2026 European Conference on Computing in Construction
Corfu, Greece
July 12-15, 2026

TOWARDS AUTOMATED BUILDING MAINTENANCE AND RENOVATION: A MULTI-AGENT LLM-BASED APPROACH

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Abstract

This study presents a multi-agent AI framework for automating building maintenance and renovation recommendations. Given inputs such as building location, type, and reported issues, a task identification agent classifies cases as maintenance or renovation. A knowledge agent retrieves and interprets relevant building codes, standards, and guidelines, while a solution generation agent produces maintenance recommendations, renovation strategies, or compliance assessments. By integrating task classification, regulation interpretation, and recommendation generation through large language models (LLMs), the framework automates key decision-making processes traditionally performed by human experts.

Introduction

Europe's building stock is ageing, with over 40% constructed before the 1960s, and the sector accounts for more than 40% of final energy consumption and 36% of greenhouse gas emissions (European Parliament, 2016; Vendel et al., 2025). As a result, the Repair, Maintenance and Improvement (RM&I) sector is identified as a key growth area (Gov.UK, 2025). Building maintenance and renovation are knowledge-intensive processes requiring integration of fragmented information from multiple sources. While digital technologies such as BIM and AR improve data accessibility, they remain largely data-driven and lack the ability to capture and reason over regulations, standards, and expert knowledge.

To address this gap, this study proposes a multi-agent LLM-based framework for maintenance and renovation decision-making. The framework decomposes complex tasks into specialised agents, including task identification, knowledge retrieval, and solution generation. By coordinating these agents, it enables context-aware and structured decision workflows, supporting more intelligent and efficient maintenance and renovation processes.

Methodology

This study proposes a multi-agent LLM-based framework for automated maintenance and renovation decision-making in buildings. Figure 1 presents the workflow of the proposed multi-agent framework for enhanced building maintenance and renovation decision-making.

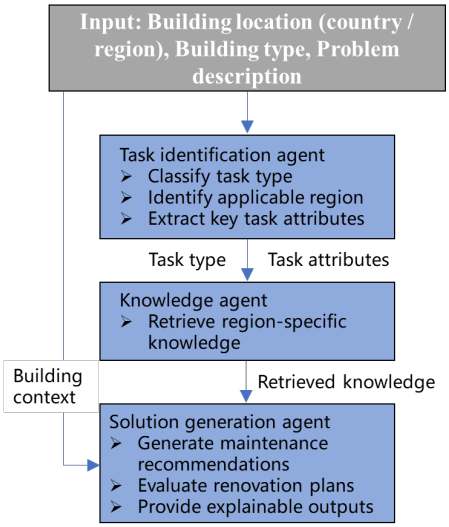

Figure 1: Workflow of the proposed multi-agent LLMs

Case study

The case study focuses on a heritage building located in Poland, originally constructed in 1928. As a historically protected structure, the building presents typical challenges associated with ageing construction, including material deterioration and constraints imposed by conservation requirements.

LLM agent development

The proposed multi-agent framework is implemented using the GPT-4o large language model, which serves as the core reasoning engine for all agents. GPT-4o was selected due to its strong capability in understanding technical text, handling contextual information, and generating coherent and explainable outputs (Dai et al., 2025).

Results

Maintenance recommendation

Table 1 summarizes the outputs of the task identification agent and the solution generation agent for the façade crack maintenance scenario.

Based on these outputs, the solution generation agent produces corresponding maintenance recommendations that prioritise minimal intervention and material compatibility.

Table 1: Maintenance recommendation for façade cracks (heritage building)

Agent	Results
Task identification agent	Task type: Maintenance (façade condition) Context: Heritage building in Poland (likely protected/subject to conservator oversight) Observed issue: Surface cracks + local material degradation on external wall/facade (image-supported) Decision constraint: Minimal intervention, reversible where possible, retain historic fabric; ensure traceability of actions and rationale (documentation)
Solution generation agent	(1) Immediate, low-intrusion actions Condition recording and baseline survey: photo log, crack mapping (location, length, width), and date-stamped documentation before any intervention. Traceability basis: conservation actions should be documented; maintaining best possible condition requires evidence-based monitoring. (2) Heritage-compatible repair measures Localized plaster/finish repair using compatible materials (e.g., lime-based where historically appropriate; avoid hard cement-rich patches that can trap moisture and accelerate decay). If cracks indicate structural instability: prioritize stabilization measures designed to minimize loss of historic fabric (e.g., local reinforcement only where necessary, reversible techniques where possible).

Limitations and Future Directions

Despite the promising results, this study has several limitations. First, the proposed framework relies on the reasoning capabilities of LLMs. Although it's effective for interpreting unstructured regulatory text and contextual information, it does not replace formal regulatory approval or expert judgement. The generated maintenance recommendations and renovation compliance assessments are intended to support early-stage decision-making rather than serve as definitive or legally binding conclusions. In addition, the evaluation is based on a single heritage building case study, and broader validation across different building types, regulatory contexts, and levels of data availability is required to further assess generalisability.

Future work will focus on extending the framework in several directions. Additional case studies across multiple regions and building typologies will be conducted to evaluate scalability and robustness. Moreover, future research will explore tighter coupling between LLM-based agents and quantitative analysis modules, such as structural assessment using numerical simulation or energy performance evaluation, as well as the incorporation of human feedback to support iterative and collaborative decision-making in maintenance and renovation workflows.

Conclusions

This paper presents a multi-agent LLM-based framework to support building maintenance and renovation decision-making, with a focus on heritage buildings. By decomposing complex tasks into specialised agents for task identification, knowledge handling, and solution generation, the approach enables structured and explainable decision support, addressing the challenge of integrating domain knowledge into current workflows.

Acknowledgement

This study was supported by the EU-funded INHERIT project (Project ID: 101123326): Next Generation Solutions for Sustainable, Inclusive, Resource-efficient and Resilient Cultural Heritage.

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