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Rule-Based and AI-Assisted Workflows for DBP: Insights from Applied Research

O. Schneider, E. Jost, and D. Marcinkeviciute
Institute of Virtual Design and Construction | FHNW, Muttenz, Switzerland

ABSTRACT: Digital building permit procedures still rely heavily on fragmented, document-based workflows, requiring manual checks for completeness, consistency and regulatory compliance. This paper presents an applied research project investigating how rule-based and AI-assisted workflows can improve the quality and efficiency of building permit applications, with a particular focus on the pre-submission phase. The project, conducted by the Institute of Virtual Design and Construction at FHNW with squaretech GmbH and the City of Winterthur, develops a "Step 0" framework combining an automated compliance checker and an AI-supported chatbot. The system combines deterministic rule-based methods with selected AI components and geospatial information, including GIS, where these provide clear added value. The paper presents the conceptual framework, system architecture, pilot validation and initial implementation insights. It further discusses key challenges related to data quality, legal requirements, explainability, transferability and integration into existing administrative workflows.

1 INTRODUCTION

The digitalisation of building permit procedures is increasingly recognised as a key opportunity to improve efficiency, transparency and consistency in public administration. Recent research has strongly focused on automated compliance checking (ACC), BIM-based rule checking and AI-supported permitting workflows. Nevertheless, many municipalities still rely on fragmented and document-based review processes with high manual effort.

Initial findings from the presented applied research project indicated that significant process inefficiencies within the investigated municipal context were frequently linked to incomplete and formally inconsistent submissions during the pre-submission phase.

This observation reveals an important research gap. While current research primarily focuses on technical compliance checking and model-based expert workflows, comparatively little attention has been given to applicant-oriented support mechanisms that improve submission quality before formal review procedures begin ('Digital Building Permit Conference 2025 : Book of Abstracts', 2025).

This paper presents the results of an applied research project commissioned by the City of Winterthur, Switzerland (hereafter referred to as the municipal authority), and conducted by the Institute of Virtual Design and Construction FHNW together with the startup squaretech GmbH as practice partner.

The project developed two complementary minimum viable products (MVP) addressing the identified "Step 0" bottleneck: an AI-supported chatbot guiding applicants through recurring questions and submission requirements based on validated municipal knowledge sources, and an AI-assisted compliance checker for the automated pre-validation of submitted applications regarding completeness, formal consistency and selected rule-based

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requirements. From a technical perspective, the project prioritizes deterministic and rule-based approaches wherever feasible. AI methods are applied selectively, particularly where they provide clear added value without compromising transparency, controllability, cost efficiency or data protection requirements in public administration.

The paper addresses the research question of how AI-assisted and rule-based support mechanisms can support submission quality and reduce administrative friction in municipal permitting workflows. The novelty of the present paper lies in framing applicant-oriented pre-submission support as a distinct "Step 0" within digital building permit workflows. Rather than presenting chatbots, rule-based checking, GIS-supported validation or AI-assisted document analysis as novel standalone technologies, the paper demonstrates how these components can be integrated into a coherent framework for pre-submission quality assurance in a real municipal context. This framework is complemented by selected project-specific ACC algorithms developed for heterogeneous architectural plan documents where existing open-source tools proved insufficient.

2 BACKGROUND AND RELATED RESEARCH

Recent research highlights the relevance of digital, automated and AI-supported workflows in building permit procedures. The field has evolved from digital submission platforms towards more integrated approaches involving automated compliance checking (ACC), BIM-based model validation, machine-readable regulations, geospatial data integration and AI-supported interpretation of regulatory and application data. Noardo *et al.* (2022) and Ataide *et al.* (2023) show that technical feasibility has been demonstrated in several sub-domains, while end-to-end implementation remains limited due to interoperability, integration and organisational challenges. Bloch and Fauth (2023) further argue that research on digitalization and automation in building permitting remains unevenly distributed across technical and organizational dimensions.

A central research stream concerns ACC, where regulatory requirements are translated into computable rules and checked against structured building information. Beach *et al.* (2020) discuss the adoption of automated regulatory compliance checking in the built environment, while Fauth and Seiß (2023) propose an ontology for building permit authorities to support more advanced digital permit processes. Such approaches are frequently linked to BIM, IFC-based data exchange, ontologies and rule-based checking environments. Urban *et al.* (2024) demonstrate through the BRISE Vienna case that model-based and rule-based checks are technically feasible, but also depend on structured data, machine-readable regulations and stepwise implementation.

In Switzerland, Jost and Marcinkeviciute (2025) previously demonstrated the procedural feasibility of BIM-based fire safety review in a clearly defined regulatory domain. Their study developed structured information requirements, IDS-based formal checks and software-assisted review mechanisms. At the same time, it showed that full automation remains difficult under current data conditions and that partial automation combined with expert interpretation is often more applicable in practice.

A further technical challenge concerns the spatial context of permit applications. Many regulatory checks depend on parcel boundaries, zoning, protection areas, neighbouring conditions or distance-related constraints. Accordingly, GIS integration is increasingly relevant for context-aware compliance checking. Schildknecht *et al.* (2025) show that geodata are an important basis for planning and permitting processes, while their integration into BIM/IFC-based workflows remains technically and semantically challenging. In the present study, GIS is therefore not treated as the primary contribution, but as an enabling layer for selected rule-based and AI-assisted checks.

AI-supported approaches have recently gained importance, particularly for information extraction, natural-language processing and the interpretation of regulatory or application

data. Kruiper *et al.* (2024) propose an NLP-driven strategy for digitalising regulatory compliance processes, while Chen *et al.* (2024) explores the combination of large language models, deep learning and ontologies for BIM-based compliance checking. These approaches indicate new opportunities, but also raise questions regarding explainability, reliability, governance and legal accountability in public administration.

Recent Swiss public-sector initiatives confirm this cautious and practice-oriented position. The Zurich AI Sandbox project on building permits (2022) found that rule-based systems are effective for clearly structured requirements, while AI-supported pre-checks add value for plausibility and completeness checks. The FHNW potential study on AI and automation in Zurich's building permit procedures (2024) further identifies the early phase of application preparation as a major field of action, particularly through improved first information, structured submission guidance and automated pre-checks.

Despite these developments, current research remains strongly oriented towards technical compliance checking, BIM-based expert workflows and machine-readable regulation. Less attention has been given to the intermediate phase before formal submission, in which applicants translate procedural, regulatory and spatial requirements into a formally complete application.

This gap is not only procedural, but also technical. Many existing approaches assume structured digital inputs, such as BIM models, standardised data formats or machine-readable rule sets. In municipal practice, however, applications are often submitted as heterogeneous document-based material, including architectural PDF plans, forms, signatures, title blocks, dimension lines, elevation points and cadastral references. The automated interpretation of such plan-based inputs remains a practical challenge, particularly where no structured BIM model is available and where applications are submitted by private applicants or other non-specialist users.

The present paper addresses this combined process and implementation gap by investigating how applicant guidance, automated pre-validation and selected geospatial information can be connected within a real municipal permitting workflow.

3 METHODOLOGY

The study follows an applied design-and-lessons-learned research approach with a strong focus on operational applicability and stakeholder-oriented value creation within real municipal permitting workflows. The methodology focuses on the design, implementation and pilot validation of two MVPs in a real administrative setting. While selected technical functionalities were evaluated using descriptive performance indicators, the study does not yet provide a full quantitative evaluation of operational impact, such as effects on resubmission rates, processing times or applicant satisfaction. Methodologically, the project combined process analysis, stakeholder workshops, iterative MVP development and continuous validation within an operational administrative environment.

The initial project phase focused on identifying practical bottlenecks and process inefficiencies within the existing permitting workflow of the municipal authority. For this purpose, three large stakeholder workshops were conducted involving representatives from the municipal authority, the research team and the practice partner. These workshops were complemented by recurring iterative coordination sessions with a smaller interdisciplinary core team throughout the project duration. In addition, on-site process observations and workflow walk-throughs were conducted within the municipal administration to better understand recurring applicant questions, operational challenges and existing review processes.

Based on the identified findings, the project developed and iteratively refined two complementary MVPs addressing the early pre-submission phase ("Step 0") of the permitting process. Both systems followed an iterative PDCA-oriented development process including continuous testing, stakeholder feedback, and pilot implementation within the investigated

municipal context. A validation of the Automated Compliance Checking (ACC) was performed. Depending on the functionality and development stage, this included data available during development as well as additional datasets not used for system development. The validation focused on assessing the practical plausibility, robustness and applicability of selected technical functionalities within municipal workflows. Detailed validation results for the compliance checker are presented in Section 4.3. In addition, both the ACC and the AI-supported chatbot were evaluated by employees of the City of Winterthur, including administrative assistants involved in the permitting process. Their feedback supported the practical assessment of usability, relevance, and applicability within a municipal administration environment.

From a technical perspective, the project intentionally prioritised deterministic and rule-based approaches wherever feasible, while AI methods were applied selectively where they provided clear added value. This decision was motivated by requirements regarding transparency, controllability, costs and data protection within public administration.

4 CASE STUDY: CITY OF WINTERTHUR

4.1 *Identified bottlenecks and "step 0"*

The initial stakeholder workshops, process analyses and on-site observations revealed that many operational challenges within the investigated municipal permitting workflow originated before the formal administrative review process itself. A considerable amount of administrative effort was associated with incomplete or formally inconsistent submissions, recurring applicant questions and iterative clarification processes between applicants and municipal authorities.

Typical issues included incorrect permit procedures, missing signatures, incomplete documentation and inconsistencies between submitted forms and plans. These deficiencies frequently resulted in delays, repeated resubmissions and additional manual review effort. Municipal employees further reported recurring requests via telephone and e-mail concerning submission requirements, permit categories and interpretation of basic regulations.

Many of these interactions focused on procedural clarification rather than the actual technical assessment of planning content. As a result, municipal staff increasingly assumed the role of procedural consultants and support providers for applicants instead of primarily acting as reviewing and controlling authorities within the permitting process.

The investigations additionally showed that a significant share of applications originated from private applicants rather than professional planning offices. Within the investigated municipal context, many applicants possessed limited procedural and regulatory knowledge, reducing the practical applicability of highly specialised BIM-based workflows for large parts of the submission process. This highlighted the need for low-threshold and applicant-oriented support mechanisms.

Based on these findings, the project introduced the concept of "Step 0", describing the pre-submission phase as a critical intervention point within digital permitting workflows. The concept focuses on supporting applicants through guided access to procedural information, clarification of submission requirements and automated pre-validation of formal application quality before administrative review procedures begin.

4.2 *AI-supported chatbot*

As part of the identified "Step 0" approach, an AI-supported chatbot was developed to provide structured and guided assistance to applicants during the pre-submission phase. The primary objective of the chatbot is not to offer open-ended conversational capabilities, but to support users in navigating municipal permitting requirements in a controlled and traceable manner.

The system is based on a guided workflow design in which user interactions are structured along predefined procedural steps. Instead of free-form dialogue generation, the chatbot operates within a constrained interaction logic that ensures consistency with municipal regulations and reduces the risk of incorrect or misleading outputs. No model-specific training or fine-tuning of the underlying large language model (LLM) was performed.

A central design principle is the use of a controlled knowledge base, which forms the exclusive information source for all chatbot responses. The knowledge base consists of validated legal and administrative sources across multiple governance levels, including 31 municipal regulations, 20 cantonal regulations and 25 federal regulations. In addition, it incorporates GIS and Public Law Restrictions on Landownership (PLR/ÖREB) data, municipal application forms and further official content published on the City of Winterthur's website. By limiting responses to this curated and authoritative information set, the system explicitly avoids open-domain generative behaviour. Responses are only generated when sufficient evidence is available in the controlled knowledge base; otherwise, the chatbot returns a transparent fallback response rather than attempting to infer or fabricate information. This design prevents uncontrolled content generation and substantially reduces hallucination effects typically associated with large language models.

To further ensure legal and procedural reliability, all responses are designed to include references to the underlying regulatory or official sources whenever applicable, as shown in Figure 1. This traceability requirement is essential in the context of public administration, where transparency and accountability of information provision are critical.

The knowledge base and interaction logic were developed in close collaboration with municipal domain experts. Staff members from the responsible authority were actively involved in the iterative definition, validation and refinement of the content structure. This co-design process ensured that the chatbot reflects actual administrative practice, terminology and recurring applicant questions.

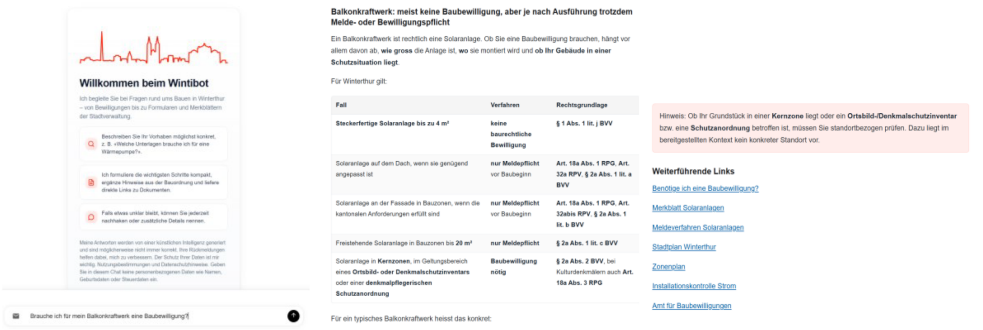


Figure 1. User interface of the developed AI chatbot for the city of winterthur.

In addition to its advisory functionality, the system includes an email drafting feature that generates structured email templates containing relevant case information and references for municipal employees. This functionality is particularly valuable for administrative staff, as it reduces manual effort, improves consistency in communication, and facilitates efficient case handling.

At the current stage, the chatbot is implemented as a pilot system within the City of Winterthur. The pilot phase focuses on evaluating usability, content completeness and practical relevance in real-world applicant interactions.

Overall, the chatbot serves as a low-threshold entry point into the permitting process and acts as a preparatory layer for the subsequent submission and compliance checking stages of the "Step 0" framework.

4.3 *AI-assisted compliance checker*

In addition to the AI chatbot, the second core component of the "Step 0" framework is an AI-assisted compliance checker designed to support the pre-validation of building permit applications. The system is intended to identify formal inconsistencies, missing information and selected rule-based compliance issues prior to the formal submission review by municipal authorities to ensure the submissions quality.

The overall architecture follows a hybrid approach that deliberately prioritises deterministic rule-based processing, complemented by selective use of AI components. This design decision reflects key requirements of public-sector environments, in particular the need for transparency, controllability, legal robustness and predictable system behaviour.

The rule-based layer forms the foundation of the system and is responsible for validating clearly defined and machine-readable constraints. These include, for example, completeness checks of required documents, verification of whether the proper owner has signed the document, scale verification (mass scale checks), and validation of formal submission requirements. Wherever possible, regulatory requirements are translated into explicit rules to ensure traceable and reproducible decision logic.

A key aspect of the system is the structured output of detected issues, which are communicated back to applicants and administrative staff in a transparent and interpretable format. Instead of providing binary approval or rejection decisions, the system generates a structured list of findings (Figure 2), including missing elements, inconsistencies and recommended corrective actions.

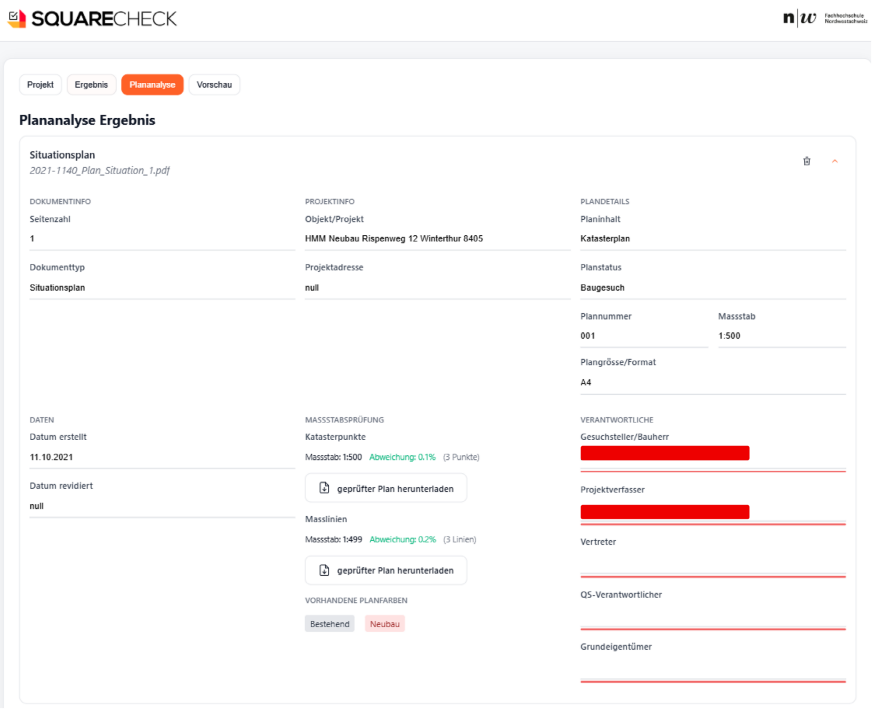


Figure 2. Web based user interface of the AI compliance checking.

The scale verification represents an important component of the rule-based validation layer for submitted planning documents. Using cadastral points as a reference, it ensures that spatial reference data and their representation within submitted plans are correctly scaled

and geometrically consistent. In this process, predefined cadastral reference points are used to automatically verify the scaling accuracy of the plan materials. As a result, shown in Figure 4, deviations between expected and actual distances can thus be reliably detected. This check is particularly relevant, as incorrect scaling may directly affect the legal and technical assessment of a building application. By integrating scale verification into the rule-based system layer, such inconsistencies are identified at an early stage and documented in a transparent and traceable manner.

Scale checks were investigated for three use cases: mass chains, elevation points (height annotations), and cadastral points. As shown in Figure 3, metadata extracted from the title block (plan header) is automatically analysed in order to identify the declared drawing scale and plan dimensions.

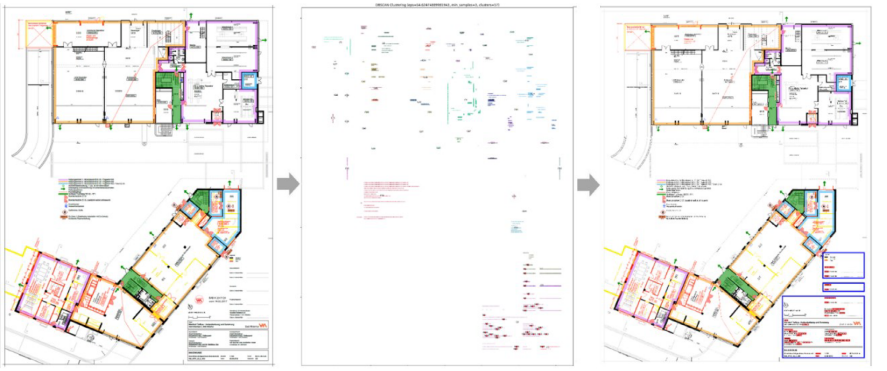


Figure 3. Automatic extraction of title block information of the plans.

Depending on the use case, different procedural approaches are applied. The workflow for mass chains is described in more detail below:

– Automatic detection of mass chains (dimension lines with annotations in floor plans)
– Recognition of dimension values (annotated numerical labels)
– Calculation of the actual geometric length based on the detected elements

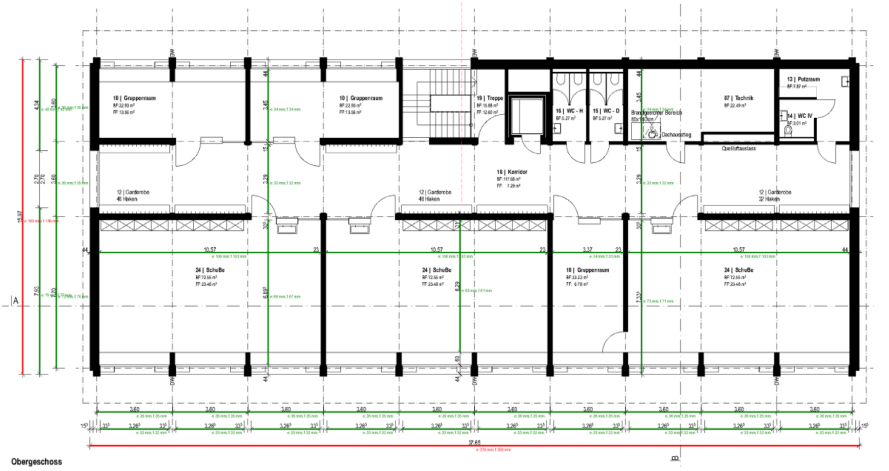


Figure 4. Automatic mass chains control on a layout plan (green: correct mass chains within the tolerance; red: incorrect mass chains which are outside the tolerance).

The compliance checker is further designed to integrate spatial information through geographic information systems (GIS). Since many regulatory constraints in building permitting are location-dependent, GIS data such as parcel boundaries, zoning information and contextual spatial constraints are used to enrich selected rule checks and improve contextual accuracy.

At the current stage of the project, the compliance checker is implemented as a pilot system and is being evaluated within the operational context of the City of Winterthur. The focus of the pilot phase lies on testing rule coverage, accuracy of issue detection, system robustness and integration into existing administrative workflows.

4.3.1 *System concept/architecture*

The majority of the software was developed in Python 3.11. Python was selected due to its flexibility, modular design capabilities, and the extensive availability of open-source libraries. Although Python 3.11 is not the latest version, it was chosen to ensure compatibility and stable operation of specific required dependencies.

The codebase follows a modular architecture and is structured into multiple independent functions, many of which can be executed separately. Configuration is largely externalised through configuration files, allowing key parameters, such as tolerance thresholds for analytical procedures to be adjusted without modifying the source code.

The system integrates a hybrid approach combining classical geometric analysis methods with selected artificial intelligence components. However, a rule-based methodology is prioritised wherever possible to ensure transparency, reproducibility, and controllability. The use of large language models (LLMs) is deliberately limited and only applied in specific cases where they provide a clear functional advantage. This design choice is motivated by considerations of cost efficiency, data protection, and the need for interpretability in scientific workflows.

A technical contribution of the prototype lies in the development of project-specific algorithms for processing real architectural plan documents. During development, existing open-source tools for engineering drawing extraction, layout analysis, table recognition and natural-language processing were tested, but proved insufficiently robust for the heterogeneous plans and forms used in the municipal case study. Therefore, several core functionalities were developed specifically for the project, including title-block metadata extraction, dimension-line detection, scale-related plan interpretation and extraction of project participant information. Existing libraries were used selectively only where they provided reliable support, such as the detection of handwritten signatures within predefined form areas.

4.3.2 *Validation*

The development and validation of the algorithms relied on different datasets depending on the use case, development stage, and availability of ground truth data. Therefore, individual functionalities were evaluated using different validation approaches.

To evaluate object recognition and submission completeness, the final algorithm was tested on 17 previously unseen building permit projects. Each building permit project consists of several plans and documents; in total 72 plans and 89 other documents over 17 projects. The submitted object was correctly identified in 9 of 17 projects (53%), while the completeness check was successful in 5 of 17 projects (29%). The suboptimal performance of these functions can be attributed to limited data availability and the absence of ground truth during development Although additional test data became available later, time constraints prevented further refinement of the approach.

Title-block extraction, GIS integration and scale verification were evaluated in two rounds. The first round used data available during development. Title blocks and associated metadata were successfully extracted from 32 of 33 plans (97%). Only vectorised plans containing title blocks were considered eligible for this evaluation. Scale verification was successful for all 19 eligible plans (100%) containing the required reference elements, i.e., a

specified scale combined with dimension lines, elevation points, or cadastral reference points. GIS integration was successfully demonstrated for all 4 plans containing cadastral reference points. Project participants were correctly identified, and signature presence was successfully detected on all 6 available forms. However, OCR performance when reading participant names was poor, particularly when names overlapped with handwritten signatures.

The second round used new datasets that had not been available during development. Title blocks and associated metadata were successfully extracted from 30 of 31 new plans (97%). Scale verification was successful for 15 of 21 new plans (71%). Two unsuccessful cases were caused by software bugs and were resolved through debugging. The remaining four unsuccessful cases involved previously unseen variations in the representation of measurement information. These cases could be addressed through additional rule extensions; however, their implementation was outside the scope of this project due to time constraints. GIS integration was successfully demonstrated for all five plans containing cadastral reference points. Project participants could not be identified due to a technical issue.

After a round of debugging, scale verification was successful for 17 of 21 eligible plans (81%). Project participants and signature presence were successfully extracted from all 15 forms provided. The OCR limitations observed during the first testing round persisted.

Overall, the developed algorithms demonstrated promising performance across the evaluated functionalities, with particularly strong results for metadata extraction, GIS integration, and scale verification after debugging. At the same time, the results indicate that object recognition, completeness checking and OCR-based participant extraction require further development before broader operational deployment.

4.4 *Initial implementation insights, challenges and limitations*

The initial implementation and pilot application of the developed systems provided several important insights regarding the practical use of AI-supported solutions within municipal permitting processes. A key aspect identified during the implementation phase was the importance of transparency. Since administrative decision-making processes require traceability and accountability, users need to understand how results are generated rather than relying on a "black-box" system. Consequently, explainability emerged as a critical requirement, particularly for the ACC system. Beyond providing a result, parts of the underlying solution process and decision logic should be visualized to enable users to understand the reasoning behind compliance assessments and increase human trust in the system outputs.

Furthermore, technical limitations related to data availability and quality became evident. The current implementation of the ACC system relies on structured and vectorized plan data (pdf format), while scanned or image-based plans cannot be processed directly without additional preprocessing or digitization steps. This limitation may reduce applicability in municipalities where digital planning data is not yet consistently available.

Another challenge concerns administrative adoption. The integration of AI-supported tools into established municipal workflows depends not only on technical performance but also on acceptance among administrative staff. User trust, ease of use, and alignment with existing procedures are therefore essential factors for successful implementation and long-term adoption.

5 CONCLUSIONS AND OUTLOOK

5.1 *Findings and discussions*

The project findings indicate that significant inefficiencies in municipal permitting workflows frequently originate during the pre-submission phase rather than during formal

compliance assessment itself. In contrast to much of the current Digital Building Permit research, which mainly focuses on BIM-based automated compliance checking and machine-readable regulation, the investigated case demonstrated that incomplete submissions, recurring procedural questions and iterative clarification processes represent major operational bottlenecks within municipal practice.

The presented "Step 0" framework therefore shifts the focus towards applicant-oriented support and early-stage quality assurance. The study shows that guided workflows, structured information access and automated pre-validation mechanisms can support submission quality and reduce administrative friction before formal review procedures begin. In this context, the combination of deterministic rule-based mechanisms with selective AI support proved particularly relevant for public administration environments, where transparency, explainability and controllability are essential requirements. The developed chatbot further provides precise, regulation-compliant answers on a 24/7 basis, significantly improving accessibility and response times for applicants throughout the entire pre-submission phase.

The findings further highlight that fully automated BIM-based permitting workflows are currently not realistic for large parts of municipal permitting practice, especially in contexts involving private applicants and heterogeneous submission formats. Human-in-the-loop approaches there-fore remain necessary, particularly for interpretation tasks, legal assessment and exceptional cases. Similarly, the investigations confirmed that unrestricted large language model (LLM) us-age is problematic within public administration due to risks regarding hallucination, traceability and legal accountability.

At the same time, the study indicates that several findings are transferable beyond the investigated municipal context. The overall "Step 0" process concept, including applicant-oriented guidance, structured pre-submission support and the hybrid combination of deterministic rule-based mechanisms with selective AI support, is largely independent of the specific municipality and can therefore be adopted in other administrative settings with only minor procedural adaptations.

However, the individual system components differ considerably regarding their transferability. The AI-supported chatbot can be reused as a technical solution, but its knowledge base must be adapted to the applicable legal and administrative framework of the target municipality. While federal legislation and, to some extent, harmonised cantonal regulations provide a reusable foundation, municipality-specific regulations, local procedures, GIS information, public-law restrictions on landownership (PLR/ÖREB) data and administrative guidance documents require manual curation and validation by domain experts. Likewise, the AI-assisted Compliance Checker follows a transferable rule-based architecture, whereas the implemented validation rules and application forms must be adapted to local permitting requirements. Consequently, the proposed architecture is highly transferable, while the regulatory content remains jurisdiction-specific.

5.2 *Limitations and outlook*

The study is subject to several limitations. First, the developed systems are currently still in a pilot phase and no full quantitative evaluation of operational performance has yet been conducted. Furthermore, the investigated workflows and requirements are strongly influenced by the specific municipal context of the City of Winterthur, limiting direct generalisability.

Future work will focus on broader pilot implementation, systematic quantitative evaluation and further refinement of the developed "Step 0" framework. In particular, the integration of GIS-supported contextual checks represents an important next development step. Possible future BIM integration may additionally enable more advanced model-based compliance checking for suitable application types and professional planning workflows.

Future research should therefore focus not only on evaluating operational performance but also on reducing the effort required for cross-municipal deployment. In the Swiss context, initiatives such as the Intercantonal Agreement on the Harmonisation of Building

Terminology (IVHB) provide an important basis for improving transferability by harmonising core building definitions and regulatory concepts across cantons (2019). Although municipal implementation will continue to require adaptation of local regulations and administrative procedures, increasing regulatory harmonisation is expected to substantially reduce the effort required to configure AI-supported knowledge bases and rule sets for additional municipalities. Further research should therefore investigate methods for semi-automated knowledge-base generation, reusable rule libraries and standardised regulatory representations to facilitate scalable deployment across municipalities.

Overall, the paper contributes to addressing an important research gap by demonstrating that applicant-oriented pre-submission support constitutes a critical yet currently under-represented component of digital building permit research and implementation practice.

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