infrastructures

MDPI

Technical Note

Digital Transformation of Building Inspections: A Function-Oriented and Predictive Approach Using the FastFoam System

Jacek Rapiński [1,*], Michał Bednarczyk [1], Dariusz Tomaszewski [1], Aldona Skotnicka-Siepsiak [1], Tomasz Templin [1], Jacek Zabielski [1], Veronica Royano [2] and Carles Serrat [2]

[1] Faculty of Geoengineering, University of Warmia and Mazury in Olsztyn, 10-719 Olsztyn, Poland; michal.bednarczyk@uwm.edu.pl (M.B.); dariusz.tomaszewski@uwm.edu.pl (D.T.); aldona.skotnicka-siepsiak@uwm.edu.pl (A.S.-S.); tomasz.templin@uwm.edu.pl (T.T.); zabiel@uwm.edu.pl (J.Z.)

[2] Barcelona School of Building Construction—EPSEB, Universitat Politècnica de Catalunya—BarcelonaTECH, Dr Marañón Ave. 44-50, 08028 Barcelona, Spain; veronica.royano@upc.edu (V.R.); carles.serrat@upc.edu (C.S.)

* Correspondence: jacek.rapinski@uwm.edu.pl

Abstract

This paper presents the concept, implementation, and evaluation of FastFoam—a web-based inspection system designed for the technical assessment of buildings. Developed through international collaboration, FastFoam supports flexible inspection workflows, structured data collection, and integration with classification systems and geospatial data. The system enables civil engineers to create, customize, and manage inspection templates, store inspection results in a centralized database, and analyze inspection data using both descriptive and extensible analytical tools.To assess user needs and guide system development, a nationwide survey was conducted among Polish civil engineering professionals. The results confirmed strong interest in mobile and web-based inspection tools, as well as specific functional expectations regarding template customization, defect documentation, and automated reporting. The system architecture follows a multi-layered design with separate user, server, and external service layers. It supports modular data structures, role-based access, and integration with external platforms such as OpenStreetMap and BIM systems. A key innovation of FastFoam is its implementation of the FOAM (Function-Oriented Assessment Methodology), which enables temporal analysis and prediction of building condition over various timeframes. A case study demonstrates the application of FastFoam in a real-world building inspection in Poland. The evaluation confirmed the system's practical usability while also revealing opportunities for future enhancements including AI-based defect detection, IoT integration, offline mobile functionality, and open data export.

Keywords: building inspection; condition assessment; web application; FOAM methodology; inspection system; classification systems; BIM integration; predictive analysis

check for updates

Academic Editor: Carlo Rainieri

Received: 13 October 2025
Revised: 12 November 2025
Accepted: 13 November 2025
Published: 17 November 2025

Citation: Rapiński, J.; Bednarczyk, M.; Tomaszewski, D.; Skotnicka-Siepsiak, A.; Templin, T.; Zabielski, J.; Royano, V.; Serrat, C. Digital Transformation of Building Inspections: A Function-Oriented and Predictive Approach Using the FastFoam System. *Infrastructures* **2025**, *10*, 310. https://doi.org/10.3390/infrastructures10110310

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The assessment of building condition is a crucial task in ensuring the safety, functionality, and sustainability of the built environment [1–3]. Over the years, numerous systems have been developed to support this process, ranging from standardized inspection protocols to digital applications that facilitate data collection and reporting. Many of

these systems are designed for specific categories of buildings—for example, sustainability-focused assessments tailored to green or energy-efficient structures, healthcare or electrical systems [4–6]—or adapted to the legislative and technical context of individual countries. This diversity, while addressing local needs, has led to significant fragmentation in how building conditions are assessed and classified across regions.

Several studies have highlighted the implications of this lack of harmonization. Some studies emphasized the necessity of international standardization of building classification systems to enable comparative assessments and promote global knowledge exchange [7–9]. Without common data structures and terminologies, it becomes difficult to aggregate findings or analyze trends across jurisdictions. Earlier comparative research on classification schemes (e.g., [10–12]) similarly pointed out inconsistencies in scope and content between national systems, which hinder interoperability. The authors of [13,14] further discussed the challenge of integrating these heterogeneous systems with digital information management environments, such as Building Information Modeling (BIM), which increasingly serve as central repositories of building data.

Alongside these classification studies, other strands of research have explored the use of information systems in supporting inspection and asset management. Various comparative studies have discussed the diversity of building classification frameworks across national contexts [15,16]. The authors of [10] demonstrated the potential of linking classification systems to BIM models to improve information flow during the building life cycle. Subsequent works have proposed frameworks to coordinate inspection data, manage documentation, and enhance communication among stakeholders. However, most of these efforts focus on data organization rather than predictive or analytical capabilities. A recent review [17] on fault detection and diagnosis (FDD) in building systems underscores this limitation, noting that while digital monitoring tools are increasingly used, they often provide static assessments rather than dynamic or time-dependent evaluations.

Commercial software platforms have also contributed to digitizing the inspection process. Tools such as PlanRadar, ArchiSnapper, and Fieldwire enable mobile data collection, issue tracking, and automated report generation. These systems have been widely adopted in construction and facility management practice due to their ease of use and integration with project workflows. Nevertheless, their reliance on fixed templates and closed architectures restricts adaptability to local regulations, unique inspection scenarios, or integration with external data sources such as GIS and BIM. Consequently, these platforms support operational documentation but offer limited functionality for long-term data analysis or predictive modeling.

Addressing these gaps requires a new generation of inspection systems that are modular, interoperable, and standards-aware. The FastFoam platform presented in this paper seeks to meet these needs by introducing an open architecture that integrates flexible classification schemes, geospatial data, and customizable inspection workflows. A distinguishing feature of FastFoam is its implementation of the Function-Oriented Assessment Methodology (FOAM), which enables both descriptive and predictive analyses of building condition across various time horizons [18]. This approach supports not only the systematic recording of inspection data but also the modeling of deterioration processes and the planning of maintenance interventions. The connection with OpenStreetMap (OSM) allows users to embed building inspection data within an open geospatial framework, improving visualization, interoperability, and accessibility without relying on proprietary GIS sources [19]. The novelty of this research lies in the integration of predictive modeling, function-oriented assessment, and fully configurable inspection logic within a single, web-based environment. FastFoam unifies data acquisition, temporal modeling, and decision-support capabilities in one platform. This combination bridges the gap between inspection practice and predictive

infrastructure management, introducing a new methodological framework for data-driven assessment of building condition.

The remainder of this paper is organized as follows. Section 2 presents the system development methodology. Section 3 discusses the user requirements survey. Section 4 details the data structure and software implementation. Section 5 provides a case study of a building inspection conducted in Olsztyn, Poland, while Section 6 concludes with a discussion and implications for future research.

2. System Development Methodology

2.1. Technical Implementation

The inspection of building components plays a crucial role in reducing maintenance costs throughout the building's life cycle [20,21]. The FastFoam system was developed following an iterative, user-centered design process. The development team collaborated closely with civil engineering professionals and academic partners to ensure that both functional and usability requirements were properly addressed. Early prototypes were tested and refined based on feedback from potential users, including building inspectors and managers.

2.2. Architecture Overview

The system architecture was designed as a multi-tier web application, consisting of three core layers: the user interface layer, the application server layer, and the external services layer. This separation promotes modularity, scalability, and maintainability.

The backend was implemented using Python and PostgreSQL, containerized with Docker to ensure portability and a consistent runtime environment. The frontend was built with modern JavaScript frameworks including Bootstrap and Leaflet, supporting a responsive and interactive user experience.

2.3. Implementation Details

The database schema follows a relational model with referential integrity between key entities such as buildings, inspections, elements, and classification groups. APIs were designed to allow for future integration with external systems, including BIM platforms and national building registers.

Special emphasis was placed on creating a configurable inspection logic engine, enabling users to define templates, elements, and evaluation rules without the need to modify the source code. This ensures adaptability to various legal systems and organizational structures, supporting both local and international use cases. The full system architecture is depicted in the diagram in the Figure 1.

Figure 1 illustrates the architecture of the FASTFOAM system, which is organized as a modular, containerized web application. The architecture follows a microservice-based approach, ensuring scalability, security, and interoperability. The system operates through both web and mobile frontends, communicating securely with the backend via HTTPS and a reverse proxy server (Nginx).

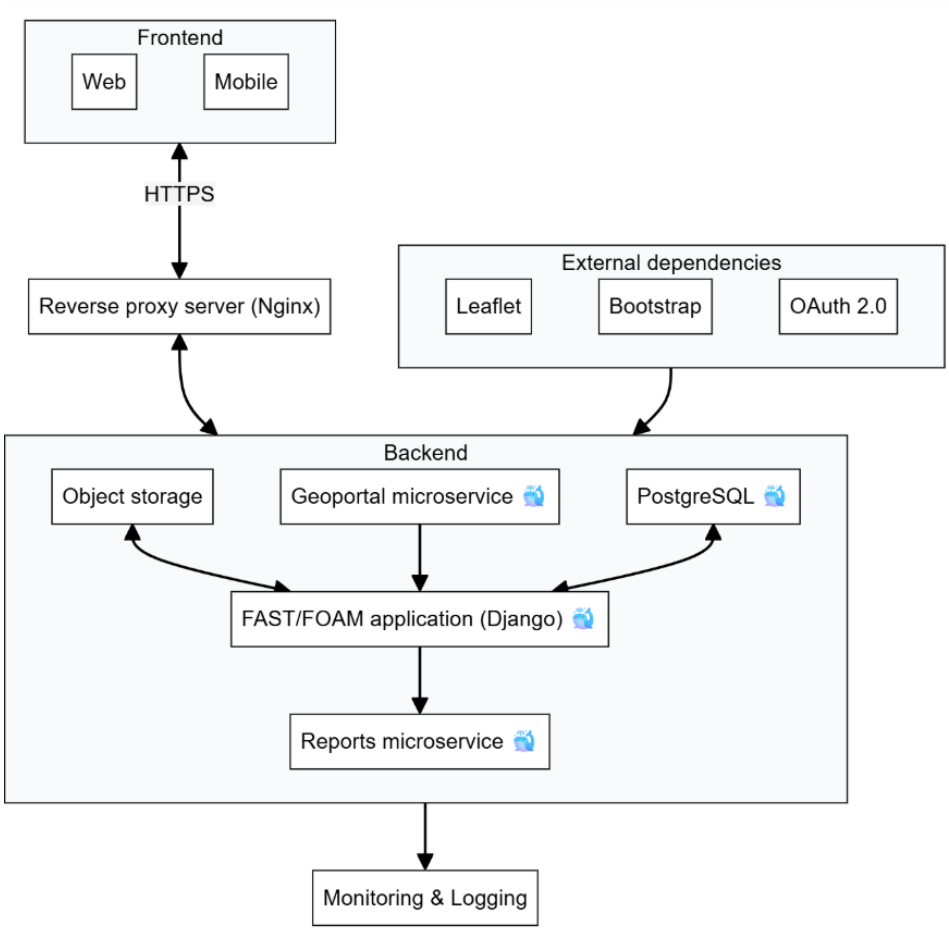


Figure 1. Summary architecture diagram of the FastFoam system.

3. System Requirements Survey

To assess the need for the online system designed for building inspections, we conducted a poll among civil engineering technicians. More than 4000 engineers were invited to take the survey; among them, 94 responded (2.35%). The survey took place from 24 February 2023 to 22 March 2023. The survey was conducted as an anonymous online poll. Most of the participants were members of the Polish Association of Construction Engineers and Technicians (which is a major association of construction engineers in Poland). The main goal of this study was to obtain information about a tool dedicated to the effective collection, management and analysis of data related to the construction stock. The information obtained made it possible to:

- Determine the need to develop a mobile application dedicated to inspections of the technical condition of the building;
- Provide information about how the application should work and its demanded features.

The survey questionnaire contained 11 single-select questions with the option to comment in the "Other" field. Respondents were asked the following questions:

1. When performing an inspection of the technical condition of a building using a mobile application, would you like to be able to freely modify each template and create your own protocol?
2. When inspecting the technical condition of a building using a mobile application, would you like to use predefined templates of inspection protocols?

3. When inspecting the technical condition of a building using a mobile application, would you like to place and mark the defect locations in photos and describe each of them precisely by dictating notes?
4. When inspecting the technical condition of a building using a mobile application, would you like to place and mark the defect locations in photos?
5. Would you like to receive an order via the platform to prepare a report on a periodic inspection of the technical condition of the building from the building owner/manager?
6. Should the application automatically transmit reports of periodic inspections of the building's technical condition to the building owner/manager?
7. Should the application automatically transmit reports of periodic inspections of the building's technical condition to construction supervision authorities?
8. If the mobile application for preparing a report on the periodic inspection of the technical condition of the building had access to the archive of reports of various buildings for a small fee, would you take advantage of such an opportunity?
9. Would you use a mobile application to prepare a report on the periodic inspection of the technical condition of the building?
10. What kind of device would you use to prepare a report on the periodic inspection of the technical condition of the building (mobile phone, tablet, laptop, other)?
11. Are you familiar with the following classification systems (PKOB, CCI, CCS)?

The results of the answers to the first nine questions are shown in Figure 2. The answers clearly indicate that 85% of respondents are in favor of using the mobile application to perform periodic inspections. Additionally, an average of 88% were in favor of using both their own and predefined inspection protocol forms. Up to 93% of respondents would like to mark defects on the walls photographically, while only 58% of people would like to add dictated notes to a detailed description of the defect. On average, 67% of respondents would like to have automatic contact with the person ordering the inspection, both during the order and when submitting the report. Up to 62% of respondents expressed negative opinions about the idea of automatically sending reports to construction supervision.

Figure 3 shows the kind of device that inspectors would like to use while conducting periodic inspections. Over 54% of respondents indicated a preference for a mobile device, while the rest would like to use a laptop or other devices.

Last question was concerning the classification systems: "Do you know the listed classification systems for construction objects/works?". Only eight inspectors out of the group were familiar with CCS or CCI.

The CCI Core in its original version was developed by Construction Classification International Collaboration (CCIC). Currently, extensive efforts are being made by the buildingSMART association to develop a Polish translation of the CCI tables [22].

Based on both the survey results and the literature review, the following conclusions can be made:

1. There is a growing demand for the digitalization of processes related to the construction and maintenance of building structures [23].
2. Building inspections are conducted for health and safety, economic, managerial, and environmental reasons.
3. There is a need to integrate the system with BIM models to enable the combination of spatial and technical data.
4. It is necessary to take into account the building regulations in force in Poland, as well as to adapt to potential regulations in other countries.

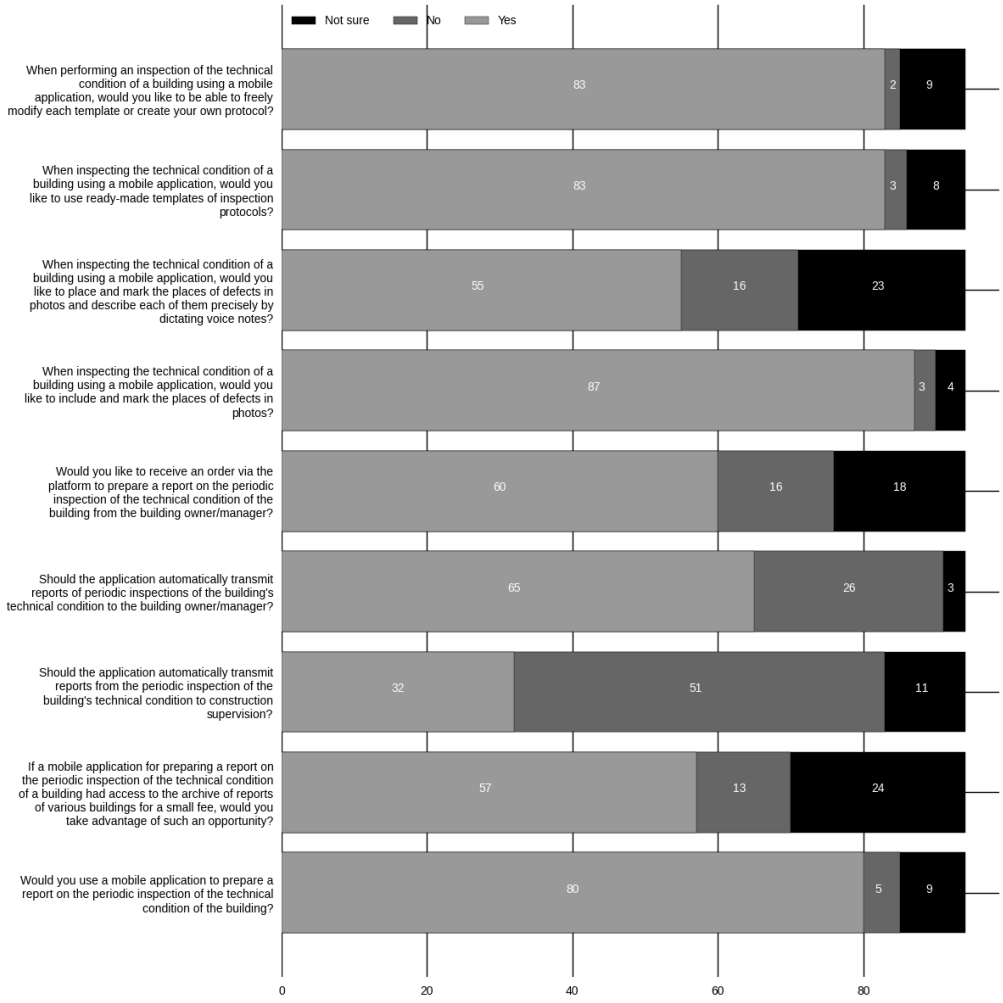


Figure 2. Survey results.

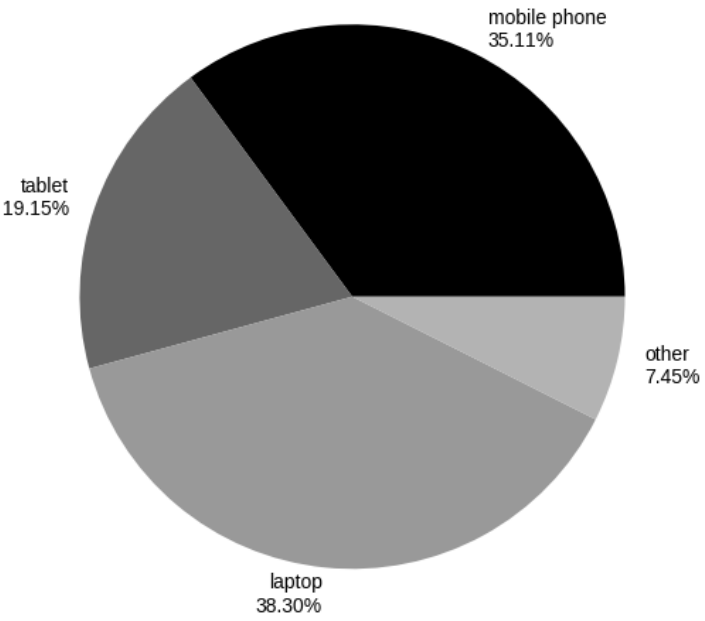


Figure 3. Device selected by users.

Although the survey provided valuable insights into user expectations, the relatively small number of responses (n = 94) limits the representativeness of the results. Never-

theless, the questionnaire targeted a specific professional group that conducts inspection activities within a formalized framework. Therefore, even a limited number of highly consistent responses can be considered indicative of broader trends relevant to application design. For instance, the strong preference for customizable templates (88%) and photo-based defect documentation (93%) directly influenced the implementation of these functionalities in the FastFoam system. Overall, the findings should be interpreted as reflecting prevailing tendencies among experienced professionals rather than statistically representative outcomes.

4. Data Structure

This section provides an overview of the key data organization methods and formats used within the system, detailing how information is stored, accessed, and manipulated.

4.1. Object-Oriented Data Structure

The object-oriented approach provides a powerful framework for designing and implementing modular, reusable, and maintainable software systems, ultimately leading to more efficient and robust applications. In this approach, objects encapsulate data and behavior, allowing for modular design. This means that changes to one part of a program do not necessarily affect other parts, promoting easier maintenance and updates. Objects and classes can be reused in different program parts, reducing redundant code and promoting code efficiency. All implementation details are encapsulated behind simplified interfaces. The data objects follow the rule of encapsulation, which refers to the bundling of data with the methods that operate on that data. This prevents direct access to data from outside the object's scope, providing better control over data and preventing unintended modification. The object-oriented approach promotes cleaner, more organized code that is easier to understand and maintain. This is especially beneficial for large and complex projects where code readability and maintainability are crucial.

4.2. System Design

The system is designed as a standard web application. It consists of three main layers (Figure 4):

1. User layer serving as an application front-end.
2. FastFoam server layer providing a back-end functionality. All data processing and storage are performed in this layer.
3. External services layer—connection to external services and APIs.

User layer is accessible through a web browser and is developed as a modern user interface leveraging many front-end technologies and libraries (JS, Bootstrap, Leaflet, Mermaid etc.). Its main role is to allow for interaction between users (managers, inspectors) and the system.

The FastFoam system server layer can be considered the application back-end. It consists of a Web Application, Web Server Gateway Interface (WSGI), and a reverse proxy configured to act as an intermediary between client devices and WSGI. The back-end of the application is developed using Python and Docker containerization.

The External services layer can be seen as an interface to external services. The main external service used in the application is Open Street Map (OSM) [19]. It provides a spatial reference to the buildings in building stock. As an additional feature, the interface to existing Building Information Modeling (BIM) systems is available as an abstract interface which defines a set of methods that can be implemented to interact with particular software.

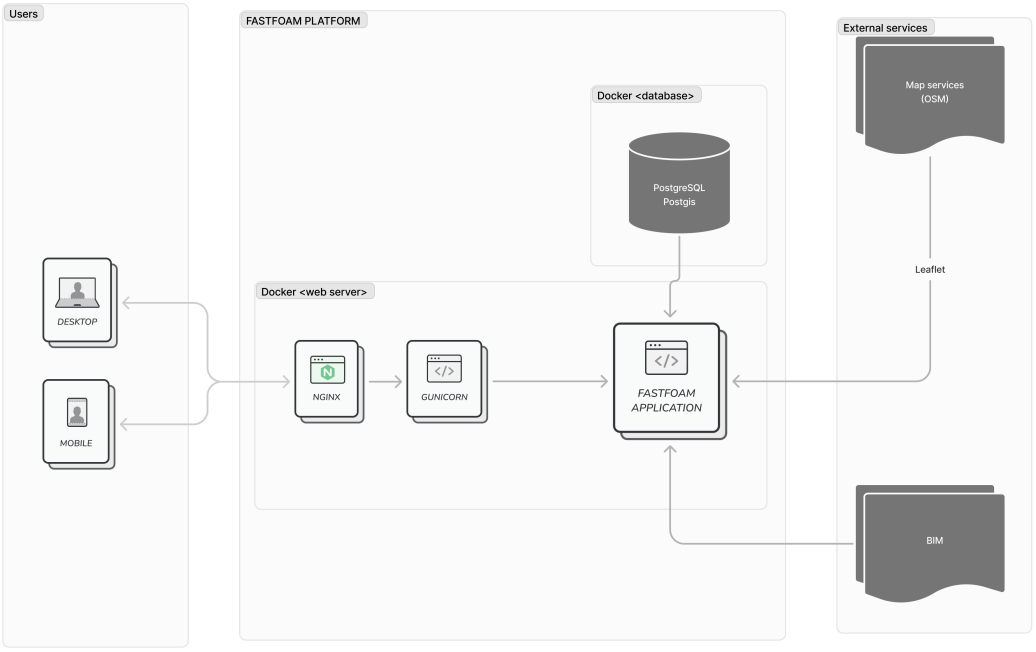


Figure 4. System design.

Figure 5 depicts the data structure used in the application. Each building can have many inspections. The elements of a building being inspected are introduced by the inspector during the on-site inspection procedure. Each element belongs to a "group of elements". A "group of elements" consists of predefined data sets containing the information about CCI classification and questions that should be applied for all its elements. In this manner, the "group of elements" (e.g., walls or elements providing ventilation etc.) can have the same questions in the inspection template. The groups of elements and questions to be used are defined before the on-site inspection is made and can be saved as an "inspection template". Each inspection stores the answers for all the questions connected to all the elements. All of this information is stored in the PostgreSQL database and can be displayed or modified in the user layer.

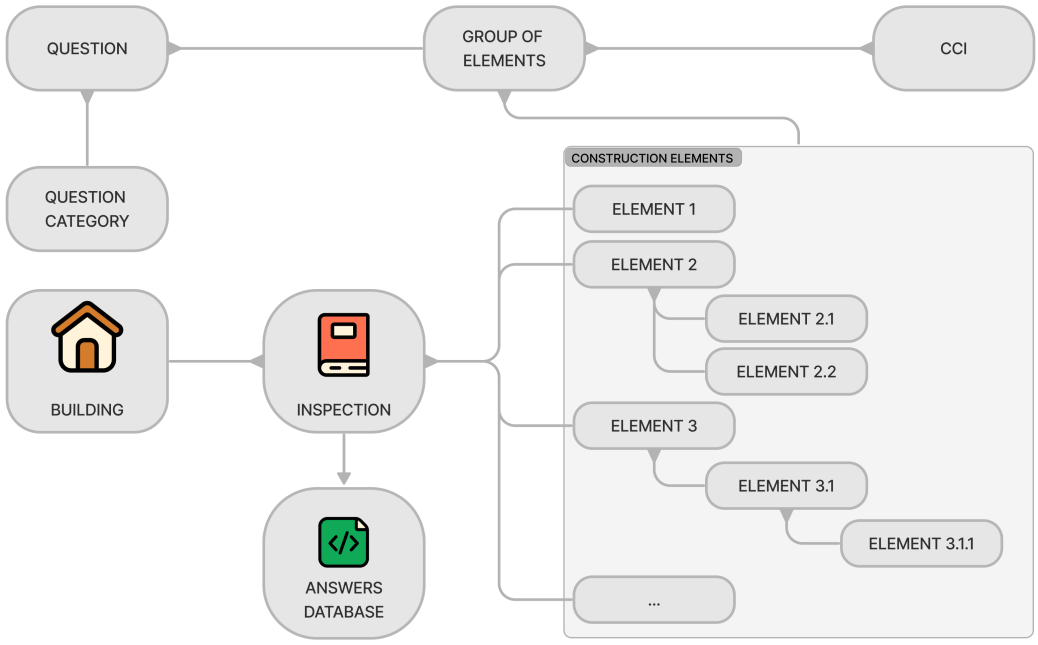


Figure 5. Data structure.

4.3. Users

The application assumes four levels of user access levels:

I System administrator;
II Building stock manager;
III Inspector/technician;
IV Viewer.

The System Administrator plays an integral role in maintaining organizational policies to ensure the integrity of the entire systems. He is responsible for database management, system security, data backup, user management and all the technical issues of the system. He is not a construction engineering professional but someone with a strong IT background.

The building stock manager plays a key role in system management. It is up to him to introduce his building stock to the application. He can designate particular buildings for evaluations. He is the one who can and should design his own inspection templates. He can see all the data for each building in his stock. He can also perform analyses of the collected data.

The inspector is a construction engineering professional or technician, who is performing the inspections on site. He has access to the inspection sheets assigned to him by the building stock manager. He can not define questions in the inspection sheet, however he can add or remove building elements from the inspection sheet.

Viewer can see general information about buildings like basic analyses, spatial distribution of inspected buildings. Viewers can see particular inspection sheets if the access is granted by the manager. For example a viewer can be a resident of a building if he is not playing the role of building stock manager.

4.4. Functionality

The system operates with a four-tier access model, supporting distinct user roles and permission levels. It offers administrative capabilities for managing the database, user accounts, access rights, and overall system configuration. In addition to administrative functions, users can input, modify, and analyze data, as well as conduct inspections. The main application interface is divided into four primary sections: Buildings, Templates, Evaluations, and Analyses. Each section corresponds to a specific area of functionality within the system:

- The Buildings section manages data associated with individual facilities.
- The Templates section allows for the creation and configuration of inspection schemas, including evaluation criteria and scoring logic.
- The Evaluations section allows for the execution of inspections based on selected inspection templates and building data.
- The Analyses section supports post-inspection data processing, and reporting.

To perform an inspection, two conditions must be met: the relevant building must exist in the system, and a suitable inspection template must be selected. Once these prerequisites are satisfied, the inspection process can be initiated. Analytical operations can be performed only after the corresponding inspection data has been collected.

4.4.1. Buildings

In this section, users can manage the building stock by browsing, selecting, and editing individual building records. The user interface is divided into two primary panels: a list of available buildings on the left and an interactive map on the right. Selecting a building triggers the display of a data entry form populated with the building's attributes, which can be edited as needed. Below the form, a historical log of inspections performed

on the selected building is shown. Building data can be entered manually via the form or automatically by selecting an object on the map. In the latter case, the application performs attribute extraction and autofills the form using spatial data from external sources. Specifically, the system integrates with OpenStreetMap and national geoportals to retrieve both attribute data and spatial geometries (e.g., building footprints). All acquired data is standardized and persisted in the FOAM database. This design enables the construction of a unified, inspection-relevant dataset within the FOAM system, ensuring consistency and traceability. Users can iteratively enrich and update this dataset over time. Although data acquisition from multiple external services may introduce latency, centralizing the information in a normalized schema within the FOAM database ensures interoperability, improves query performance, and facilitates further processing and analysis.

4.4.2. Templates

In this section, users can create and browse templates required to define the structure of an inspection form. Each form is composed of Elements, which can be nested in a tree-like structure. One or more Questions can be assigned to each Element. These Questions are linked to a corresponding group of elements, which serves as a higher-level logical unit grouping related to physical components of the building subject to inspection. Example:

Element:	Roof covering
Group of elements:	Roofs and coverings
Questions:	Condition of the covering, Type of covering
Element:	Guttering
Group of elements:	Roofs and coverings
Questions:	Technical condition, Material, Diameter of downspouts

The template creation process begins with defining the Questions, specifying their type (e.g., descriptive, value, scale, likert scale, boolean), assigning them to a Ggoup of elements, categories, and setting codes and weights. Once the Questions are properly defined, they can be associated with the relevant Elements to build a complete inspection template.

This structured approach supports modular and reusable template design, ensuring logical consistency, facilitating data capture during inspections, and enabling advanced analytical workflows such as scoring, reporting, and comparative assessments across inspections.

4.4.3. Evaluations

Once an inspection template has been defined, the user can proceed to perform the inspection. In this section, it is possible to add a new inspection or edit an existing one. When creating a new inspection, the form is initially empty. The user must then add individual Elements to be evaluated and specify the corresponding group of elements to which they belong. Based on this input, the inspection form is automatically populated with the appropriate Questions, grouped and assigned according to the structure defined in the Templates section. The form can be built incrementally during the inspection or prepared in advance. Regardless of the chosen approach, performing an inspection consists of answering the assigned Questions for each Element.

4.4.4. Analyses

In this section, the user can perform analyses based on data collected from inspections. The analytical process begins with selecting a data sample. The selection can be filtered using criteria such as Inspection template, date range, Element, and Function. Alternatively, buildings can be selected directly from the map to define the sample. Once the sample

is defined, the user can proceed to Descriptive analyses or Predictive analyses. The Descriptive analyses module provides an overview of the sample in terms of size, inspection results—both at the overall inspection level and for individual Questions. The data can be reviewed in both tabular and graphical formats.

The predictive analyses module can provide information about the deterioration of building features (technical, functional etc.) based on the models created with historical data and b-spline modeling using generalized estimation equations (GEEs) [24]. It enables more accurate, data-driven decisions by forecasting future outcomes and trends. Additionally, it improves operational efficiency and reduces risks.

5. Case Study

5.1. Scope of the Inspection

Polish law obliges building owners to conduct annual and five-year inspections of the technical condition of a building. In this scope, it is a significant market of professionals involved in performing the inspections. The proposed tool can be of a great help in performing the inspections and maintaining the inspection data. To illustrate practical use, a case study in the city of Olsztyn was prepared. The inspection data was introduced on the basis of existing, traditional inspection sheets supplemented with on-site inspections. For the case study, an eleven-floor residential building was selected. It was raised in 1975 and two consecutive inspections are available—from 22 November 2012 and 8 November 2013. To incorporate these historical inspections and to perform a new one according to Polish annual inspection standards, the appropriate inspection template was created. The scope of the inspection is regulated in general by the Polish law [25], but practical inspection sheets vary among the inspectors. The proposition of the inspection sheet implemented in the application is a product of available sheets (PINB in Ciechanow, PINB of Lublin city, PINB in Bydgoszcz city) and expert knowledge of professionals involved in the project. The inspection structure (elements under evaluation and additional data) is organized as follows:

1. Basic building data:
    (a) Type of construction;
    (b) Building equipment;
    (c) Building characteristics;
    (d) Owner/Manager of the facility.
2. Underground elements of the building/structure:
    (a) Footings/foundation slab; †
    (b) Foundation walls/basement columns †;
    (c) Vertical and horizontal insulation †;
    (d) Service penetrations/pass-throughs †;
    (e) Basement floors †;
    (f) Garage floors †;
    (g) Circulation area floors †;
    (h) Storage room doors †;
    (i) Technical rooms †;
    (j) Driveway ramp to the garage hall †.
3. Roof elements and drainage:
    (a) Roof access †;
    (b) Roof covering †;
    (c) Roof structure †;
    (d) Chimneys above the roof, chimney steps †;

(e) Downspouts, gutters †;
(f) Flashing †;
(g) Devices and installations mounted on the roof †;
(h) Attic, loft †.

4. External elements of the building/structure:
   (a) Exterior walls, cornices †;
   (b) Balconies/loggias/terraces/bays †;
   (c) Plasters, claddings †;
   (d) Devices and installations mounted to walls †;
   (e) Windows †;
   (f) Entrance doors †;
   (g) Entrance/garage gates †;
   (h) Window sills, flashing †;
   (i) External stairs, landings, ramps †;
   (j) External handrails, balustrades †.
5. Internal elements of the building/structure:
   (a) Stairwells, halls, corridors †;
   (b) Floors †;
   (c) Stair flights/ramps †;
   (d) Handrails, balustrades, grips †;
   (e) Doors †;
   (f) Load-bearing walls/columns †;
   (g) Partition walls †;
   (h) Plasters/painting/claddings †;
   (i) Elevator/hoist shaft structure †;
   (j) Ceilings, columns, beams, girders, suspended ceilings †;
   (k) External inspection of chimney shafts †.
6. The owner (manager) presented the following inspection reports:
   (a) Chimney inspection (ventilation, flue gas, smoke ducts);
   (b) Mechanical ventilation;
   (c) Electrical installation;
   (d) Gas installation;
   (e) Sanitary installation;
   (f) Environmental protection installations and equipment;
   (g) General construction.
7. Final information:
   (a) Recommendations;
   (b) Conclusions aimed at eliminating identified irregularities.

The elements marked with † use the following questions:

1. Description of technical condition (text field);
2. Material (text field);
3. Condition grade (Likert scale).

Other elements are specific to their content (such as names, protocol availability and similar). Each construction element can have additional digital objects connected to it, including images (photos, scans, etc.) and recommendations. Recommendations are designed as a tool to allow the inspector to give guides that must be completed to bring the object to the correct condition. The above structure allows for the performance of a complete inspection of a building. It serves as an example of the possible uses of the

application. The entire inspection template was designed inside the application without introducing modifications to the application code.

5.2. Inspection Process and Interacting with the Application

The inspection process begins with logging into the user's account. Each account is assigned a designated user type, which defines the sections of the application that may be accessed (Figure 6). User passwords are stored securely using the PBKDF2 encryption algorithm with SHA256 hash. The user roles are assigned by the system administrator during the registration process.

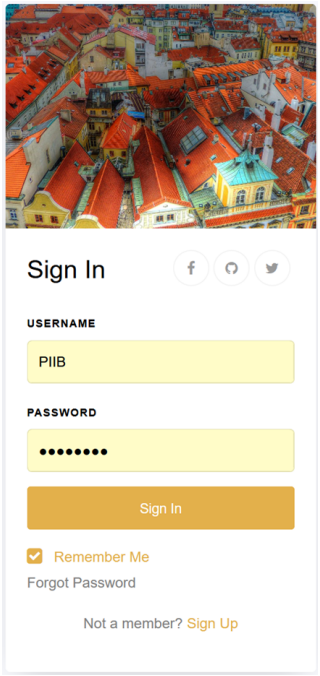
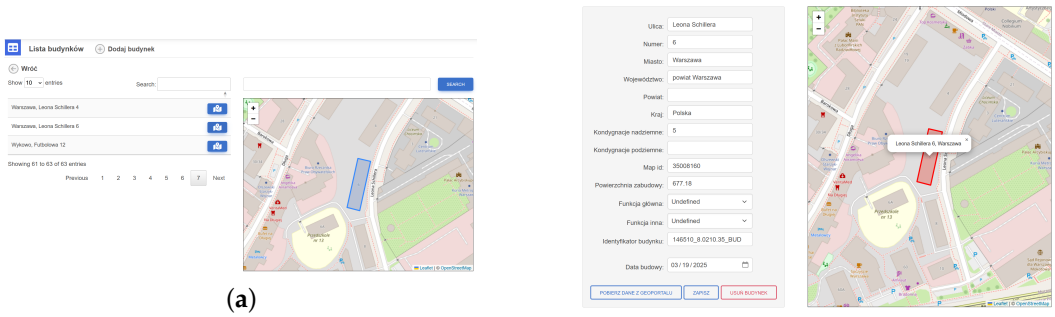


Figure 6. Login window for user authentication.

One of the key features of the platform is its capability to store building stock data. This information is maintained in the application's database and can be updated via an integrated map interface connected to OpenStreetMap. Where available, detailed building data may also be retrieved from publicly accessible, government-maintained data repositories (Figure 7). In Poland, such data can be obtained from the WFS services of the Geoportal application [26]. In this way, the building database maintained by the application can be updated and expanded, ensuring accurate and current inspection activities.



(**a**) (**b**)

Figure 7. User interface for building selection (**a**) and building edit (**b**).

With an up-to-date and properly maintained building stock, building inspections can be performed. Users have the ability to select one of the inspection types previously defined

by the system administrator. Figure 8 depicts the inspection selection interface screen. This image was taken from the version of the platform prepared for the 'beta tests' conducted by professionals in Poland.

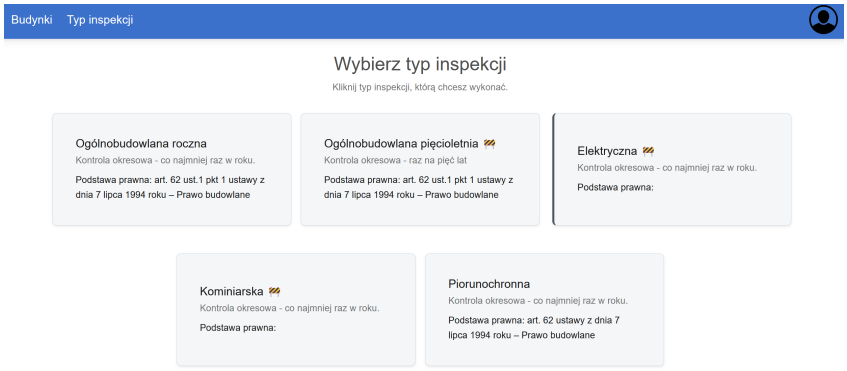
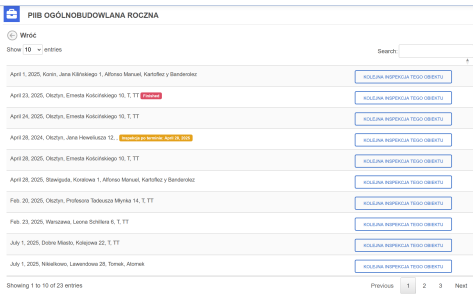
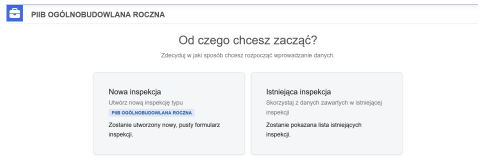


Figure 8. Application interface displaying inspection type choices.

In the next section, the user can view all buildings for which the selected type of inspection can be performed (Figure 9a). After selecting the building, the user has the option to start with an empty inspection sheet or to use data from a previous inspection to streamline and simplify the inspection process and enhance the quality and usability of inspection records (Figure 9b).



(**a**)



(**b**)

Figure 9. User interface for selecting a building for inspection (**a**) and choosing whether to create a new empty inspection or reuse data from a previous inspection of the building (**b**).

Figure 10 illustrates a sample web-based inspection form used for conducting annual general construction inspections of a building located at 6 Leona Schillera Street in Warsaw. The form is designed to systematically assess the structural and functional elements of the building and includes key features such as the inspection date, inspector details, and inspection categories. It is organized into expandable and collapsible sections, for example, basic building data, underground elements, and roof and drainage elements. Within each section, specific components are listed; for instance, the roof and drainage category comprises the exit to the roof ("Wyjście na dach"), roof coverings ("Dach–pokrycie"), roof structure ("Dach–konstrukcja"), chimneys above the roof and smoke ducts ("Kominy ponad dachem, ławy kominiarskie"), downpipes and gutters ("Rury spustowe, rynny"), roof fittings ("Obróbki"), as well as equipment and installations mounted on the roof ("Urządzenia i instalacje zamocowane do dachu"). For each item, the inspector may provide a technical description, information on materials, and a technical condition rating using a color-coded 1–4 scale, accompanied by a textual summary. Furthermore, the form enables the addition of recommendations ("Zalecenia") and photographs ("Zdjęcie"), with icons indicating the presence of such attachments.

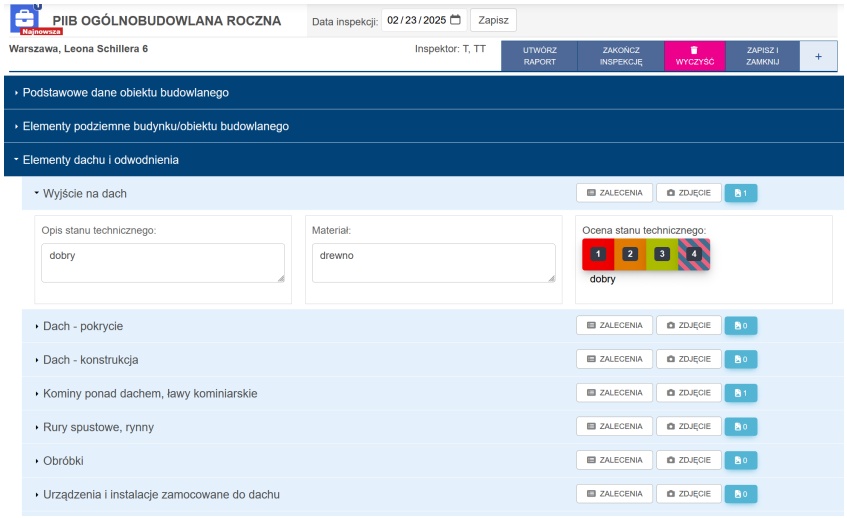


Figure 10. Detailed inspection view displaying the elements and the questions associated with them.

Figure 11 presents an example of a system-generated form used to visualize the results of a technical condition assessment of a building. The form refers to the inspection of a facility located at 14 Profesora Tadeusza Młynka Street in Olsztyn, conducted on 20 February 2025. The interface integrates graphical tools for presenting the aggregated evaluation of structural and functional components. On the left, a radar chart illustrates the distribution of ratings across four predefined categories of technical condition (niedostateczny, dostateczny, dobry, zadowalający), enabling a synthetic overview of the building's state. On the right, a bar chart quantifies the frequency of assessments assigned to individual categories, thus providing a clear comparative representation of evaluation outcomes. In the example shown, the majority of elements are classified as being in "good" condition, with fewer ratings in the "satisfactory" and "sufficient" categories, and only a minor share identified as "insufficient". The combined use of radar and bar charts facilitates both a holistic and detailed interpretation of the results, thereby supporting the decision-making process in the context of construction safety, maintenance planning, and long-term monitoring.

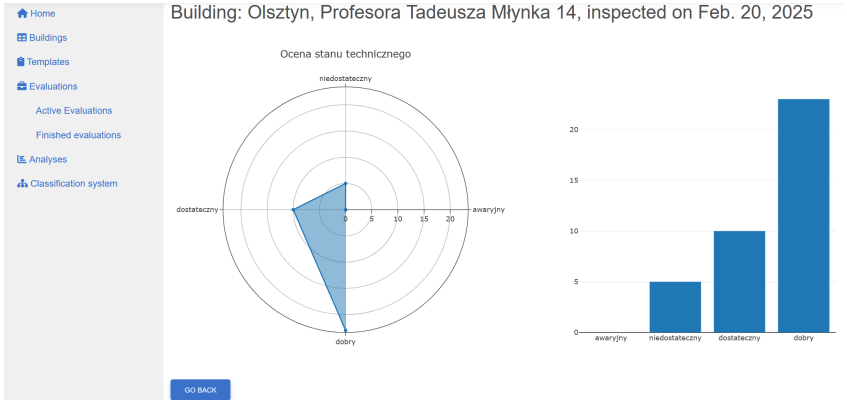
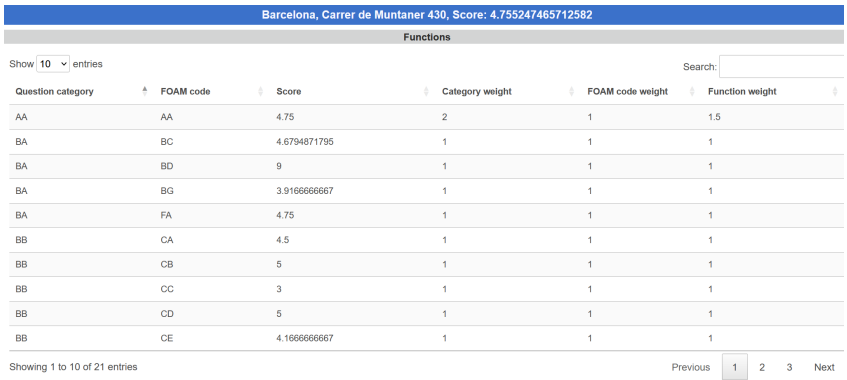


Figure 11. Graphical representation of the technical condition assessment of a building within the created inspection system.

Figure 12 presents a system-generated form illustrating the functional assessment of a building located at Carrer de Muntaner 430 in Barcelona. The table displayed in the interface contains a structured summary of the scoring process based on predefined question categories and FOAM codes. Each row represents an individual functional element, with columns specifying the question category, FOAM code, obtained score, and corresponding weights (category weight, FOAM code weight, and function weight). This structure enables

the transparent presentation of both the raw scores and the weighting factors applied in the aggregation procedure. Such an arrangement facilitates the traceability of the final result, allowing users to verify how individual elements and categories contribute to the global score. The interactive format of the table, including sorting, searching, and pagination functionalities, supports efficient navigation and analysis of the dataset. The form thus constitutes an integral component of the developed system, enhancing both the interpretability and reproducibility of the building evaluation process.


Barcelona, Carrer de Muntaner 430, Score: 4.755247465712582

Functions

Show 10 entries Search:

Question category	FOAM code	Score	Category weight	FOAM code weight	Function weight
AA	AA	4.75	2	1	1.5
BA	BC	4.6794871795	1	1	1
BA	BD	9	1	1	1
BA	BG	3.9166666667	1	1	1
BA	FA	4.75	1	1	1
BB	CA	4.5	1	1	1
BB	CB	5	1	1	1
BB	CC	3	1	1	1
BB	CD	5	1	1	1
BB	CE	4.1666666667	1	1	1

Showing 1 to 10 of 21 entries Previous 1 2 3 Next

Figure 12. Tabular representation of functional assessment scores and weighting factors within the building evaluation system.

5.3. Predictive Analyses-FOAM Implementation

The predictive analysis within FOAM relies on a population-averaged longitudinal model implemented through generalized estimating equations (GEEs). This approach accounts for temporal autocorrelation in repeated inspections of the same building elements by employing an autoregressive AR(1) correlation structure. The response variable is the time-dependent Functional Condition Index FCI(t), expressed on a 0–100 % scale, which quantifies the capability of a construction element to perform its intended function throughout its life cycle. Under the assumption of no intervention, the functional condition index $FCI(t)$ follows a non-increasing trend, with 100% representing the maximum functional condition at the initial moment (commissioning) and declining throughout its service life. The index evaluates the fundamental capacity of elements as determined by their original design, irrespective of user preferences, evolving regulatory requirements, or technological advancements. The estimator for the functional condition index associated with an element e_{ijk} and a function f^{rs}, denoted as $\hat{FCI}^{rs}_{ijk}(t)$, is defined as follows:

$$\hat{FCI}^{rs}_{ijk}(t) = \frac{100 \cdot \left(FCAQ^{rs}_{ijk}(t) - 1 \right)}{9} \quad (1)$$

where $FCAQ^{rs}_{ijk}(t)$ is the Likert-type score assigned during the inspection process. To capture the nonlinear nature of functional degradation, the mean loss-of-function profiles are modeled using a cubic B-spline basis. Knot placement is determined adaptively through a Kernel Density Estimate (KDE) of the data distribution, allowing the model to flexibly fit different degradation trajectories while maintaining smoothness and stability. The fitted model produces point predictions of the mean degradation trajectory along with their 95% confidence intervals, thereby quantifying the uncertainty of the estimates. Model performance and predictive accuracy were validated through standard diagnostic and evaluation metrics:

- EstBias. The sample mean bias is approximately zero (mean = −0.048, 95% CI (−0.158, 0.061)), which demonstrates the desirable unbiased property of the proposed estimator.

- Error. The estimated mean half-length of the 95% probability interval is 3.50 percentage points (95% CI (3.444, 3.545)).
- RMSE. The resulting RMSE is 2.83 (95% CI (2.784, 2.884)). As a joint measure of estimator accuracy and variability, the RMSE remains limited in magnitude for most scenarios.
- Coverage. The median coverage (0.899) is close to the nominal design level (0.95) for many scenarios, but the mean (0.670) and the first quartile (0.289) reveal substantial dispersion.

Since the process of collecting real degradation data is inherently long-term, no sufficient longitudinal inspection dataset was available to directly verify the FOAM predictive performance during application development. Therefore, the model was evaluated using a Monte-Carlo-like simulation framework to assess its stability and robustness under varying data conditions. The complete simulation code is available in the accompanying GitHub repository for reproducibility (https://github.com/jacekrapinski/foam.git, accessed on 12 November 2025). This open access repository ensures that the modeling and validation process is transparent and independently verifiable. To illustrate the operation and interpretability of the predictive framework, Figure 13 presents an example outcome from one of the simulated scenarios.

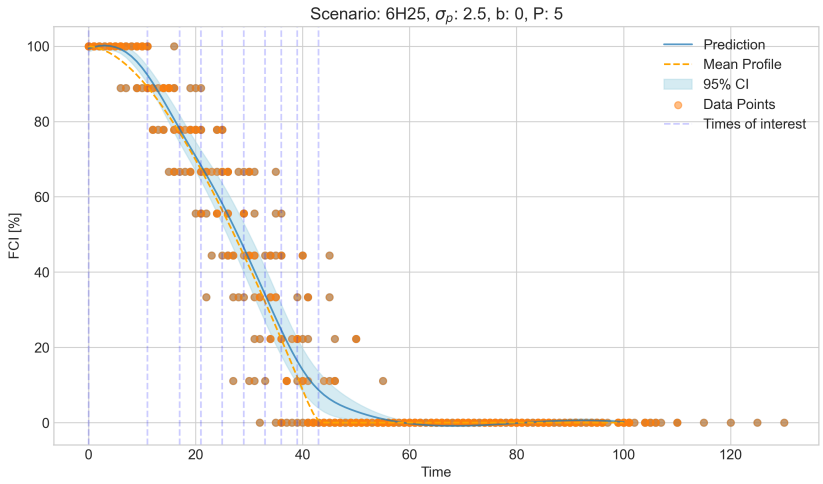


Figure 13. Estimated population-level functional condition curve and 95% confidence interval band based on a single simulation.

Figure 13 presents an example of the simulated degradation process and the corresponding predictive performance of the B-spline model fitted using GEE.

The orange dots represent individual inspection ratings converted to the continuous Functional Condition Index (FCI) scale ranging from 0% to 100%. Each dot corresponds to a single inspector's assessment simulated within the Monte Carlo framework. These discrete observations emulate real-world inspection data, reflecting random variability and subjectivity in expert judgment.

The dashed orange curve ("Mean Profile") denotes the true degradation trajectory of the modeled element—one of the reference functions used to generate the simulated inspection responses. It illustrates the theoretical decline in functional condition over time, with a smooth nonlinear transition from full functionality (FCI = 100%) to complete degradation (FCI = 0%).

The solid blue line ("Prediction") represents the B-spline model fitted using GEE to the simulated inspection data. This line demonstrates how the predictive model captures the overall degradation trend while compensating for the randomness and dispersion of individual inspector ratings. The close alignment between the blue prediction line and the cloud of orange points confirms the high accuracy and stability of the model estimation.

The light-blue-shaded area around the prediction line corresponds to the 95% confidence interval (CI) of the predicted population mean. It quantifies the uncertainty associated with the estimation of the mean degradation path. The narrow width of the CI across most of the time range indicates strong precision and reliable predictive consistency. The interval widens slightly near the end of the service life, where the number of available data points decreases—a natural effect in time-to-failure modeling.

The vertical dashed purple lines indicate the times of interest (T-F) at which model evaluation metrics (e.g., RMSE, bias, coverage) were computed. These checkpoints are evenly distributed across the degradation process and serve as reference positions for validation.

Overall, Figure 13 clearly demonstrates the accuracy of the predictive framework. The model successfully reproduces the underlying degradation pattern and produces statistically well-calibrated predictions. The strong agreement between the simulated data, the true degradation curve, and the model prediction confirms that the GEE + B-spline approach can reliably generalize the behavior of functionally degrading components based on noisy, inspection-based input data.

5.4. Comparison with Other Web-Based Inspections Systems

As mentioned in the introduction, several web-based inspection applications are available to support both the construction phase and subsequent stages of a building's life cycle. Among the most popular are PlanRadar, ArchiSnapper, and Fieldwire. Although these platforms share certain similarities, their functionality and intended use differ, as each has been developed with emphasis on distinct aspects of the construction and maintenance process.

PlanRadar is primarily designed for building-condition inspections and comprehensive documentation management. It offers integration with Building Information Modeling (BIM), 360° imagery, and the ability to link observations directly to digital plans or models. The platform is particularly suitable for detailed condition surveys, lifecycle management, and facility handover inspections, providing robust support for documentation, verification, and progress tracking over time.

ArchiSnapper focuses on streamlining on-site inspections and report generation. It allows users to capture condition issues, perform site walkthroughs, create punch lists, and generate standardized reports directly from the field. Compared to PlanRadar, it places greater emphasis on inspection and reporting efficiency while offering limited functionality related to full BIM integration or long-term facility management.

Fieldwire is oriented toward on-site project coordination, integrating inspection workflows within construction and maintenance operations. It excels in environments where inspections are directly linked to task management, trade coordination, and issue tracking. While it can be adapted for condition surveys, its strength lies in supporting collaborative construction management and translating inspection findings into actionable tasks and remedial actions.

In contrast with the above-mentioned commercial systems, FastFoam offers a higher level of flexibility and analytical depth. The platform allows users to create completely customized inspection templates and reporting schemas without modifying the application's source code. This means that both the structure of the inspection protocol and the logic of scoring or evaluation can be adapted to any regulatory environment or engineering practice. Unlike tools that rely on fixed form structures, FastFoam enables dynamic definition of elements, questions, and evaluation rules, supporting a true function-oriented workflow. In addition, the system integrates descriptive and predictive analytics within the same environment, using both empirical data and simulation-based models to support decision-making. Its built-in FOAM (Function-Oriented Assessment Methodology) module enables not only static condition reporting but also trend and deterioration analysis over time,

based on generalized estimation equations (GEEs) and B-spline modeling. The analytical module supports comprehensive metrics, such as predictive fit and coverage, facilitating model calibration and validation.

The novelty of this approach lies in the integration of predictive analytics and function-oriented assessment within a fully configurable, web-based inspection framework. Unlike existing platforms, which typically separate condition documentation from analytical modeling, FastFoam unifies both processes in a single architecture. This combination allows users to move seamlessly from data collection to predictive assessment, transforming inspection results into quantitative forecasts of functional degradation. Furthermore, by linking inspection logic directly with classification systems (e.g., CCI) and geospatial data sources (e.g., OpenStreetMap or BIM models), FastFoam extends traditional inspection software toward a research-grade analytical environment that supports standardization, interoperability, and long-term infrastructure monitoring. Finally, FastFoam includes advanced reporting tools that enable inspectors and managers to generate detailed, publication-ready summaries, export results, and visualize performance through tabular and graphical dashboards. The combination of open architecture, multi-level user management, and full integration with external data sources makes FastFoam a versatile and extensible platform for both operational inspections and scientific research in building condition assessment.

6. Discussion and Limitations

The development and initial deployment of the FastFoam system demonstrate the feasibility of a flexible, web-based platform for managing building inspections and condition assessments. The system addresses key needs identified through user surveys, particularly in terms of template customization, data structuring, and digital workflow integration. Feedback collected during testing with engineering professionals confirmed the usability and relevance of the system in real-world inspection scenarios.

Despite these strengths, several limitations should be acknowledged. First, the current implementation relies on constant internet connectivity, which may hinder usability in field conditions with limited or unstable network access. The lack of an offline mode is a significant drawback noted during pilot testing. A mobile version with offline capabilities is planned for future development to address this limitation.

A further limitation is the scope of evaluation. The pilot involved a relatively small group of professionals, and the collected feedback was mostly qualitative. Future evaluations should include a broader user base and incorporate quantitative metrics such as time efficiency, error rates, and data completeness.

The system currently enables users to perform various types of analyses on collected inspection data. The analytical capability represents a key strength of the platform. For the FOAM methodology, predictive analyses are also available. Users can obtain tabular data and plots about building assets of their choice, enabling data-driven decision making.

Finally, while privacy and data protection were considered during development, the system has not yet undergone formal legal certification (e.g., GDPR compliance audits). International deployment will require ongoing review to align with regional regulations and data handling standards.

While the preceding discussion outlines the principal limitations, it is also essential to consider the broader theoretical and practical implications of the presented approach. The FOAM methodology and the FastFoam system represent a shift towards function-oriented and predictive assessment in building inspections, moving beyond descriptive and checklist-based practices common in existing commercial and academic tools. By supporting temporal modeling and scenario analysis, the system enables stakeholders to

anticipate future condition trends, optimize maintenance planning, and support long-term investment decisions, potentially improving lifecycle management for building assets.

From a theoretical standpoint, the use of B-spline modeling with generalized estimating equations offers an innovative solution for handling longitudinal inspection data. However, this methodology also entails several challenges, including sensitivity to the choice of knot positions in spline estimation and assumptions regarding the correlation structure in GEE. A critical reflection reveals that, while these methods are statistically rigorous, their application in practical settings depends on the availability of high-quality and frequent inspection data, which may not always be attainable in real-world deployments.

In comparison with pre-existing approaches, the FastFoam system distinguishes itself by its modularity, openness, and adaptability to diverse regulatory environments. However, unlike some established commercial platforms, it is still undergoing extensive field validation and lacks certain features such as offline operation and full-scale AI-driven defect recognition. Furthermore, while the current system architecture supports integration with BIM and GIS data sources, the actual degree of interoperability with legacy industry solutions remains to be systematically benchmarked. In summary, while FastFoam provides an advanced, flexible tool for predictive analytics in building inspections, its methodology should be considered in light of both the strengths and limitations inherent to advanced statistical modeling and the practical realities of data availability and system integration in the construction sector.

Pilot Testing with Civil Engineering Professionals

To evaluate the practical usability and effectiveness of the FastFoam system, a group of civil engineering professionals was invited to use the application in real-world inspection scenarios. Participants were asked to perform an on-site inspection of a selected building using a tablet device with internet access and then provide structured feedback.

All participants were professionals in the field of civil engineering and conducted inspections of construction facilities as part of their professional work. This means the group consisted of experienced engineers who regularly assess the technical condition of buildings and carry out specialized inspections related to structural safety and compliance with building regulations. Therefore, their observations and conclusions held high substantive value and practical significance for the construction industry. The evaluation process included a questionnaire divided into four main categories:

1. Completeness and relevance of the inspection form;
2. General user experience and interface usability;
3. Open-ended comments and observations;
4. Missing or desired features.

The survey aimed to identify potential usability issues, functional gaps, and opportunities for improvement from the perspective of end users. Participants generally confirmed that the application interface was clear and intuitive, and that the logic of inspection template creation aligned with professional workflows. Ten professionals participated in the hands-on session with the application.

Key feedback included positive responses regarding the clarity of the application layout, benefits from online data access, and centralized storage of inspection data. Professionals emphasized that a key added value is the application's ability to store data in one centralized location. Some users expressed a need for additional, field-specific templates, as well as an offline mode for use in areas with poor connectivity.

Insights gathered during the pilot were incorporated into the next development cycle and informed planned improvements to the mobile interface.

7. Conclusions

This paper presented the FastFoam system—a flexible, modular, and web-based tool designed to support civil engineers and facility managers in conducting structured building inspections. The system enables the creation and reuse of inspection templates, storage of standardized data in a centralized database, and user role management across an intuitive, browser-accessible interface.

The system was developed in response to specific needs identified in a professional survey, and further validated through pilot testing in real-world conditions. The implementation includes integration with geospatial and classification data sources, and supports extensibility through its modular architecture and open interfaces.

A distinguishing feature of FastFoam is the implementation of the FOAM methodology, which lays the groundwork for performing both descriptive and predictive analyses of building conditions over time. Analyses based on FOAM support better cost planning, investment optimization, and preventive maintenance. They enable a comprehensive assessment of the entire lifecycle of an asset—from design and operation to decommissioning. This supports better cost planning, investment optimization, and data-driven decision-making. Moreover, FOAM facilitates preventive maintenance planning, helping to reduce failures, minimize downtime, and improve overall system reliability. Risk classification, as part of the FOAM approach, allows organizations to identify, evaluate, and prioritize potential threats, leading to more informed decisions regarding safety and operational continuity. Implementing FOAM-based analyses enhances operational efficiency, lowers maintenance costs, and promotes a more strategic approach to infrastructure management. The novelty of the FastFoam approach lies in the seamless integration of function-oriented assessment and predictive analytics within a single, fully configurable web-based environment. Unlike conventional inspection tools that focus solely on documentation or reporting, FastFoam unifies data acquisition, temporal modeling, and analytical interpretation, thereby transforming inspection data into actionable predictive insights.

While the system is already functional and in use, several enhancements are planned, including the addition of offline mobile capabilities, deeper BIM integration, and automated data analysis tools. In future work, further user testing and benchmarking are expected to validate performance and usability at scale. FastFoam represents a step toward standardized, intelligent inspection tools that can adapt to local regulations while supporting long-term digital transformation in the construction and facility management sectors.

8. Future Work

The FastFoam system presented in this study demonstrates the feasibility and practicality of a web-based, data-driven approach to building inspections. However, there are several directions for future development that can enhance its usability, scalability, and applicability in broader contexts.

8.1. Integration with Artificial Intelligence

One of the most promising areas for further enhancement is the integration of artificial intelligence (AI) techniques. Image recognition algorithms could be used to automatically detect and classify structural defects from photos taken during inspections. Additionally, AI-driven predictive models may assist in estimating the remaining service life of building elements or forecasting maintenance needs based on historical inspection data [27].

8.2. UAV-Based and Remote Monitoring

Future versions of the system could incorporate data collected via unmanned aerial vehicles (UAVs) to support remote structural assessments. Such methods offer rapid, high-resolution inspection capabilities in hard-to-reach areas [28].

8.3. IoT and Real-Time Monitoring

Integration with IoT (Internet of Things) sensors, such as temperature, humidity, or vibration devices, could provide real-time data streams to support continuous monitoring and early-warning systems for infrastructure management [29].

8.4. BIM Integration and Standardization

Although FastFoam currently offers a basic interface for integration with BIM (Building Information Modeling), further efforts will focus on deeper interoperability with standardized formats (e.g., IFC). This will support automated linking of inspection data with digital building models, improving lifecycle documentation and regulatory compliance [29].

8.5. Internationalization and Legal Adaptability

The FastFoam system was developed as part of a collaborative effort between the University of Warmia and Mazury in Olsztyn and the Universitat Politècnica de Catalunya, with the explicit goal of supporting international applicability. From the outset, the system's architecture was designed to be flexible and adaptable to a wide range of national requirements, legal norms, and classification systems.

8.6. Mobile Application and Offline Mode

While the current version of the system is fully web-based, feedback from users suggests that an offline-capable mobile application would be highly valuable, especially for fieldwork in areas with limited internet connectivity. A native mobile client is planned to enhance usability in such scenarios.

8.7. Open Data and Interoperability

To support the principles of open science and enhance the reproducibility of research, future versions of the system will include a function for exporting structured and anonymized inspection data. This feature will enable researchers, policymakers, and industry professionals to perform cross-sectional benchmarking, develop evidence-based maintenance strategies, and conduct large-scale academic studies on building infrastructure and technical condition trends [30].

Author Contributions: Conceptualization, J.R., M.B., D.T., A.S.-S., T.T., J.Z., V.R. and C.S.; methodology, J.R., M.B., D.T., A.S.-S., T.T., J.Z., V.R. and C.S.; software, J.R. and M.B.; validation, J.R., M.B., V.R. and C.S.; formal analysis, J.R., M.B., D.T., V.R. and C.S.; investigation, J.R., M.B., D.T., A.S.-S., T.T., J.Z., V.R. and C.S.; resources, J.Z., V.R. and C.S.; data curation, J.R., M.B., D.T., V.R. and C.S.; writing—original draft preparation, J.R., M.B., D.T., V.R. and C.S.; writing—review and editing, D.T. and V.R.; visualization, J.R., M.B., D.T., A.S.-S., T.T., J.Z., V.R. and C.S.; supervision, J.R., V.R. and C.S.; project administration, J.R. and C.S.; funding acquisition, J.R., M.B. and D.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research has been partially funded by the National Center for Research and Development (Poland) under the Innoglobo framework [INNOGLOBO/I/84/FOAM/2022], by the Departament de Recerca i Universitats de la Generalitat de Catalunya (Spain) [2021 SGR 01421 (GRBIO)], and by the GREiP UPC research group (Spain).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to the fact that they are not externally available.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Li, Y.; Chen, X.; Wang, X.; Xu, Y.; Chen, P.H. A review of studies on green building assessment methods by comparative analysis. *Energy Build.* **2017**, *146*, 152–159. [CrossRef]
2. Alyami, S.H.; Rezgui, Y. Sustainable building assessment tool development approach. *Sustain. Cities Soc.* **2012**, *5*, 52–62. [CrossRef]
3. De Wilde, P. *Building Performance Analysis*; John Wiley & Sons: Hoboken, NJ, USA, 2018. [CrossRef]
4. Zamzam, A.H.; Abdul Wahab, A.K.; Azizan, M.M.; Satapathy, S.C.; Lai, K.W.; Hasikin, K. A systematic review of medical equipment reliability assessment in improving the quality of healthcare services. *Front. Public Health* **2021**, *9*, 753951. [CrossRef] [PubMed]
5. Valdes, M.E.; Cunningham, K. The New National Fire Protection Association 70B-2023 Standard for Electrical Maintenance: The Major Points and Primary Intent. *IEEE Ind. Appl. Mag.* **2023**, *30*, 23–33. [CrossRef]
6. World Health Organization. Medical equipment maintenance programme overview. In *Medical Equipment Maintenance Programme Overview*; World Health Organization: Geneva, Switzerland, 2011.
7. Royano, V.; Gibert, V.; Serrat, C.; Rapinski, J. Analysis of classification systems for the built environment: Historical perspective, comprehensive review and discussion. *J. Build. Eng.* **2023**, *67*, 105911. [CrossRef]
8. *ISO 15686-1:2011*; Buildings and Constructed Assets—Service-Life Planning—Part 1: General Principles and Framework. International Organization for Standardization: Geneva, Switzerland, 2011.
9. Faqih, F.; Zayed, T. Defect-based building condition assessment. *Build. Environ.* **2021**, *191*, 107575. [CrossRef]
10. Howard, R. Classification of building information—European and IT systems. In Proceedings of the CIB-W78 International Conference: IT in Construction in Africa, Mpumalanga, South Africa, 30 May–1 June 2001; pp. 9–14.
11. Afsari, K.; Eastman, C.M. A comparison of construction classification systems used for classifying building product models. In Proceedings of the 52nd ASC Annual International Conference, Provo, UT, USA, 13–16 April 2016; Volume 10. [CrossRef]
12. Saleeb, N.; Marzouk, M.; Atteya, U. A comparative suitability study between classification systems for BIM in heritage. In *Building Information Systems in the Construction Industry*; MIT Press: Cambridge, MA, USA, 2018; Volume 137. [CrossRef]
13. Biscaya, S.; Tah, J.H.M. A literature review on information coordination in construction. In Proceedings of the Seventh International Postgraduate Research Conference in the Built and Human Environment, Salford Quays, UK, 28–29 March 2007; pp. 192–198.
14. Ekholm, A.; Häggström, L. Building classification for BIM—Reconsidering the framework. In Proceedings of the CIB W78-W102 2011, Sophia Antipolis, France, 26 October 2011.
15. Lou, E.C.W.; Goulding, J.S. Building and Construction Classification Systems. *Archit. Eng. Des. Manag.* **2008**, *4*, 206–220. [CrossRef]
16. Grussing, M.; Liu, L. Knowledge-Based Optimization of Building Maintenance, Repair, and Renovation Activities to Improve Facility Life Cycle Investments. *J. Perform. Constr. Facil.* **2014**, *28*, 539–548. [CrossRef]
17. Melgaard, S.P.; Andersen, K.H.; Marszal-Pomianowska, A.; Jensen, R.L.; Heiselberg, P.K. Fault detection and diagnosis encyclopedia for building systems: A systematic review. *Energies* **2022**, *15*, 4366. [CrossRef]
18. Royano, V.; Gibert, V.; Serrat, C.; Rapinski, J. Toward an innovative function-oriented assessment methodology (FOAM) for evaluating the functional condition of buildings during the operation and maintenance phase. *Dev. Built Environ.* **2024**, *20*, 100548. [CrossRef]
19. Grinberger, A.Y.; Minghini, M.; Juhász, L.; Yeboah, G.; Mooney, P. OSM Science—The Academic Study of the OpenStreetMap Project, Data, Contributors, Community, and Applications. *ISPRS Int. J. Geo-Inf.* **2022**, *11*, 230. [CrossRef]
20. Amrouni Hosseini, M.; Ravanshadnia, M.; Rahimzadegan, M.; Ramezani, S. Next-generation building condition assessment: BIM and neural network integration. *J. Perform. Constr. Facil.* **2024**, *38*, 04024050. [CrossRef]
21. Bajno, D. Metody diagnostyki konstrukcji obiektów budowlanych oraz ustalanie stopnia ich zużycia technicznego. *Izolacje* **2021**, *26*, 40–46.
22. BuildingSMART Association Web Page. Klasyfikacja CCI-PL. 2024. Available online: https://klasyfipedia.org.pl/ (accessed on 29 April 2024).
23. Zabielski, J.; Szafranko, E. Wybrane problemy oceny stanu technicznego obiektów budowlanych w świetle obowiązującego prawa i stosowanej metodyki. *Przegląd Bud.* **2021**, *92*, 108–112.

24. Ballinger, G.A. Using generalized estimating equations for longitudinal data analysis. *Organ. Res. Methods* **2004**, *7*, 127–150. [CrossRef]
25. Sejm Rzeczypospolitej Polskiej. Ustawa z Dnia 7 Lipca 1994 r.—Prawo Budowlane. Dziennik Ustaw, 1994, nr 89, poz. 414 z późn. zm. 1994. Available online: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu19940890414 (accessed on 12 November 2025).
26. Główny Urząd Geodezji i Kartografii. Geoportal Krajowy. 2025. Available online: https://www.geoportal.gov.pl (accessed on 28 August 2025).
27. Plevris, V.; Papazafeiropoulos, G. AI in Structural Health Monitoring for Infrastructure Maintenance and Safety. *Infrastructures* **2024**, *9*, 225. [CrossRef]
28. Villarino, A.; Valenzuela, H.; Antón, N.; Domínguez, M.; Méndez Cubillos, X. UAV Applications for Monitoring and Management of Civil Infrastructures. *Infrastructures* **2025**, *10*, 106. [CrossRef]
29. Mannino, A.; Dejaco, M.C.; Re Cecconi, F. Building Information Modelling and Internet of Things Integration for Facility Management—Literature Review and Future Needs. *Appl. Sci.* **2021**, *11*, 3062. [CrossRef]
30. Kitchin, R. The real-time city? Big data and smart urbanism. *GeoJournal* **2014**, *79*, 1–14. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.