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Comparative review for theoretical and practical geospatial frameworks for effective building permitting lifecycle in municipalities

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Municipal sector performance is significantly impacted by rapid urban sprawl globally, posing challenges for service providers in land management and the effective control of new building permitting processes. Technology has the potential to address these challenges; however, it does not resolve the lack of clarity in the municipality's guidelines, which hinders the deployment of solutions. The study's significance in improving the permitting process is considered a significant contributor to cities' growth speed, quality, and growth directions. The study aims to examine building permit frameworks from a land management technology perspective to develop guidelines and frameworks that support effective building permitting processes. Integrating land management permitting processes and geospatial systems led to the adoption of technology that merges theoretical and practical frameworks, focusing on Geographic Information Systems (GIS) and Building Permitting Systems (BPS), as well as emerging technologies. The study was conducted by coding and pairing the main items among the theoretical and practical frameworks under the technology, process, organization, and legislation to define the areas of improving BPS. Hence, the research identified key components of selected frameworks between processes, technology, and organizations to identify guidelines for building a robust framework for future BPS considering geospatial data. Also, it emphasized standardizing data to enhance permit processing and land management efficiency and effectiveness.

KEYWORDS

municipality, GIS, building permits, land management, integration

1 Introduction

Governmental agencies aim to meet the needs of citizens' consistent demands in urban areas from the municipal level, with cities' sprawl and population increasing from 4,081 million in 2014 and is forecasted to grow to 6,605 million in 2050, with a ratio of 68% ([Publications UN, 2022](#)). Necessitating the adoption of strategies to face the rapid urbanization's speed and direction that impact social, economic, and infrastructural aspects, and meet citizens' needs. Municipalities struggle with fragmented functions, inadequate system integration, and poor interdepartmental communication, leading to inefficiencies in building permit approvals and ultimately

impacting project stakeholders. Building Permitting Systems (BPS) is a key enabler of strategy execution as a tool for land development, building, and streamlining regulatory implementation. Still, BPS processes hinder integrating municipal systems and data management, delaying public and private investments, housing development, and urban planning initiatives. According to (Aljobaly et al., 2022), the persistent challenges due to departmental siloing and lack of integration among systems and departments reduce workflow efficiency, leading to decreased efficiency and delays in permit approval, and producing challenges in adopting technological solutions. Likewise (Mandeli, 2015), has reported that poor governance is a cause of weaknesses, transparency issues, and rigid workflows. Therefore, modernizing permitting systems, aligning them with evolving regulations, and integrating workflows to overcome barriers and improve services.

At the same time, the gap between academic research and practical application remains a barrier to effective monitoring, planning, and decision-making. Geographic Information Systems (GIS) platforms have shown the capability to improve the quality of municipal services by offering spatially relevant data for urban planning (Rachekhu and Kgobe, 2024). However, municipalities struggle to fully utilize GIS technologies for decision-making because of inadequate data integration across planning departments and the lack of geospatial frameworks to tackle urban development issues. This study emphasizes the importance of integrating municipal agencies to enhance land development processes, building permit systems, and urban planning management. Specifically, it explores the potential of transitioning from two-dimensional to three-dimensional geospatial models to improve decision-making, regulatory compliance, and data utilization (Hobeika et al., 2022). Additionally, it highlights enhancement areas for processes by identifying municipal functions related to building permits. However, the research aims to identify the most suitable guides for integrating geospatial data with building permit systems, assessing efficiency, and understanding the main components of BPS and GIS within municipalities, which are essential for comprehensive analysis and improvement. Responding to the raised questions, the authors defined three objectives to establish the scope and deepen the study.

1. To examine the effectiveness of land geospatial data in supporting municipal building permit systems.
2. To identify the building permit system components for the effective municipal geospatial framework.
3. To develop guidelines for geospatial management that support municipal building permit systems.

The addressing of objectives seeks to develop guidelines that align municipal geospatial systems with building permitting processes, providing insights into the system's impact on urban management and identifying opportunities for improvement.

2 Literature review

2.1 Municipal role in land development

Cities are urban areas providing essential services, while municipalities manage local governance through elected officials

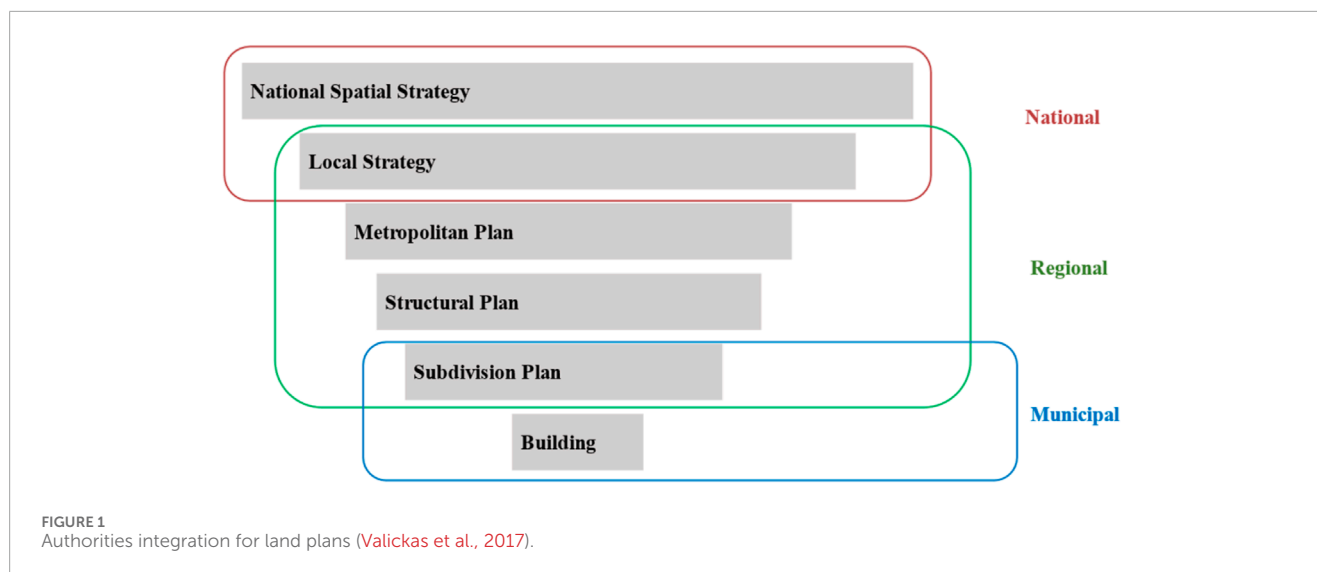
TABLE 1 The primary and regional-based functions of municipalities (Centre, 2015).

Primary functions	Regional-based functions
Assist sectors of housing, health, education, water, recreation, and environmental health needs	Political dimension: Establishing new policies and regulatory mechanisms
Take over organizational planning of economic, social, and environmental development. Also, it facilitates construction and municipal services	Economic dimension: Municipal taxation, funding, donations, and implementation of the budget.
Manage and monitor property development and natural resource preservation	Administrative dimensions: Provision of municipal public services and contracting and deployment of staff
Promoting community participation and socio-cultural improvements	-

to meet community needs (Gallegos-Baeza et al., 2023). Historically, municipalities evolved from utility providers to addressing education, public safety, transportation, and economic development, now facing modern challenges like climate change and social inequality. A strong BPS framework integrates multiple domains to support municipal services, balancing national goals with local service delivery. Governments align objectives with Sustainable Development Goals (SDGs) to improve social well-being and resource efficiency (MoMRAH, 2022). From city management practices, municipalities play a key role in achieving national strategic goals, whether centralized or decentralized modules.

Municipal functions are shaped by the distribution of authority across planning, operations, development, and monitoring. Decentralization frameworks distinguish between primary and secondary functions, enabling municipalities to focus on core responsibilities while delegating supportive tasks to specialized units. The federated and decentralized governments shall facilitate the primary and secondary functions to be managed by the mayors, from governing the city and supporting legislation to the administrative level for city managers. According to (Centre, 2015), the authors defined that municipalities' functions vary among countries, along with the levels of delegation of authority that enable government roles based on the country's structure. Thus, the changes in municipalities' roles fall under several core and secondary functions within the municipal responsibility. The literature identified two types of primary and regional-based functions municipalities should perform, as shown in Table 1.

The primary functions include providing public safety and education, such as police, fire, emergency medical services, public schools, libraries, and other educational institutions, utilities infrastructure, social services for vulnerable populations, and programs for the elderly and disabled. On the other hand, the secondary functions of municipalities include enhancing the quality of living through parks, recreation, arts and culture, economic development, and environmental protection. Municipal functions are measured and prioritized, and a positive relationship exists between services provided and citizens' satisfaction (Ozdogan et al., 2020).



Land management at the local level involves implementing growth strategies, monitoring delivery, administering zoning and land use regulations, ensuring development aligns with municipal goals, providing infrastructure, waste management, and integrating municipal departments to facilitate city growth. However, planning land is one of the most critical decisions in city history, and city managers have been responsible for planning and implementing the development by controlling the tools of constructing utility services, approving subdivided plans, urban growth boundaries, and preventing leapfrog issues (Hanberry, 2023). Tools are varied to control growth and thrive by developing action plans based on strategic goal parameters, overseen by time, location, and change status, to ensure functioning municipal services. Growth spatial strategy, time, and financial factors in land development affect the comprehensive planning, defining urban growth boundaries, preventing sprawl, and managing zoning plans and ordinances. Additionally, emphasizes the role of planners in overseeing changes at the local level and aligning them with national goals under the current level of authority. Figure 1 shows the overlaps of city plans and authority roles from the national strategy to the local municipalities (Affairs, 2019).

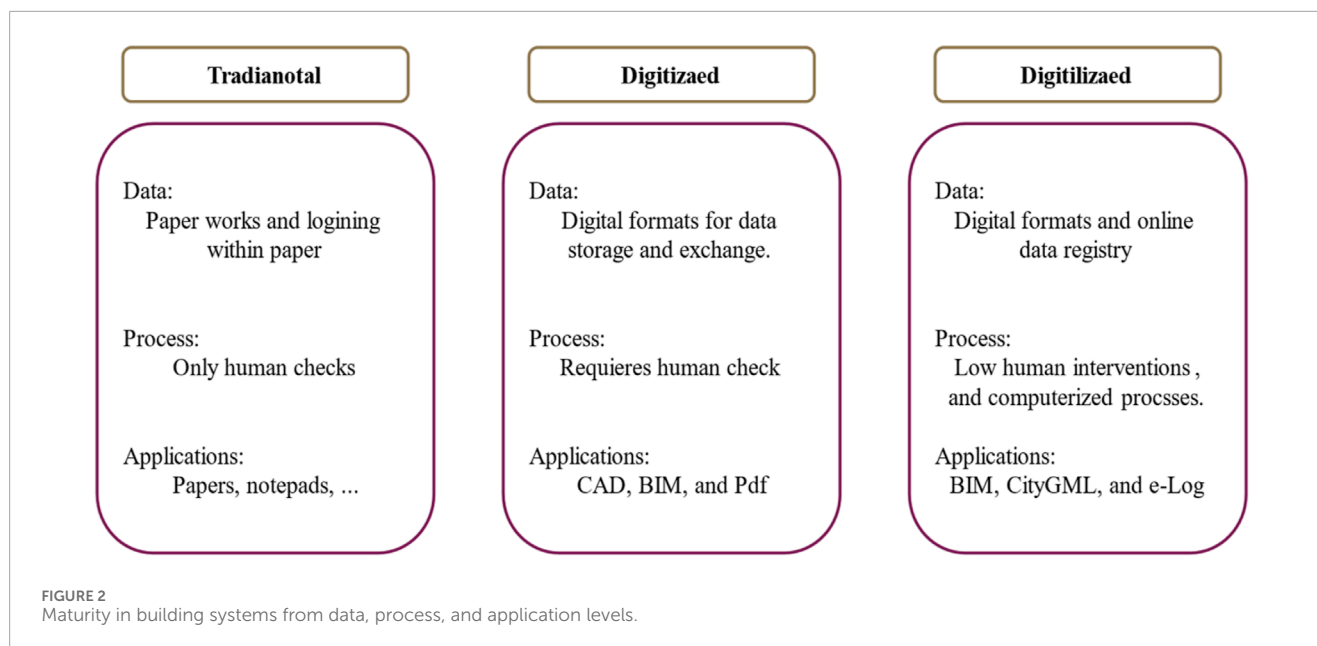
Land information is essential for overseeing development carried out by local municipalities, including zoning, planning regulations, infrastructure projects, and building permits. As a result, the pivotal role municipalities play in land planning and management significantly influences both capital and asset markets. This underscores the importance of adopting technologies to handle large datasets and create geospatial systems that align with spatial strategies (Holdstock, 2016). Utilizing both technological and non-technological systems is considered significant to meet urban governance requirements. Overall systems aim to improve municipal management by integrating a thorough review of non-technological aspects, such as regulations, bylaws, and internal procedures that govern operations and align with national objectives, as previously mentioned in the context of secondary functions. Meanwhile, technological systems incorporate tools like infrastructure, Information and Communication

Technologies (ICT), and hardware and software solutions to enhance efficiency (Claver-Cortés, Juana Espinosa et al., 2015).

2.2 Land management spatial system

Municipal departments increasingly rely on technological tools, yet their effectiveness depends on complementary non-technological factors such as governance structures and regulatory frameworks (Coutts, 2022). Aligning spatial and legal dimensions requires systematically identifying institutional gaps, opportunities, and challenges to support evidence-based decision-making. Thus, providing the public access to GIS data storage with the possibility of exploring controlled online platforms meets municipalities' needs for GIS. According to (Asia Adam and Caglin, 2013), building guidelines for development are considered significant to enhance GIS-based municipal services and integrate planning functions. Developing Spatial Data Infrastructure (SDI) provides a holistic approach to integrating institutional, human, system, and data aspects, facilitating technological adoption and improving government services, (Dangermond and Goodchild, 2020). Successful GIS implementation requires understanding asset use, analysis methods, and integration with GPS and BIM.

The Municipal Spatial Data Infrastructure (MSDI) framework includes four pillars: a centralized geographic database, data standards, a collaborative environment, and a cadastral foundation, ensuring efficient service integration (Labs, 2021). The City Information Model (CIM) improves urban design and municipal planning by integrating spatial databases, stakeholder activities, and performance-based design, allowing emerging technologies (Thompson et al., 2016). Building permits are essential for city safety, health, and aesthetics, but bureaucratic systems hinder efficiency (Fauth and Soibelman, 2022). Institutions often fail to involve the public in decision-making adequately, and governments face limitations in capacity, leading to short-sighted service development (da Cruz et al., 2019). As a result, permitting stakeholders encounter rigid regulations that restrict progress, while fragmented departments hinder reforms and collaborative efforts.



Challenges directly impact BPS as they oversee urban processes, deliver requirements, and manage legislation. Traditional urban management practices include manual reviews of documents, drawings, and outdated legislation. Therefore, incorporating more efficient methods and leveraging information technologies shall be considered (Koptyakova et al., 2019). The inefficient processes and inadequate software for code compliance and integration between GIS and BPS remain significant obstacles as the BPS hosts the building planning regulations and architectural and engineering data with city plans as structural plans, zoning ordinances, and bylaws.

2.3 Technologies in spatial management

The adoption of new systems within governments increased with the Internet revolution. Developing systems requires investigating the tools and applications to assess the system's capabilities to grasp data and build for change. Digital transformation of BPS requires a robust foundation to manage the vast datasets contributed by governmental and private stakeholders (Shamim et al., 2019). However, data centralization, processing, and collection for decision-making can benefit all stakeholders. Working in an integrated environment requires a transformation in organizational technical challenges. Successful transformation requires a thorough understanding of existing systems, information, and data to adapt to changes within municipalities. A study by (Ataide et al., 2023) emphasized the urgency of assessing BPS to define the digital requirements for transformation. Evaluating the maturity level of digitalization helps identify pathways for future development. Figure 2 illustrates the commonalities in traditional, digitized, and fully digitalized management across data, processes, and applications, particularly in machines that automate data collection and verification (e-log to e-check). Many cases integrate various elements to progress through these stages, achieving

meaningful digital transformation by transitioning from outdated registries to modern, data-driven permitting processes.

For effective digital transformation in municipalities, strong governance is essential to improve internal and external functions. Thus, Quality management involves integrating technology and engaging various stakeholders, including government entities, private sector organizations, and civil society (Mandeli, 2015). The permit issuance process, for instance, consists of three main steps: submission, review, and approval. These steps depend on seamless data flow, precise decision-making mechanisms, and the participation of external actors during the review stage (Ataide et al., 2023). Traditional practices rely on continuous awareness of land-use regulations, building heights, and planning challenges, often creating difficulties for government entities. Manual cross-checking of documents across the design, submission, and permitting phases also leads to inefficiencies and hinders the success of BPS (Noardo et al., 2020c). Some countries have adopted automated code-checking systems to enhance efficiency and minimize errors. However, municipal fragmentation poses challenges, necessitating the definition of business functions, organizational structures, and priority objectives to streamline government roles.

According to (Ahuja et al., 2016) the local government transformation follows four steps: needs assessment, system design, integration, and implementation. The electronic platforms develop BPS by integrating technologies for urban-scale city management, as the transition from manual regulation checking to an automated e-system depends on identifying automation needs, including code-checking, submission, and pre-checking models (Kim et al., 2020). Adopting technologies requires evaluating worker expectations and the capability to utilize data to optimize existing systems for efficient data exchange. Successful implementation hinges on proper resource allocation and prioritization (Holdstock, 2016). According to (Han et al., 2020), technologies offer opportunities to visualize data and processes as BIM, transforming workflows and enabling

management across segregated departments to provide transparent decisions utilizing GIS. However, traditional permitting relies on paper submissions and visual checks as the E-Systems within BPS encompass electronic stages that facilitate automating processes for central management (Abdel Wahed and Ismail, 2022). However, central municipal databases allow for streamlining procedures and improving collaboration across departments to enhance systems ranging from fee collection to land management. A holistic integration is considered essential to drive progress, with strategies to simplify permitting processes and implement automated checks to ensure accurate decision validation.

By extending the framework proposed by (Ul Din and Mak, 2021), for Landsat images to digitize data based on imagery, the sample training enables the creation of vector data with areas containing specific features. Data classification is considered significant for developing land frameworks. A guide covering permits is necessary to promote the translation of survey maps and images into effective monitoring solutions. However (Bogale et al., 2025), refer to the capacity of machine learning to detect urban changes based on various classifications. Studies referred to the need for significant early embedding of classification into systems to enable technology utilization and overcome limitations. Studies highlighted the need to capture the polices in place and high imagery capture to facilitate growth monitoring.

2.4 GIS and BPS application

Many studies highlighted the significance of bridging planning with buildings between GIS systems and BPS to overcome legislation ambiguity (Guler and Yomralioglu, 2022). Urban planning has advanced significantly since the 1990s, with the adoption of CAD and GIS systems, which have enabled the digitalization of planning data on both national and international scales. Experts emphasize the need to manage data transitions between various formats. A flexible data model supports precise and efficient data conversion in GIS applications, integrating attributes with spatial formats like raster or vector and paving the way for measurable progress in system development. Computing priorities are at the core of recognizing that decisions are made based on complex relationships between many factors with different priorities in the hierarchy of legislation, and the data that satisfies the requirements shall be determined and clearly articulated for all stakeholders (Noardo, 2022b).

Information models can serve as a foundation for national-level planning through development programs and legislation, as illustrated in Table 2. Information models can serve as a foundation for national-level planning through development programs and legislation, as illustrated in Table 2. Interoperable and structured data with the e-system shall support the high-level information for planning the structural, local, and land-use plans and ensure city planning aligns with the national level (Nummi et al., 2023). The permitting process relies on data to assess permit types, allowances, regulations, and issuing aspects. Each permit type requires specific information, while general data, such as building location, zoning ordinances, and height restrictions, remains standardized across applications. According to (Noardo et al., 2020d), the permitting data are varied, and the levels of compatibility and harmonization

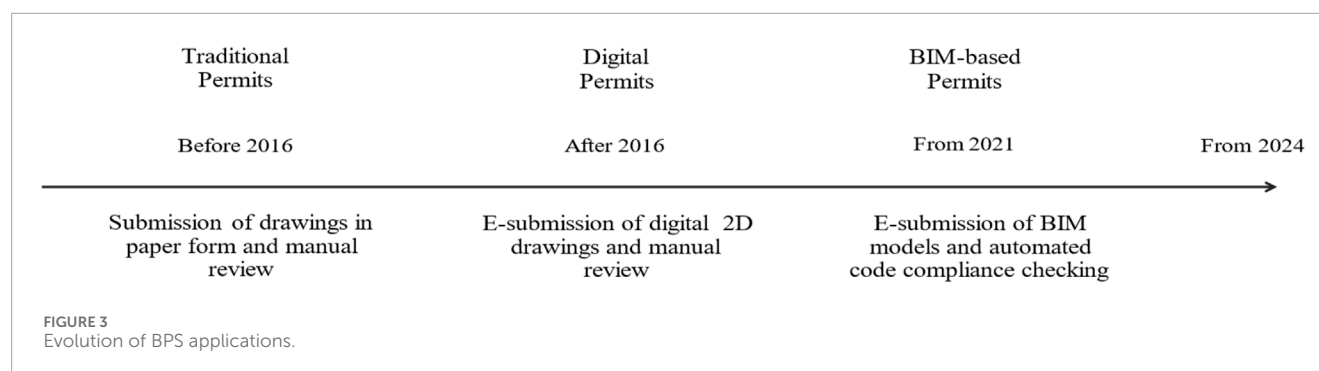
TABLE 2 Attributes in both environments.

Land/Building	Urban environment	Design process
Attributes	Mobility network	Axes and grids
	Urban growth boundaries	Focal points
	Information system	Design analysis
	Landscape	Design regulations
	Infrastructure	Elevation analysis

affect the permitting process and cause challenges in the Common Data Environment (CDE), leading to issues in utilizing data effectively. Therefore, structuring data is significant from both technological and non-technological matters to contain the object, regulations, and supplementary information, including land type, land use, maximum and minimum floor area, and unique values, as Table 2 shows the areas of integration between urban and building design.

Future technologies within municipalities can improve services by enhancing their processes and utilizing technology in management. So, traditional methods for granting a building permit were paper-based. With the advent of the internet and CAD software, permits were submitted electronically and manually checked, as Figure 3 illustrates the evolution of systems within the BPS environment and future directions for managing permit workflow. Also, many studies and practices have moved toward utilizing technology in permitting buildings, from digitizing documents stored in archives to digitalizing processes.

Technologies within municipalities have strong relations in systems (Aljobaly et al., 2022), highlighting the importance of building a capacity within organizational procedures, workers, and technological infrastructure to overcome the lack of system integrations. Therefore, understanding the future of technology allows comprehensive and futuristic planning that maintains strategic results, sustains resources, and prevents rework. According to (Labetski et al., 2023), the urban analysis of 3D information is considered significant for building metrics for municipalities' primary and secondary functions. Urban data enables displaying building uses based on 3D building models for permitting processes. Thus, data retrieval between urban and 3D models benefits data integration, automating processes, and capturing information that prevents duplication and internal oversharing. Externally, such integration enables clients from both the private and public sectors to share permitting requirements and processes, thereby enhancing performance and benefiting investors through transparency (Aguar Costa and Grilo, 2015). The lack of clarity and processes for information exchange leads to the overproduction of information between departments (Aljobaly and Banawi, 2019). Thus, information must consistently serve the organization's strategy to facilitate planning and decision-making. Due to the lack of qualifications and documentation for technology practices, a system with reliable data is needed for organizational plans and frameworks that follow the established standards and fit the challenges (Noardo et al., 2019).



Researchers have focused on enhancing the use of technologies like GIS as spatial tools and BIM for building information, adhering to standardizing technical processes for modelling and developing databases that support action plans across various systems in local industries and applications (Noardo et al., 2019). Data performance in modelling has benefits beyond 3D, as it enhances 2D plans' interoperability and georeferencing. The advancement of geospatial data enables exploring opportunities to improve city supervision of compliance and construction safety (Liu et al., 2021). Mandating the use of BIM in several countries has the potential for linking permits to E-Systems. Data governance is crucial for managing execution plans and project supervision. Technologies such as 3D models, CIM, and machine learning enable the improvement of knowledge and laws for BIM integration, with remaining challenges including the integration of 3D models with E-Systems.

3 Comparison methodology

Building permitting systems (BPS) have been widely studied in terms of their digital transformation, with evidence showing that integrating advanced technologies into traditional processes can significantly improve efficiency. This study adopts a comparative methodology to evaluate both theoretical and practical frameworks of BPS, with a particular focus on the role of geospatial data in enhancing municipal permitting workflows. A comparative analysis of frameworks will establish cohesive permitting workflows, focusing on technology adoption for transitioning from manual to advanced integrated systems in building permits and city planning.

3.1 Data collection

The researchers employed multiple collection methods, focusing on keywords related to municipal functions, GIS, SDI, building permit systems, and spatial data, as well as resources and mediation with municipal functions. The collection included a literature review, frameworks, governmental BPS processes, and applied systems and data with components to facilitate a comparative review of frameworks and permitting workflows, spanning from 2010 to 2025. The initial part of the literature review laid the groundwork for comparing the layers of municipalities' functions, land management, BPS, GIS, advanced technologies, and their applications. The last part covered the theoretical and practical frameworks to structure

results based on the academic and practical levels. Regarding the practical frameworks, an assessment highlighted the seven critical elements of BPS frameworks that align with the theoretical framework. The practical framework scoring system evaluates each framework based on the criteria availability scale (Available = 5; Not Available = 1). Frameworks with a mean score above 2.5 were retained for detailed analysis, as shown in Table 3.

3.2 Data analysis

A comprehensive review identifies key components linking land management and BPS, addressing inefficiencies, high costs, and lengthy processes. The investigation focused on the aspects of the relationship between geospatial data and BPS, identifying the integration of geospatial data into permitting processes, and areas of alignment between municipal practices with data management requirements, and the main guidelines for effective permitting workflows. The structured approach created guidelines for optimizing BPS performance, enhancing current practices, and promoting data-driven decision-making by mapping theoretical with practical frameworks, as shown in Figure 4.

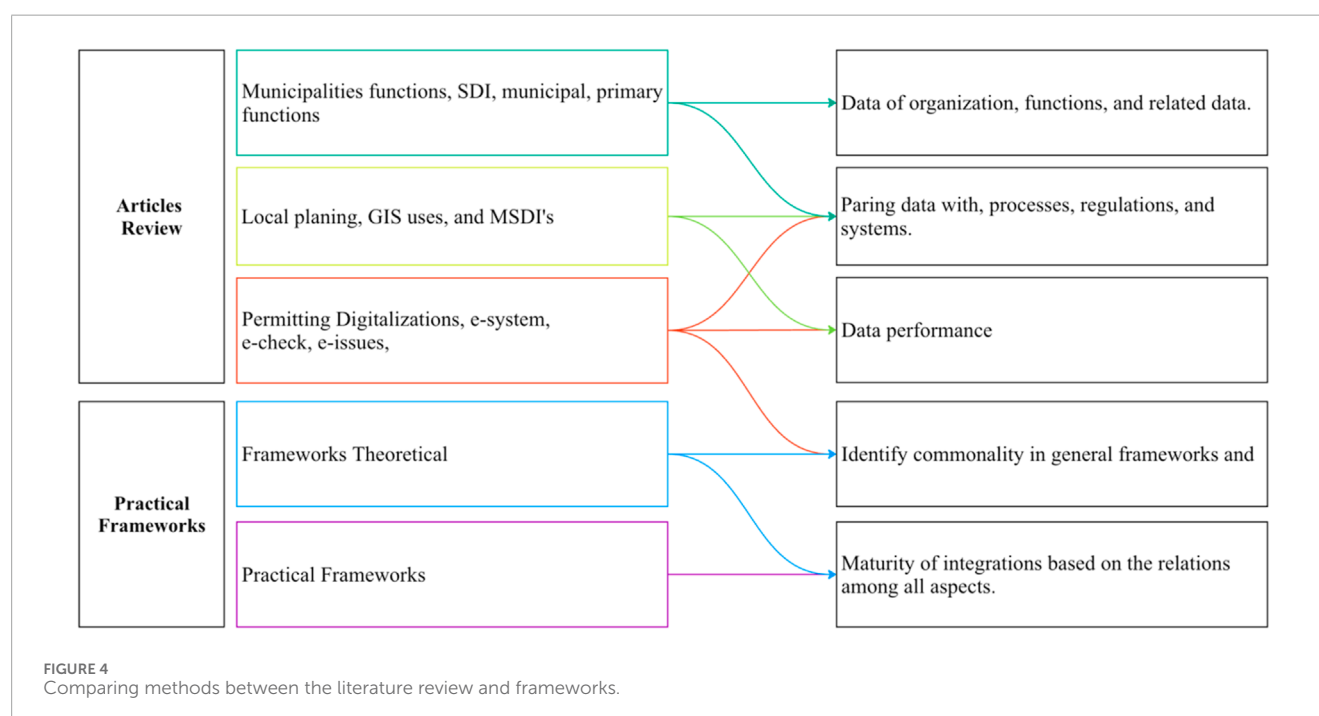
Framework analysis aims to define the core components of the BPS, permitting layers in line with municipal functions. Theoretical frameworks highlighted the overarching approach to enable technology adoption. However, the selected practical frameworks defined the significant barriers, process workflows, and effective technology implementation to reflect on the theoretical framework. In conclusion, a comparison of the municipal models assesses technological integration maturity. Additionally, an evaluation shall address the process matrix connecting key permitting aspects to theoretical models. Coding was applied to categorize findings into four common domains of organization, process, technology, and data to enable systematic identification of significant framework components. This structured methodology produced guidelines aimed at optimizing BPS performance, improving current practices, and supporting data-driven decision-making.

4 Theoretical frameworks

Integrating land planning systems with BPS requires understanding the geospatial framework's components in academia and best practices. Some topics covered BIM integration and GIS

TABLE 3 Practical frameworks review assessment scoring.

Criteria/Country	USA	Germany	Greece	Italy	Australia	Slovenia	Dubai
Stakeholder engagement	4	3	3	4	4	3	5
Regulatory compliance	4	4	3	4	4	4	4
Technology adoption	3	3	2	4	4	2	4
Process transparency	3	3	2	4	4	3	5
Procedural efficiency	3	3	2	3	4	3	4
Standardization and interoperability	3	3	2	3	4	2	3
Public and private partnership	4	3	3	4	5	2	5
Total	24	22	17	26	29	19	32
Mean	3.43	3.14	2.43	3.71	4.14	2.71	4.57



governance in municipalities. Thus, a technological framework of GIS integrations, standardization, and BIM adoption of processes such as digitization, E-Systems, and e-submissions (Noardo et al., 2020b). Literature covered the organizational levels, including the processes, procedures, and compliance (Noardo et al., 2019; Ellul et al., 2020). Moreover, legislative frameworks defeat ambiguity, facilitate policy and regulatory content, and each aspect covers an element of the topic and enhances BPS. The framework review identifies key development areas and metrics for assessing municipal performance. It aims to align frameworks and highlight challenges in municipal adoption. Researchers are creating models to improve the permitting process

and explore BPS variables for integrating GIS. Systems theory supports a comprehensive building permit system and future BIM utilization.

4.1 Organizational aspects

A BPS taxonomy has assisted organizations in comparing advancements across countries and works as a foundation for areas of enhancement towards achieving digital permitting. The framework considered the assurance of safety and compliance with local regulations, with digitalization enhancing accuracy,

transparency, and efficiency to meet organizations' goals. These encompassing intricate interrelationships require careful representation, capturing vital connections while maintaining meaningful abstraction for problem-oriented analysis during digital transformation. The resulting framework from high-level systems can facilitate the creation of initiatives within a broader system. Each municipality has unique requirements, as each function shares commonalities in planning and building cases. Consideration should be given to business rules, municipal requirements, and stakeholder engagement, aligning with established practices and unique processes. The framework outlines the roles, responsibilities, and decision-making points of permitting stakeholders, as well as the business rules rooted in each organization's charter and mission.

4.2 Procedural aspects

Another conceptual framework for building permit processes (Fauth and Soibelman, 2022) examined the as-is applied processes that identified learned lessons by developing a conceptual model for BPS enhancement to improve the digital building permits. The identified model has three pillars: rules, requirements, and technology. Moreover, significant studies investigating building permits from technological aspects do not provide validation for a pilot enhancement. The lack of process grasping leads to a poor ability to adopt technologies such as automated checking. In the federated system, insufficient administration leads to poor productivity. On the other hand, the German system faces staffing challenges in finding experts in building permits, necessitating that both countries adopt digital solutions.

A significant consideration has been made (Guler and Yomralioglu, 2021) for creating reformative processes related to land ownership and harvesting spatial information. The issue has acquired importance and has become more common in municipalities in need. The land ownership framework revealed inadequate data interoperability between GIS and BIM and insufficient data processing methods to evaluate ICT effectiveness to enhance the provided services to the public sector and benefit the extensive stored spatial data by clarifying the roles of stakeholders by utilizing existing e-registry information for permitting purposes, linking a variety of data formats for better regulation management within municipal operations.

4.3 Technological aspects

The role of technology in facilitating the submission of building permit requests and capitalized to enable the utilization of open standards in online systems (Kim et al., 2020). The valuable lessons gained from the technological development created a robust future model, enabling the maturation of functions. Many countries, such as Dubai, have introduced BIM nationally with a transparent platform, from requesting permits to commissions with tracking features. The e-submission embeds a checking tool for the models with automated rules for the levels of compliance. Moreover, Korea has developed an e-submission system to read open standards, ensure alignment with global practices, and ensure widespread documentation.

Nevertheless, the BIM model suits public works applications and is not dependent on specific design tools. Consequently, this technology has developed a system for an e-submission process based on the data model (Yoo et al., 2015). The framework comprises essential modules for code compliance, online submission, and automated regulations. The use case was employed to verify this framework and evaluate the system's capacity. As a result, the processes effectively utilized BIM for submission and verification through open collaboration CDE, promoting design best practices and efficiently transmitting the necessary information for permit issuance from a building perspective in a compatible format, thereby maintaining a record of each request. Additionally, the system includes an early check module to minimize time spent reviewing and ensuring the quality and accuracy of reports. Compliance rules are in place to help designers grasp permit requirements and spatial regulations.

5 BPS practical frameworks

Governments have implemented strategies to leverage the existing technological infrastructure. Several factors, including insufficient transparency, recurring errors, and protracted review procedures hinder the processes in BPS. Experiences shall be investigated from the practical system across various regions to identify commonalities and opportunities for improvement and overcome challenges. The frameworks of the United States of America, Europe, Asia, and Australia have taken significant steps towards developing BPS that align with national objectives and local building permit capacities.

5.1 United States of America (USA)

The United States of America is experiencing a shift towards bureaucracy as opposed to productivity; despite this trend, many authorities are now prioritizing efficiency in building permitting. The typical process involves submitting building application documents, requesting and obtaining statements from other agencies, conducting a formal pre-check to ensure conformity with zoning codes, issuing planning approval, and forwarding documents to the building department for another round of formal pre-checks to ensure compliance with building regulations before issuing the building permit. The permitting workflow typically starts with submitting building applications, followed by zoning checks with planning and regulation agencies. The tools used in this process can vary from manual checks to application consultations and meeting (Fauth and Soibelman, 2022).

5.2 Germany

Germany implements various permitting procedures and regulations, with their efficiency varying based on several factors (Fauth and Soibelman, 2022). analysed building permits across European countries, including criteria like exemptions and various procedural types. The finding is that some nations, such as Germany, lack sufficient staffing and personnel

dedicated to the building permitting process, which affects the stages that occur post-application submission. The relevant authority that initially conducts a review of challenged process tracking submissions. As follows, the planning laws, building regulations, and inputs from other agencies are evaluated. The process may differ depending on the authority involved, as there can be an internal protocol for examining planning law, building law, and the engagement of different agencies. For instance, a building permit authority gathers the necessary statements and incorporates them into the decision-making process regarding the issuance of building permits. A final decision hinges on the inputs from these agencies, with responses categorized as either positive or negative to be communicated back to the applicants.

5.3 Slovenia

Building permits are a set of minimum requirements for the building's safety, health, and energy efficiency. Slovenia's adoption of a new planning law has contributed to accelerating the planning process and enabling faster permitting issuance (Marot, 2021). Countries rely on traditional methods, using paper forms and responses to permit spatial planning documents, project documentation, and other necessary documents, including consents, fee payments, and those allowing utility services. Slovenia presented a set of factors that need to be considered for developing the BPS, including organizational, normative, spatial, and stakeholder roles in issuing building permits, as well as vertical, horizontal, and organizational participation (Kaczmarek et al., 2024).

5.4 Italy

Digitalizing BPS increasingly considers BIM for transformation. The BPS model in South Tyrol demonstrated a robust procedure and has been adopted into Italian systems. Permitting involves external participants who review planning and building laws to approve or deny requests. The formal review covers planning, drawings, forms, and receipts, with applications sent to agencies for statements. The municipal building permit department initiates reviews, approvals, and meetings, thereby exerting time pressure on reviewers to ensure timely assessments. In South Tyrol, urban planning and engineering focus on processes rather than aesthetics. Unlike Germany and the U.S., Italy's governmental structure is not federal, necessitating consideration of municipal, regional, and national regulations. Building a framework for digitalization requires process-based information for managing hierarchy and stakeholder involvement to facilitate inter-organizational actions. Regulation-based information includes tax regulations and reliance on IFC entities tailored to the specific project within the surroundings (Fauth et al., 2022).

5.5 Australia

Many sectors in the Australian government have several governing agencies led by main stakeholders. The Victorian

Building Authority has a compliance requirement to grant a building permit to the applicant, with an option of sending a private surveyor or a municipal building surveyor. In both cases, the applicant shall send a request for building permits for review of the required documents for certifications. Following the fee payment, the assessment process for requests will commence, followed by issuing the permit to initiate the construction and inspection of work, and finally, obtaining an occupancy permit (Authority, 2025). The mandate of utilizing technology to benefit BIM adoption and the available standards for building permits pose challenges in harmonizing the data within the system. The submission of subdivision plans has been integrated with GIS, utilizing CAD for permitting. However, BIM has faced challenges due to the procedural arrangement by the survey department (Olfat et al., 2019).

5.6 Dubai

In the Gulf area, Dubai's municipality exhibits similarities to models adopted in Saudi Arabia, such as hiring a consultant office by citizens to request building permits. The system is integrated with the GIS platforms in the municipality, as part of the digitalization process, spanning from e-submission to compliance (Ullah et al., 2022). The processes are illustrated in Figure 5, showing the main steps from the request for a permit to each stakeholder role clarified. The first step for the producers of villa permits is to request online all inquiries, such as drawings, documents, and filled forms. The second step involves on-site inspection of the structural framework by the building control department and survey department from the municipality side and from the client part, the consultant, and contractor teams. The third and last step involves the client, consultant, and contractor requesting a final on-site inspection to provide municipal services from the government side, including the building control department, survey department, and telecommunications company.

Building permits ensure safety and environmental compliance for new constructions, retrofitting, and demolitions. Frameworks primarily focus on design review, zoning, and building codes, with GIS departments playing a role in BPS functions. Permits regulate zoning, land use, and infrastructure development, impacting public and private sector services. In the EU, permit procedures vary—some countries separate planning and technical approvals, while others combine them. However, a planning permit does not guarantee a building permit. Submission requirements also differ and generally include drawings, specifications, and calculations, with all EU countries enforcing statutory requirements. Post-permit compliance varies, with some countries requiring inspections. In the U.S., efforts aim to streamline complex permitting processes, which differ across states. The technology adoption for permitting varies, influenced by different management models and legislation, requiring applicants to understand their country's specific regulations and submission procedures (Messaoudi et al., 2019).

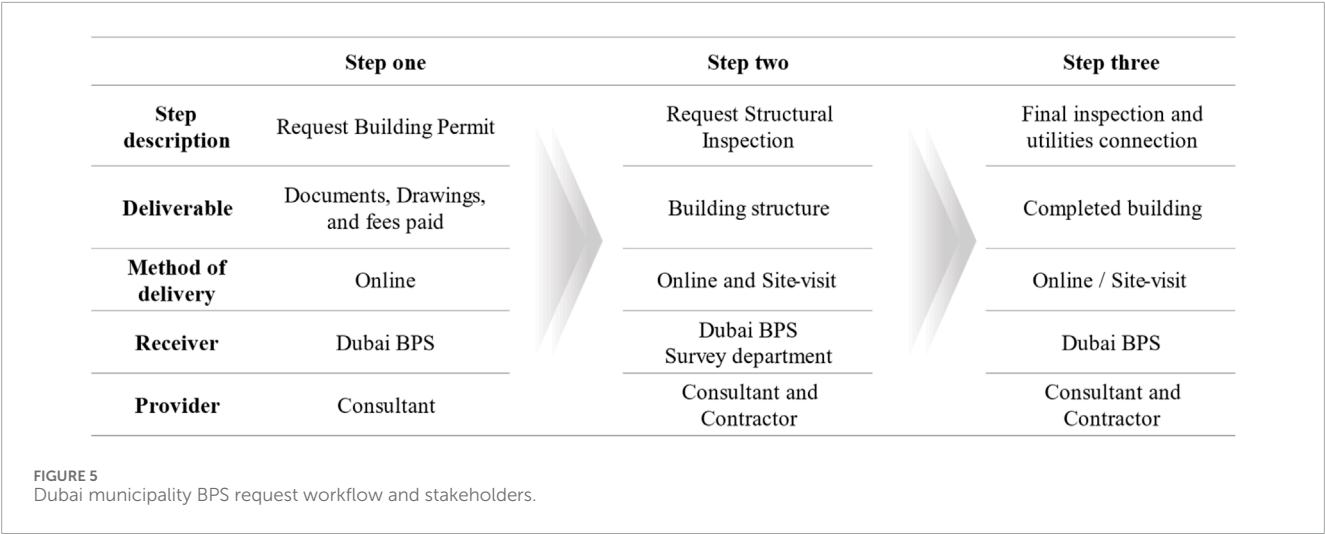


TABLE 4 Integrate the themes of academia and practice for effective integration.

Domain	Sub-domain	Theoretical and practical mapping
Organizational	Capacity and maturity gap	Academic models outpace practice, and there shall be targeted pilot practices to tie the BPS taxonomy with expected maturity
	Training and capability building	Institutionalized municipalities' continuous training in e-permitting and governance shall be durable for constant management changes and define role clarity
	Regulatory alignment	Encoding statutes into machine-readable checks with operationalized governance improves traceability and enhances regulatory compliance
Procedural	Workflow orchestration	Rules, requirements, and technology are leveraged to automate platforms using CAD, BIM/GIS, thereby reducing handoffs and cycle time
	Standards adoption	Rule library rollouts anchor open standards to stabilize reviews and curb inconsistency
Technology	infrastructure and integration	The national CDEs shall track and instantiate modular with open-standard
	Modular validation components	Plug-in code-check demonstrates the scalability and local extensibility based on the technologies in place
	Version control	Version-managed submissions within CDE to allow permit trails auditability
	Semantic models and vocabularies	Shared schemas realize theoretical calls for semantic alignment, cutting conversion errors, and enabling e-registry reuse
	Dataset standardization	Standard CAD, BIM to GIS submission templates enact interoperability guidance and smooth cross-agency data reuse and approvals

6 Results

6.1 Land management system

A key role of the municipality is land management, which impacts various other municipal functions. Consequently, the literature outlines land development processes, from structural plans to individual buildings, overseen by municipalities in collaboration with applicants as the Authorized Engineering Offices (AEO). The role of high-level stakeholders and municipalities extends beyond merely completing the automation of BPS to reach certain levels. Municipalities extensively utilize GIS to manage change and

allow decision-making. Some municipalities have central systems requiring more unified geospatial data management standards and robust SDI and integrated systems. Land information and attributes are stored in the GIS databases and with unified BPS platforms. The lack of standardization in permit management hinders the effective use of geospatial data for land benefits. Furthermore, barriers to leveraging land use information have been identified, particularly in the context of modern technologies that enable machine learning and meaningful data classifications. Therefore, defining GIS layers, datasets, and attributes for effective BPS integration beyond code compliance and creating compelling and informative urban compliance performance dashboards.

TABLE 5 GIS and BPS linking to the E-system within BPS.

Domain	GIS and BPS integration issues
Technology	Server connecting
	Data conversion
	Data semantics
	Georeferencing
	Developing software/plugin
	Developing data
	Define software version
Procedural	Data conversion
	Lack of standards
	Data harmonization
	Data management practices
	Developing procedures
Organizational	Perfect BIM models exist in academia only
	Develop educational courses
	Little Knowledge
	Laws and regulations guiding
	Involvement of stakeholders

The collection of geospatial applications in municipalities has not aligned with spatial questions to fulfill the uses of GIS. Each department function has not capitalized on data utilization; however, areas for enhancement have been identified to drive integration and related functions. For instance, using GIS in permitting buildings and delivering the required data and analysis facilitates the permitting process by developing BPS to integrate 3D models, as many studies and practices have shifted to adopt models beyond 2D submissions. Therefore, prior technologies contribute to data digitalization by enabling e-logs and e-submission for permits in datasets. The information within datasets shall be grouped and assigned according to the systems, as many frameworks have similar functions despite various organizational structures. The lack of understanding of the possibilities of aligning with permit requirements, as highlighted by investigating the BIM and data retrieval from the urban level, prevents decision-making for planning and building departments due to poor data integration.

Frameworks analysis revealed, through a cross-mapping of practical and theoretical frameworks, that across various jurisdictions, governance clarity and semantic interoperability emerge as the two strongest predictors of practical success. The cross-mapping, as shown in Table 4, outlines the main domains and sub-domains for connecting academia with practices. The integration of laws and responsibilities is formalized and encoded,

BIM to GIS semantics are standardized, and municipalities' experience enables shortening the review cycles, reducing data friction, and enhancing auditability. Illustrative cases in the procedural domain underscore the importance of established rules, requirements, and the utilized technology. The organizational domain is defined by pairing ongoing capacity building and technological modules with an open-standards stack operating within a CDE. Practical frameworks illustrated in Italy and Dubai have served as prime cases of comprehensive orchestration in legal encoding, data standardization, and well-defined workflows. Cases from the United States highlight the benefits of compliance and transparency resulting from versioned submissions. Aligning organizational charters, codified procedures, and data performance is essential for bridging the theory–practice gap and achieving measurable improvements in performance efficiency.

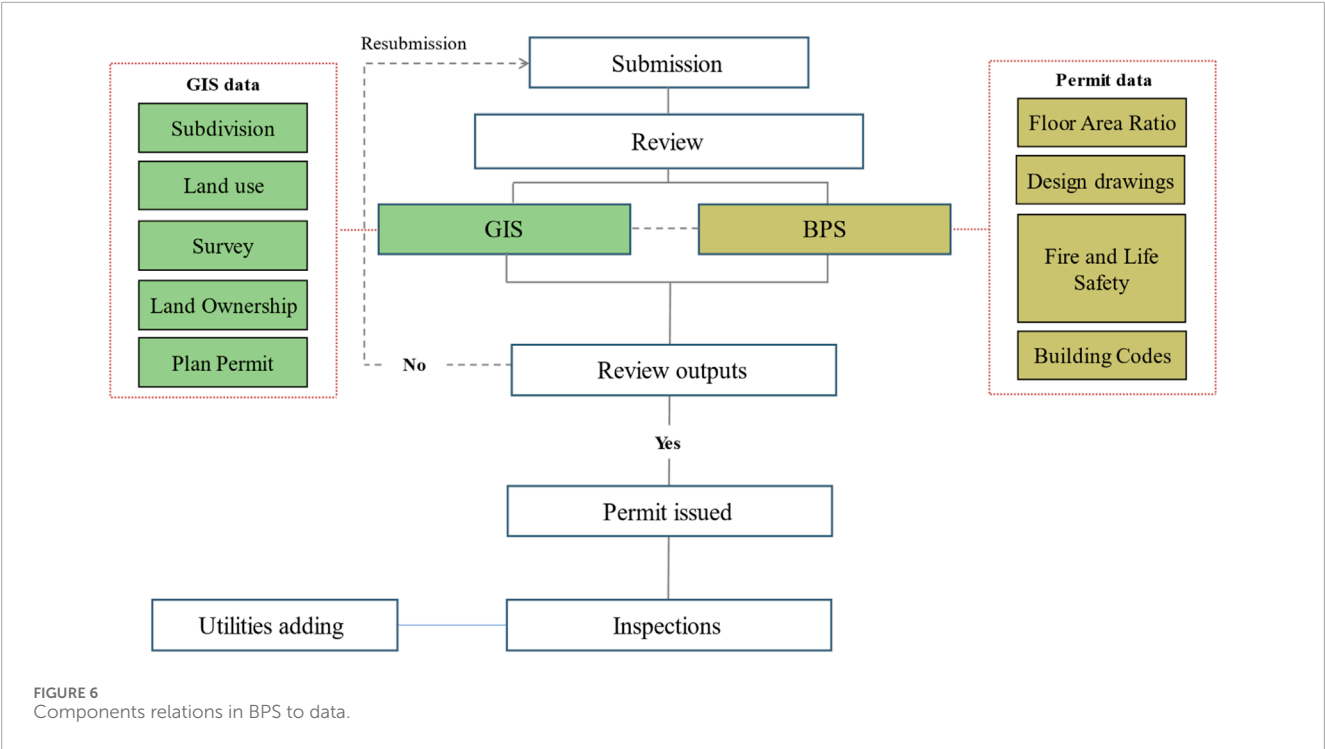
6.2 Building permit system development

Municipal building permits ensure compliance with subdivision plans, safety, and city aesthetics. However, due to fragmented CDEs and poor data integration among AEOs, permitting officers, and planners, the permitting process faces challenges. Misalignment between geospatial data and BPS further complicates efficiency, as a centralized database can unify data collection but lacks stakeholder identification and technological adoption. Automation frameworks often focus on data management, neglecting human roles. Additionally, ambiguity in data application and the deficiency of CAD, GIS, and 3D model integration hinder decision-making. Addressing these challenges requires governmental access to AEO capabilities, and municipalities must enhance awareness of improved systems to smooth changes. Integrating BIM enhanced permit processing and technological alignment (Noardo et al., 2020a). A significant technical requirement for unifying the source among municipal departments is developing a central system, including a centralized server for seamless data synchronization and the exchange of each model (Noardo et al., 2020b). The challenges in transforming municipal data utilization are outlined across the main domains of the BPS Framework in Table 5.

6.3 Framework components and matrix

BPS frameworks demonstrate that components involving process, data, and systems are integrated within a workflow to permit delivery. Certain elements ensure the completion of workflows within the BPS systems. The legislative system adheres to government-level rules and regulations, which then inform the organizational system that encompassing political, social, and business dimensions, followed by procedural systems including specific procedures and processes, and finally, technological systems as comprising software, hardware, data, and information.

Conversely, MSDI indicates that a robust integration of the GIS system is essential for building interconnected systems that span four domains: People, Data, Systems, and Institutional. As illustrated in Figure 6, this relationship reflects the stages, hierarchy, and data interconnections from both the BPS and GIS perspectives.



Main Elements	Legislative		Organizational			Technological		Procedural	
Sub-elements	Governmental level	Rules and Regulations	Political	Social	Business	Software and hardware	Data and information	Procedures	Process
Regional Office (RO)	●	●	◐	◐	◐	◐	◐	◐	◐
Municipality Office (MO)	◐	○	●	◐	●	●	●	●	●
Consultant Office (CO)	○	◐	○	○	○	●	●	◐	●
Civil Defense (CD)	●	◐	●	◐	○	○	○	●	◐
Contractor (C)	○	○	○	○	○	○	○	◐	◐

● Strong Relation

◐ Mild Relation

○ Weak Relation

FIGURE 7
Matrix of responsibility within BPS.

Aligning the MSDI with the BPS improves data retrieval and creates a strong framework for integrating survey CAD data and land registries. The BPS model highlights key areas for improvement, especially in the e-submission and review stages, which enhance efficiency in GIS, BPS, land use, and building regulations. Organizational roles and the influence of various agencies in the permitting process are considered significant, as well as data management and regulatory compliance. Stakeholders are the fundamental enablers for BPS and technology to thrive, leading from the organizational level to the AEO as the initial data provider. **Figure 7** illustrates a matrix permitting stage and shows the level of engagement across stages of initial submission to the commissioning.

The investigation reveals that municipal functions, services, and regulations are closely linked with planning and permit departments. Moreover, it aspires to create a spatial data framework integrating municipal GIS systems for improved permitting processes. The study identified gaps in current systems by analysing municipal functions and geospatial data and proposes components for an effective geospatial-based BPS, ensuring improved integration between land GIS data, permit data, and municipal processes.

7 Conclusion and discussion

Research outcomes defined the limitations of studies in municipal planning functions and the technology's influence on permit processing, emphasizing the utilization of geospatial data in improvements in decision-making and managing change, as the key role of GIS. Challenges such as inconsistent data, fragmented systems, and a lack of standardization hinder the realization of GIS potential in permit workflows. Furthermore, prevent expanding municipal capacity to utilize satellite imagery for urban sprawl compliance by using land use data for machine learning and training. The significance of mapping permit decision-making to land data enables future integration of construction and imagery compliance based on issued permits.

Improving BPS by integrating GIS and regulatory data demonstrates that creating effective data-sharing protocols enables the integration of zoning, land use, and construction codes. Moreover, standardizing geospatial data layers by applying GIS with BIM and developing a unified database is crucial to improving the efficiency of permit processing. In addition, involving stakeholders and implementing robust change management strategies are essential to ensure cooperation across municipal departments and among applicants (AEO) and other key stakeholders align their roles effectively (Noardo et al., 2022a). In comparison to prior research areas, the study delivers findings to map the land management tools to enable permit issuance with consideration to future technologies, such as machine learning.

The study addressed the key objectives. First, it examined the effectiveness of land geospatial data in supporting municipal building permit systems (BPS). The findings highlight that GIS plays a pivotal role in enhancing decision-making, regulatory compliance, and land management. However, challenges like data fragmentation and a lack of integration need to be addressed. Standardizing geospatial data and integrating it with BPS can significantly streamline the permitting process and improve its overall efficiency.

Second, the study identified the key components required for an effective municipal geospatial framework within BPS. These components include data standardization, BIM integration, and the creation of centralized data systems. Additionally, aligning organizational roles and ensuring stakeholder engagement are critical for success. Third, the study developed guidelines for geospatial management to support BPS. The defined guidelines emphasize the importance of standardizing data, adopting modern technologies like BIM models, and implementing e-logs and e-submission systems. These improvements shall enhance the efficiency, transparency, and effectiveness of the permitting process. The research contributed to improving processes to meet the digital requirements of both BPS and land uses, as an overlay of the organizational, procedural, and technological aspects to meet the utilization of digital systems. A focus shall be on the permits' impact on the polices' creation, delivery, and monitoring. Cross-mapping provided a guide based on main domains and sub-domains to enable the change to practical data usage and integrated the BPS process with stakeholders.

In summary, a comprehensive framework for municipalities to adopt that effectively integrates GIS and BPS. Thus, an essential role is to guide improvement across urban planning,

land management, and the building permitting process, ensuring municipalities' readiness to manage urban growth and development in the digital era. Modern structured guidelines are essential for aligning geospatial data with municipal systems, thereby improving urban planning and regulatory compliance. Future research should focus on applying these frameworks in various municipalities to evaluate their long-term impact on urban development and land management. Aligning geospatial data with municipal systems in the context of urban planning and regulatory practice shall be considered in future studies. Applying and implementing the global frameworks in various municipalities to evaluate their long-term impact on urban development and land management.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

OA: Investigation, Data curation, Conceptualization, Visualization, Writing – original draft, Formal Analysis. WA: Methodology, Supervision, Writing – review and editing. MM: Writing – review and editing, Validation, Project administration.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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