder evaluations are closely associated with their geographical position relative to the intervention, reflecting a structured spatial differentiation in the participatory process.

7 Conclusions and Future Insights

The high complexity of the decision processes at the base of the implementation of major territorial transformation has revealed the growing importance of integrated participatory approaches. The positive effects conferred by the stakeholders' approval have made it necessary to take their standpoint into greater consideration in order to contribute to a more sustainable and resilient projects. In particular, the development of infrastructure projects often generates opposition from local communities, which tend to perceive such interventions as top-down impositions that provide limited or no tangible benefits to the territories in which they are implemented.

In order to mitigate this phenomenon and to leverage stakeholders' knowledge, both national and international regulatory frameworks participatory processes aimed at involving the population and fostering the identification of broadly shared solutions.

Despite these provisions, decision-makers frequently approach such processes as a formal requirement rather than as a genuine opportunity to incorporate unstructured knowledge. At the same time, representatives of local communities often adopt predefined and rigid positions, which can hinder constructive dialogue.

Starting from these premises, this study proposes an approach that integrates NLP and GIS techniques to systematize and enhance the contributions emerging from public participation. By the TF-IDF and of clustering techniques, the described framework allows transforming non-structural textual data into quantitative indicators. In addition, the use of GIS-based tools and the georeferencing of data enables the visualization of such information into specific maps that permit to link sentiments and opinions to the place they are made. At the same time, it also makes this information accessible to non-expert users. This reduces the risk of the public debate being perceived as a mere bureaucratic procedure, while enhancing the actors' opinions as a key resource.

The proposed case study provides a relevant testing ground for assessing both the limitations and the potential of the approach. Specifically, the obtained results from

the Paderno bridge analysis are coherent with the hypothesized spatial-dependence of preferences varying the distance-decay paradigm. It is indeed possible to observe a negative polarization in the areas nearest to the intervention typical of NIMBY dynamics. The results through the application to the case study thus confirm the validity of the proposed approach.

Finally, the spatial-informed framework offers a sound operative medium for more inclusive and democratic planning strategies by recognizing the diversity of the population involved preventing the flattening of positions. Through the overcoming the traditional procedures, the proposed model thus allows to integrate stakeholders varied positions in a decision support tool while also granting trackability of the mad choices.

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