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THE CHALLENGE OF AUTOMATED COMPLIANCE CHECKING: A REGULATORY VIEW

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Abstract

Automated Compliance Checking (ACC) facilitates rapid and objective review of building permits. The present study, based on in-depth qualitative expert interviews with regulators and ACC experts worldwide, provides an overview of the current ACC advances in place within or linked to regulatory bodies. The interviewees highlighted key challenges, including ambiguous terminology, inconsistencies, and the balance between human oversight and algorithmic decision-making. A comparative analysis of current practices across different countries offers insights into their lessons learned, future plans, and additional research needs.

Introduction

Automated Compliance Checking (ACC) evaluates whether building designs conform to legal requirements, increasingly leveraging Building Information Models (BIM) as a source for structured data (Amor & Dimyadi, 2021). ACC is conceptualized as a four-step process: converting regulations into machine-interpretable formats, preparing building design data, reasoning about compliance, and reporting results (Eastman et al., 2009).

Several commercial tools and research efforts have contributed to ACC. Solibri Model Checker[1] is a prominent tool that allows compliance checks against predefined and user-defined rules. While it supports numerical and spatial comparisons, its limitations include vendor-specific rule formats and the labor-intensive process of rule parameterization. UpCodes[2] offers an integrated, searchable version of building codes alongside tools such as an AI assistant for question answering and a Revit plugin for compliance checks. BIM.permit[3] is a workflow-based ACC system where users can assemble checking routines based on over 100 atomic functions. Some of the German state building codes have been formalized using this ACC system.

In several countries, there were government-funded or supported ACC systems and research programs: Singapore developed CORENET e-PlanCheck, a black-box system for compliance checks using the FORNAX platform, which enriches models in Industry Foundation Classes (IFC) for ACC (Solihin, 2004). The project was renewed with CORENET-X[4] in 2023, incorporating IFC-SG extensions to capture Singapore-specific building information requirements. Norway's ByggSøk, developed by Statsbygg, adapted CORENET e-PlanCheck for the Norwegian building codes (Aagesen & Krogstie, 2010). In Australia, DesignCheck was introduced as an object-based approach with the Express Data Manager (EDM) for formalizing building regulations and including domain-specific knowledge for compliance checks (Ding et al., 2006). The United States developed SMARTcodes, led by the International Code Council, which used marked-up building codes for ACC (Wix et al., 2008), which was later developed into the RASE framework (Requirement, Applies, Select, Exception) (Hjelseth & Nisbet, 2011). Compliance Audit Systems (CAS), in New Zealand developed ACABIM. It follows a human-centered workflow combining automated quantitative checks with user input for qualitative assessments (Dimyadi et al., 2016).

Korea formalized the Korean Building Act into KBimCode (Lee et al., 2016) and used natural language processing (NLP) to support the formalization process (Song et al., 2018). Zhang & El-Gohary (2017) developed a NLP-based framework to extract and formalize rules from building codes and execute them against the BIM in Prolog. Finally, the European Union Horizon 2020 ACCORD project aims to streamline building permits and automate compliance checking, e.g., by leveraging advancements in NLP techniques (Hettiarachchi et al., 2025). The methods are developed and tested using case studies in Finland, Estonia, Germany, UK, and Spain.

Despite these and many more advancements, many early projects have been discontinued, and other projects cannot fully automate the compliance checking process of all necessary legal requirements and are difficult to transfer to other countries or states. The challenges causing this lack of widespread adoption include the lack of machine-interpretable regulations, inconsistencies between BIM

[1] https://www.solibri.com/
[2] https://up.codes/
[3] https://bimpermit.digital/en/
[4] https://www1.bca.gov.sg/regulatory-info/building-control/corenet-x

data and legal terminology, and the time-consuming manual formalization of building codes (Solihin & Eastman, 2015). Frequent amendments to regulations further complicate maintaining up-to-date machine-interpretable versions.

In this research, we examine the progress of ACC from the regulatory viewpoint. Through interviews with regulators worldwide, we investigated the regulators' perspectives on the computability of building codes and standards. The paper reports the progress towards ACC systems that were connected to those agencies, and the overall connections between regulatory bodies and the developers of ACC systems.

Methodology

While the main objective of the interviews was to investigate the feasibility of a parallel drafting process, which was reported in Fuchs et al. (2025), this paper presents a meta-analysis of the interviews with a focus on the ACC efforts of the interviewees' respective countries and institutions.

The study followed expert interview best practices as outlined by Gläser and Laudel (2010), utilizing a semi-structured interview approach. This method ensured that key questions were systematically covered while allowing for in-depth exploration of relevant topics.

While the interview questions focused on the drafting processes, formal representations of building regulations (i.e., computer-readable or computer-executable formats), and methods for creating formal representations alongside natural language texts, the following topics provided insights into ongoing ACC initiatives.

Demographics:

- Experience with regulations
- Tasks related to regulations

Drafting process:

- Ensuring the computability of regulations
- Avoiding subjectivity and ambiguity
- Quality assurance
- Ensuring consistent terminology

Formal representations:

- Understanding of formalized regulations
- Current practices for formalizing regulations in their country
- Discussing examples of formal representations

The interviewees were identified through the authors' networks and snowballing strategies, enabling the inclusion of multiple interviewees from certain countries with diverse educational backgrounds. The inclusion criteria required participants to have at least three years of experience in drafting or formalizing building regulations.

A total of 9 interviews were conducted with experts involved in regulatory processes from 7 countries between January 23 and August 26, 2024. All interviews were conducted by the main author in English or German, with support from the second author in four interviews. The interview length ranged from 48 to 72 minutes.

The interviews were automatically transcribed using the OpenAI Whisper model[5], and the transcripts were manually reviewed by one researcher. Transcripts of interviews conducted in German were translated automatically using DeepL[6]. The interviews were then coded according to the interview questions using Nvivo 14[7], with the first three interviews coded collaboratively by at least two researchers to ensure consistency. New codes were added as needed throughout the process. Of particular relevance to this paper are three of the added codes: ACC, Challenges, and Examples. Once consensus on the coding process was achieved, the remaining interviews were coded by a single researcher.

The most relevant segments from each code were extracted into a tabular format by one researcher and reviewed by a second researcher. The report on the interview results was created based on the tabularized information; however, if any parts were unclear, the Nvivo codes and the original transcripts, potentially in the original language, were reviewed for clarification. The following section presents the ACC-related interview findings.

Results

Table 1 shows the interview demographics. The interviews were sorted by relevance for the following analysis, starting with the most progressed countries in ACC (according to the interviews).

The Singaporean interviewees were connected to the CORENET-X initiative. One from the government side, in particular urban design, and one from the industry side. This showed the positive effects of collaborations between industry and governments. The Estonian interviewee was involved in the Estonian government's efforts to automate the compliance checking process. In contrast, the Swiss interviewees reported from an ACC research project based at a university. However, one of the interviewees was directly involved in the efforts of renewing the fire protection regulations, also contributing some of the lessons learned from the ACC efforts. The Belgian interviewee reported on their systems for automating the planning permit application process; however, limited content checks are in place. The UK interviewee was based at a university and reported on research efforts towards ACC and their involvement in advising on new draft regulations. The Canadian interviewee was not directly involved in ACC efforts. However, they do have planned initiatives toward making building regulations computer-executable. Sweden

[5] https://huggingface.co/openai/whisper-large-v3

[6] https://www.deepl.com/

[7] https://techcenter.qsrinternational.com/

reported on experiments using RASE to represent their regulations. However, while no further movements toward ACC were reported by the interviewee, this does not necessarily imply that there are no efforts toward ACC, either in governments or research, within these countries.

Table 1: Interview demographics ordered by ACC progress as described by interviewees

Country	Organisation	Role	Specialty
Singapore	Government	ACC	Planning
Singapore	Industry	ACC	Building, planning, etc.
Estonia	Government	ACC	Building, planning, etc.
Switzerland	Research	ACC, Drafting	Fire protection
Switzerland	Research	ACC	Fire protection
Belgium	Government	ACC, Drafting	Environmental regulations
UK	Research	ACC, Advising	Healthcare standards
Canada	Government/ Research	Drafting	Model building code, Processes
Sweden	Government	Drafting	Building codes

In the following subsections, we discuss how the different interviewees described the implementation processes behind the ACC systems, the challenges they encountered, and how they resolved them or how they could be resolved in the future.

Singapore

Singapore follows a pragmatic method of implementing its model checker, where the regulations are converted to control values for IFC representations. However, since this process is only applied at the implementation stage, no direct link is maintained to the original regulation concepts. The decision to implement specific clauses depends on their nature. Regulations are categorized into three types:

- Definitions and General Information – These do not constitute actual requirements.
- Non-Automatable Requirements – So far, these cannot be processed using available methods.
- Automatable Requirements – These are directly implementable.

The boundary between these categories can shift over time. For example, there are many requirements for elevators, such as the placement of buttons, which are currently too detailed to be modeled efficiently. However, if standard libraries for elevators become widely adopted, these checks may become feasible in the future.

The interviewees' experiences highlighted the difficulty of translating regulations into machine-executable rules. Regulatory clauses often appear simpler than they are. Additionally, they can include complex conditions and numerous exceptions, as well as intents that do not require verification. A notable example is the requirement for unobstructed balcony views, which was implemented using ray tracing. While building elements within 10 meters must not obstruct the view, IFC geographic elements, such as trees, are considered acceptable. To systematically interpret regulations, they follow a four-stage process:

1. Applicability – Identifying which IFC objects should trigger compliance checks (i.e., balcony).
2. Values to Check – Extracting relevant numerical or qualitative conditions (e.g., 10 meters of unobstructed view).
3. Objects for Evaluation – Determining which elements should be checked (e.g., building elements but not trees).
4. Checking Procedure – Defining the actual verification process.

This information is captured by the rule interpreters in flow charts or conceptual graphs as a means of knowledge capture and communication. While different experts may visualize requirements in different ways, conceptual graphs offer a more concise and less ambiguous alternative to natural language. A successful formal representation of regulations must bridge the gap between regulatory texts and building design.

Interpreting regulations requires domain expertise. For example, how should mezzanines be counted in storey calculations? Another critical question is at what level the requirements apply—for example, should smoke detection systems be checked at the building level, storey level, or individual space level?

Effective communication between the ACC system developers (from both government and industry) and regulatory authorities is essential. While communication within the government is more direct, industry partners seeking clarification can also indirectly influence regulatory changes. For example, discrepancies between three different methods for calculating the gross floor area, used across different agencies, were resolved based on feedback from ACC development. However, the lack of direct involvement of software developers in the regulatory drafting process was criticized. Still, moving towards the creation of formal representations during the drafting is likely to be considered only if applied successfully by other jurisdictions.

Once regulatory interpretations are structured into flowcharts, they are passed on to software developers for implementation in the model checker. Finding the right level of detail in these representations is critical. Regulatory experts should handle high-level interpretation, while the implementation details should be left to the programmers.

A significant challenge in ACC is the automation of subjective or outcome-driven requirements with more room for interpretation. While such requirements are often intentional, e.g., to motivate more creative design solutions or to prevent architects from doing the bare minimum, they cause problems for automation. To address such cases, Singapore has introduced a human-in-the-loop approach where, instead of giving binary results, the results are returned as a heatmap with different colors indicating the degree of compliance with the requirements (e.g., the extent of a basement protrusion).

For highly subjective requirements, such as façade aesthetics, full automation is currently unfeasible, though future advancements in AI may offer potential solutions. These requirements are still included in the model checker but require manual review. The model checker offers an IFC visualizer for this purpose.

For future AI-driven decision-making, all expert decisions on exceptions to specific requirements are required to be documented. These decisions are archived and can be utilized in the future to train a decision-making AI. There are already experiments with natural language processing to determine whether waivers can be granted based on past decisions and case-specific factors. Similarly, there have been efforts to automate the translation of regulations into computer code. However, the limited training data (around 200 implemented rules) prevents them from having "very good" results.

Another issue in ACC implementation is the variability in how building elements are modeled. For example, if stairs are modeled as slabs, stair-related compliance rules may not be triggered. This is addressed through Information Delivery Standards (IDS) and modeling guides, which specify what data must be provided by architects.

A unique aspect of Singapore's approach is that regulation drafters have direct editing rights over IDS requirements and BIM modeling guides, ensuring that automation considerations are factored in early in the drafting process. With the IFC-SG project, there were also efforts to standardize terminology by establishing a classification system. However, despite similarities between many terms used by different agencies, subtle differences make it difficult to harmonize the terminology.

A final challenge relates to inconsistencies in how regulations are maintained and referenced. The same compliance conditions appear in multiple regulatory documents, yet maintaining consistent updates across these documents is difficult. Similarly, there are interdependencies between rules within a single handbook, such as escape distance and fire engine access, which are placed in separate chapters because one applies internally and the other externally. While logical for human readers, these dependencies should be explicitly linked in the backend for automation.

Estonia

The interviewee was involved in developing Estonia's BIM-based building permit software. Their goal was to create an MVP (Minimum Viable Product) by analyzing building regulations to determine which aspects could be automatically checked.

A three-step process was followed to define the scope of automated compliance checking. First, checklists used by municipalities were analyzed to identify which parts of ministerial decrees required verification and which merely stated regulatory intent. The second step involved analyzing building regulations to determine if requirements were measurable (i.e., whether control values were specified) and whether terms were clearly defined with a finite set of possibilities. Third, how much interpretation is needed was assessed. While explanatory materials provide clarification, even experienced building permit processors, who often lack legal expertise, may interpret requirements differently. The example was given that permit processors for a project rarely change, since multiple reviewers assess regulations from different perspectives and might identify additional issues leading to further delays. While automation could mitigate this problem, regulatory interpretation adds technical challenges for the ACC system.

Based on this analysis, the MVP scope was determined by identifying the most valuable checks for automation. Initially, 70 checks were selected, but only 47 were implemented. Some checks were excluded due to technological limitations, for example, the implemented voxel-based algorithms produced inconsistent results. Others were deemed impractical because they required architects to model elements with excessive detail, which was not justified by the benefit gained from automation. The key takeaway: there must be a balance between the effort required from one party and the benefits provided to the other.

A key challenge discussed with the interviewee was automating subjective requirements, such as "The stair railing should be strong enough to prevent falling." Since "strong enough" lacks a precise definition, automation can only verify the presence of a railing, not its adequacy. Rules with too many exceptions pose another obstacle. While the law needs room for interpretation, ACC works best with clearly defined rules. One possible solution is using ranges instead of fixed values or employing a traffic light system (e.g., compliant, non-compliant, uncertain) to indicate compliance status. In such cases, the ACC system should provide all relevant data to support efficient human-machine decision-making.

A special emphasis was on the interaction between different decrees. For example, the minimum dimension of light openings was defined with fixed values for different types, but included the clause "unless the requirement of another act states otherwise." Therefore, a matrix of priorities between the decrees is required (i.e., defeasibility), and the activation mechanism for the entire decree needs to be specified clearly. For example, in the case of accessibility, which "needs to be applied for building (parts) offering public service", this is not clearly defined since public service is not explicitly defined through the classification system's usage codes. Other decrees might be activated based on details from zoning plans or design conditions, which also need to be machine-readable. Some building permit checks involved regulations from other ministries, such as health law and heritage protection law. Coordination with these entities was challenging, making it harder to clarify implementation details and propose regulatory changes.

Although Estonia's current ACC system does not include a formalized version of building regulations, the Ministry of Climate (responsible for building law) is part of the Horizon 2020 ACCORD project. To avoid duplicated efforts, they are waiting for positive results from ACCORD before integrating similar approaches into its ACC systems. A similar concern was raised more broadly: different governments building tools for the same purpose wastes resources. This creates an opportunity for private-sector developers to establish superior solutions. Since private companies need to be profitable, their tools are often more refined and efficient.

Switzerland

The Swiss interviewees reported on E-Brandschutz, a research project focused on BIM-based fire protection compliance checking. For this purpose, they developed test rules in the form of T-models, where:

- The left-hand part defines the required attributes.
- The vertical part specifies how they are processed.
- The right-hand part represents the output.

For creating these T-models, engineers first interpreted the fire protection regulations, defining a set of validation tasks (e.g., the distance between door and fire exit, the fire rating of an element) and controls that can be executed by a program against the BIM. These are communicated through event trees, flow charts, checklists, and similar means to a second person who then systematizes the different tasks and controls by adding the tasks to a relational database, establishing links, and ensuring reusability. One paragraph corresponds to one validation task flow, which consists of many reusable validation tasks. Task flows can also be linked from other paragraphs for reusability, which are also defined in the database.

A major focus was on reducing redundancy by identifying the 100 most common, highest-priority tasks out of multiple thousands. Most other tasks could be assembled from those or were simply variations of the same validation task. In such cases, discussions with the team were necessary to determine whether validation tasks can be merged, i.e., redundancy can be reduced.

The interviewees emphasized the importance of accuracy and trust in the checking tool. Black box systems are difficult to trust, so every compliance check begins with an attribute validation step, verifying whether all necessary information is available. Additionally, the reasoning trace needs to be provided. They proposed a visualization tool where building elements involved in a compliance check are color-coded, allowing fire protection engineers to perform a final review of the results. However, a good balance between automation and human interaction needs to be identified.

A key challenge they encountered was that the required IFC properties do not exist, and certain relationships or semantics cannot yet be defined or visualized. A potential solution is to define IDS requirements during the regulation drafting process, ensuring that information needs are considered early. However, there must be a balance. BIM modelers should not be required to manually define every property for each building element. Instead, the modeling software should allow for automatic property assignments. For example, if a fire-resistance rating of EI 30 is required, the system should automatically assign this property to the relevant elements. Otherwise, the modeling effort becomes too high, leading to increased errors.

Another challenge arises with abstract elements, e.g., architects do not explicitly model the zones required for fire protection checks. The project's findings led to a shift in focus from individual components to spatial elements. Instead of requiring the modeler to define properties for each compartment, inheritance mechanisms allow fire protection data to be assigned at higher levels (e.g., floor or building level) and propagated downward. Additionally, fire-resistance ratings depend on adjacent spaces, yet BIM models often lack topological structures to capture spatial relationships. To address this, the researchers explored the use of relational databases and topological models for better spatial reasoning in ACC.

A persistent challenge was dealing with vague or subjective requirements, which could not be automated directly but needed clarification from the municipalities. Conjoint efforts between municipalities, ACC developers, and architects are key to building trust.

These challenges could be mitigated if such questions were clarified already during the drafting phase of the regulations. A notable case in this regard is that one of the interviewees is directly involved in the drafting of the fire protection regulations, being able to integrate the findings from the ACC project. For example, they had discussions on aligning BIM terminology with regulatory concepts, such as defining how escape routes are related to IFC spaces. Additionally, efforts were made to reuse elements from other standards and regulations rather than redefining them.

However, Switzerland is also shifting toward performance-based codes to decrease fire protection costs while guaranteeing safety. As a result, fire protection regulations were updated in the last code cycle to introduce performance-based codes for the 20% of buildings that require specialized fire safety measures. However, this transition caused confusion among users, highlighting the need for measurable criteria even within performance-based regulations. This, in turn, supports the integration of ACC by ensuring clear, quantifiable compliance checks.

Belgium

The interviewee from Belgium is developing a system to support the building and environmental permit process. Permit data is primarily submitted in PDF format, and applicants must fill in digital forms as part of the application. The tool guides users through the process, determining which addenda are required, verifying that the entered data is complete and logical, ensuring that all relevant stakeholders are involved, and checking that the required information is provided. However, it does not assess the content of the uploaded documents.

As part of the implementation, the interviewee is responsible for translating permit procedures and information requests into digital workflows based on regulatory requirements. A key advantage is that permit process regulations leave little room for interpretation, making their automation more straightforward. Additionally, if regulatory changes impact the permit tool, the interviewee is typically involved in the drafting phase by reviewing proposed regulations to ensure they are measurable and digitizable, rather than open to subjective interpretation. Simplifying automation is much easier when changes can be made directly at the source. However, this is only possible when the ministry leads the legislative changes, highlighting the need for strong communication between permit officials, legal experts, and automation specialists.

One of the main obstacles to automation is handling multiple levels of exceptions, including the ability to waive certain rules based on well-justified requests. In such cases, the hierarchy of regulatory priorities must be clearly defined, and many of those requirements are not automated but left to civil servant interpretation. To support this process, the tool provides visualizations, such as interactive maps with layered data, to help decision-makers assess cases effectively.

UK

As part of a research project, the interviewee analyzed healthcare building regulations, classifying them based on their suitability for ACC. At the highest level, requirements were categorized as objective (straightforward to automate) or subjective (requiring interpretation or inference). For example, “adequate sound levels” is a subjective requirement that is further specified in separate guidelines. A challenge is ensuring that requirements remain connected and up to date. Instead of relying on generic regulatory statements, guidelines that further define these requirements should be explicitly referenced.

This issue is particularly relevant in the UK, where designers and architects are responsible for ensuring compliance, often through informal processes based on the lead designer’s expertise. If a guideline is not explicitly referenced, a designer who is unaware of it may overlook the requirement entirely.

The interviewee provided feedback to drafters revising the healthcare building guidelines, though only as an external advisor, meaning there was no insight into whether the recommendations were implemented. Similar to trends in other countries, the proposed draft amendments aimed to make guidelines more flexible and open to interpretation, but they were ultimately never published. The interviewee criticized the fact that documents are rarely updated based on computability, but only based on content. One possible improvement would be to flag requirements that can be directly automated, facilitating the implementation of ACC.

The key challenges for ACC in healthcare buildings include diverse, subjective, complex, and convoluted requirements. To address this, the interviewee proposed structuring requirements in a database, allowing for multiple views and interfaces tailored to different use cases (e.g., automated compliance checking, human readers, or querying). Such a structured approach would also enable more consistent updates. However, the successful development of this database would require a collaborative effort, and both the database and the ACC system need to be aligned with the processes in a country.

Canada

Canada has a 7-8-year initiative aimed at lowering carbon emissions, which includes advancing digitalization in the built environment. By 2024, they were in their third year of the initiative, which encompasses building codes, permitting processes, digital common data environments, digital twins, and even advanced manufacturing. The interviewee is involved in the digitalization of codes and specifications, with future plans to develop a proof of concept for ACC.

The primary goal is to make building codes machine-readable and executable (i.e., compatible with BIM standards such as IFC and BCF) while ensuring they remain accessible to human readers. In parallel, they are also exploring decision support tools for non-BIM-based permit submissions and compliance checks.

As part of this project, they evaluate the suitability of RASE and engage in knowledge exchange with other governments, BuildingSMART, and the ACCORD project. Their plan involves architects and engineers establishing a training set for rule formalization, followed by an exploration of NLP techniques adopted in other jurisdictions. Simultaneously, efforts are underway to modernize their XML-based content management system, improving user-friendliness. As part of this process, they are evaluating whether RASE tags and related metadata can be incorporated within the same system using layered information structures; otherwise, they will consider a synchronized derivative database to accommodate different roles in code writing and tagging.

Interestingly, tables were identified as a challenge. While they already provide structure, their multi-level headers can complicate database storage, potentially requiring nested or hierarchical data structures.

However, the interviewee noted that e-permitting has not yet been fully implemented across all municipalities, indicating that there is still significant progress to be made. At the same time, compliance-checking startups are emerging, and since they will inevitably consume regulations in some form (e.g., by parsing PDFs), the interviewee prefers to provide them with a structured digital version of the codes. To support this, they emphasized the importance of both offering an API for tool providers and having human-readable code in HTML, making it easier to navigate.

Furthermore, as with the other countries, they are working toward increasing performance-based requirements. For instance, they have introduced energy regulations with two compliance pathways: performance-based and prescriptive. However, the interviewee emphasized that any proposed code changes must be accompanied by a thorough impact analysis to ensure feasibility and effectiveness.

Sweden

In Sweden, it was reported that compliance checking is still conducted entirely manually. A transition to PDF-based permit processes occurred only about a decade ago, and no legislation currently mandates or supports BIM integration. Additionally, there are no immediate plans for widespread automated content checks. While the interviewee has explored the potential of using BIM for compliance verification, their agency's role is limited to providing support and guidance. The responsibility and liability for building permit processing and compliance checks remain with municipalities.

A step towards digitalization is the database systems for regulations in EUR-Lex notation, which is used for the provision of the regulations. The agency has also explored RASE and logical statements for drafting regulations, but due to legal traditions, such statements are not incorporated into legislation. Moreover, expressing requirements in logical form would introduce technical decisions into legal texts, which is mostly avoided. The overall trend is toward less prescriptive, more performance-based regulations to foster innovation.

As a way forward, the interviewee suggested the possibility of splitting the legislation into a machine-readable and a human-readable version. The machine-readable version could be limited to the subset of regulations required for building permits. They could be included as logical interpretations in the guidelines while clearly indicating which rules require human judgment and are not suitable for automation. However, the interviewee acknowledged uncertainty about how this approach could be implemented in practice.

Discussion

There is a growing shift toward performance-based building codes in many countries. However, this transition adds complexity to automation. To address this, it is crucial to retain explicit values and procedures for measurability while also advancing research on ACC for performance-based regulations. Practical approaches, such as traffic light systems and heatmaps instead of binary pass/fail results, could help navigate this challenge.

Such methods also promote human-machine collaboration. As demonstrated in Switzerland's ACC research with a focus on trustworthiness, it is essential to keep humans involved in the decision-making process. This requires effective visualizations of compliance results, such as color-coded compliance traces and heatmaps to highlight outputs. In particular, inferred information and implicit relationships should be made clearly visible to enhance transparency.

Furthermore, as proposed in Singapore, it is of immense value to capture the reasoning behind human decision-making as well. For example, when a waiver is granted, the justification should be documented, allowing the ACC system to learn from past decisions and propose similar waivers in the future under comparable conditions.

Addressing the issue of unclear terminology requires strong communication between regulators and building permit system developers. This dialogue should ideally begin during the drafting of regulations, as we explored in Fuchs et al. (2025). However, even more importantly, communication has to happen during the implementation of the ACC system, which in return could also lead to building code improvements in terms of computability during the next code cycles. Figure 1 illustrates the different forms of collaboration between key stakeholders. While the different countries had different organizations involved, all cases demonstrated strong links between ACC developers and regulators, facilitating more efficient implementation and regulatory alignment.

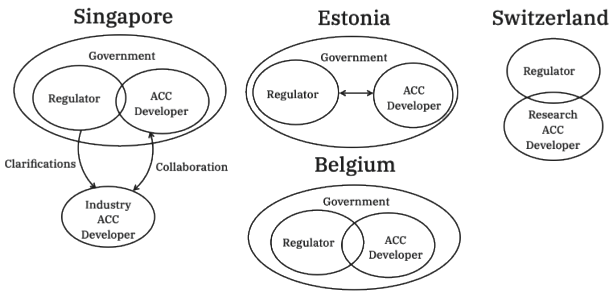

Figure 1: Stakeholder collaboration and communication

While the interviews provided valuable insights and results for ACC, it is important to acknowledge that their primary focus was on the formalization of building regulations rather than ACC itself. Consequently, the questions were primarily directed at drafting processes and the formalization of building codes, with the key challenges centered on the regulatory aspects of compliance checking.

The selection of interviewees was intentionally focused on individuals with direct involvement or expertise in drafting building regulations. However, identifying such experts proved challenging, which ultimately resulted in a highly relevant and insightful pool of participants for this paper. Future research could be expanded to include interviews specifically designed to explore regulators' perspectives on ACC systems, particularly their usability in terms of administration, such as adding new rules and configuring compliance parameters.

Conclusion

This study examined the challenges and advancements in ACC, with a particular focus on regulatory aspects and the practical implementation of ACC systems across various countries. Through expert interviews with regulators and ACC specialists, key challenges were investigated, including the complexities of subjective and performance-based requirements. Human-machine collaboration was commonly facilitated through IFC visualizers for decision support, enhancing transparency and usability.

Looking ahead, AI integration is expected to expand the scope of automatable requirements, yet further research is needed, particularly for granting exceptions and in the context of performance-based requirements. Furthermore, human-machine collaboration and the principles of human-data interaction (HDI), such as legibility, agency, and negotiability, should be explored further to improve user engagement, enhance transparency, and build trust in the compliance-checking process.

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