기본연구보고서 2025-7

인공지능 활용 주요 생활안전 법제도의 공간환경 단위 정합성 분석 연구

AI-Based Legislative Improvement Strategies for Enhancing Integrated Living Safety in Urban and Architectural Spaces

고영호 Ko, Youngho
김성준 Kim, Sungjoon
김영우 Kim, Youngwoo
허재석 Her, Jaeseok

Summary

AI-Based Legislative Improvement Strategies for Enhancing Integrated Living Safety in Urban and Architectural Spaces

Ko, Youngho Kim, Sungjoon Kim, Youngwoo Her, Jaeseok

Chapter 1. Introduction

Chapter 1 presents the fragmented implementation of legal frameworks across major living-safety domains—such as fire safety, crime prevention, pedestrian safety, and flood management—as the core rationale and necessity of this study. It highlights the policy inefficiencies and regulatory conflicts that arise when multiple safety regulations are applied independently to the same spatial environment without integrated consideration. For instance, crime-prevention window bars may impede emergency evacuation during a fire, or pedestrian safety installations may obstruct water drainage infrastructure, creating conflicts between policy objectives.

To overcome the complexity of existing legislation and the inherent limitations of manual legal analysis, this study emphasizes the need to adopt ontology-based structuring and artificial intelligence (AI)–driven reasoning as essential methodologies for assessing legal coherence.

The objectives of this study are threefold:

- To conduct an in-depth diagnosis of the fragmentation and inconsistencies within living-safety legislation,
- To develop and apply an AI-based legal coherence analysis model capable of systematically detecting legal discrepancies, and
- To derive legislative improvement strategies for establishing an integrated safety management system at the spatial-environment level.

The scope of analysis is confined to four safety domains—fire, crime, pedestrian, and flood

safety—and methodologically covers 177 Acts and 107 administrative regulations using AI-based processing. A review of previous studies reveals that while most existing research focuses on single safety domains or governance reform, the present study is distinct in that it applies a hybrid ontology–LLM mechanism to diagnose normative contradictions that emerge when multiple safety regulations overlap within a single spatial environment.

Chapter 2. Review of the Current Legislative Landscape on Living Safety

Chapter 2 examines key laws, national master plans, and judicial precedents related to fire safety, crime prevention, pedestrian safety, and flood control. It analyzes how these legal instruments are simultaneously applied to urban spaces, buildings, and facility/infrastructure units.

■ Findings from Legislation and Master Plan Analysis

Fire safety legislation such as the Act on the Prevention and Management of Fire Safety and the Building Management Act, and crime prevention legislation such as the Building Act and the Urban and Residential Environment Improvement Act were reviewed. The analysis confirms that safety regulations are cumulatively applied across hierarchical spatial units—city, building, and facility/installation—and that certain urban typologies such as multi-family housing, multi-use commercial facilities, and high-rise underground complex buildings are subject to simultaneous application of fire, crime, and flood safety regulations, making them zones of compounded risk. The legislative authorities are dispersed across multiple ministries and local governments, resulting in fragmented governance and reduced effectiveness in spatially integrated safety management. Similarly, although national master plans demonstrate policy shifts toward prevention and risk-based approaches, they continue to be implemented in a domain-specific and siloed manner.

■ Insights from Judicial Precedents

Judicial precedents were analyzed to uncover ambiguities in legal interpretation and accountability that are not visible in statutory text alone.

- Heightened Duty of Care: Courts increasingly impose high standards of protective duty on facility owners, such as hotel operators and factory proprietors, requiring enhanced safety assurance for users and workers.
- Legal Gaps and Ambiguity in Liability: In cases where certain safety installations (e.g., door closers on fire doors) are not explicitly mandated by law, courts often rule that

negligence cannot be established, exposing gaps in legal accountability.

- Conflicting Standards: Situations where one regulation mandates the installation of bollards to prevent vehicle entry while another requires unobstructed mobility for persons with disabilities have resulted in legal disputes and liability rulings against local authorities.

Overall, the judicial analysis demonstrates that fragmented legislation leads to normative conflicts and interpretative uncertainty, reinforcing the necessity of establishing legislative coherence across safety domains.

Chapter 3. Development of an AI-Based Legislative Coherence Analysis Model

Chapter 3 develops an AI-driven mechanism to assess legislative coherence in response to the complexity and ambiguity arising from fragmented safety regulations.

■ Ontology-Based Structuring of Safety Legislation

A total of 177 laws and 107 administrative regulations were converted into machine-readable triple structures (S–P–O: subject–predicate–object) through ontology modeling. Utilizing GPT-4o with few-shot prompting techniques, the legal provisions were decomposed into conditional clauses, parallel mandates, and rights–obligations interactions, resulting in the structured representation of approximately 68,153 individual provisions.

■ Development and Expert Validation of the Coherence Model

The coherence analysis mechanism consists of two main stages:

- Stage 1: Candidate Pair Reduction

By combining semantic similarity analysis using the Qwen3-Embedding-8B model and TF-IDF lexical matching, approximately 100,000 high-probability conflict pairs were extracted from over 600 million possible legal combinations.

- Stage 2: Coherence Determination

Advanced reasoning models from the O3 family were applied to perform deep inference. The model was fine-tuned through expert role prompting and iterative learning using counterexamples, significantly reducing instances of false positives. Two rounds of expert validation in law and urban planning secured the reliability and interpretive accuracy of the model.

Chapter 4. Findings from the AI-Based Legislative Coherence Analysis

Chapter 4 reports and interprets the 67 validated cases of legal conflict identified through the AI-based model, examined in terms of spatial hierarchy, regulatory targets, and the nature of conflicts.

■ Spatial and Facility-Level Conflicts

Legal conflicts occur at all spatial scales:

Urban Level: Conflicts arise in overlapping zoning regulations, such as prohibitions under the Forest Protection Act conflicting with conditional permissions under fire prevention statutes. This points to a lack of inter-ministerial coordination at the spatial planning level.

Building Level: Procedural conflicts appear in special administrative regimes (e.g., discrepancies in approval timelines between the Building Act and the Saemangeum Project Act), as well as regulatory hierarchy issues where lower-level guidelines exceed the delegation scope of higher statutes.

Facility and Equipment Level: The most direct and technical conflicts occur in facilities where fragmented performance standards—such as differing emergency power requirements for sprinkler systems—create regulatory uncertainty and compliance burdens.

■ Regulatory Areas and Conflict Types

Conflicts most frequently arise in standards and technical requirements, which in turn lead to contradictions in obligations, enforcement procedures, and liability. Over half of all conflicts (52.24%) were due to contradictions in regulatory content, such as mutually exclusive mandates or inconsistent threshold definitions (e.g., “within 10%” vs. “less than 10%”).

Chapter 5. Policy Recommendations for Integrated Safety Management at the Spatial-Environment Level

Chapter 5 outlines legislative improvement strategies aimed at resolving systemic fragmentation and supporting integrated safety governance based on the diagnosed conflicts.

■ Policy Directions by Spatial Level

- Urban Level: Establish explicit precedence rules for overlapping zoning regulations and

introduce mandatory coordination procedures for conflicting infrastructure mandates.

- Building Level: Clarify the relationship between special and general laws to eliminate duplicative sanctions and ensure administrative guidelines remain within statutory delegation boundaries.
- Facility Level: Develop unified reference standards for fire safety performance criteria (e.g., NFPC series) and mandate the application of the higher standard in cases of conflict.

Local Government-Led Integrated Safety Governance

To address regulatory fragmentation, local governments must be mandated to formulate integrated safety management plans that reflect compound risks. The study recommends institutionalizing cross-regulatory reviews during permitting processes and developing local-level safety manuals to address legal gaps identified in judicial cases.

Conclusion and Research Limitations

The study empirically demonstrates, through LLM-based analysis, that the fragmented structure of existing legislation generates significant normative contradictions. However, limitations include the scope of safety domains analyzed and the need to further enhance the ontology to capture temporal and multi-layered legal dynamics. Future research is directed toward developing an advanced legislative ontology and establishing a "Coherence Impact Assessment System" for pre-legislative conflict evaluation.

Keywords

Integrated Living Safety; Legislative Coherence Analysis; Artificial Intelligence (AI); Spatial-Environment Unit; Compound Risk Overlap