

Article

Evaluating Modular House Construction Projects: A Delphi Method Enhanced by Conversational AI

Augustinas Maceika ^{1,†} , Andrej Bugajev ^{2,*}  and Olga R. Šostak ^{2,†}

¹ The Faculty of Mechanics, Vilnius Gediminas Technical University, Sauletekio Ave. 11, LT-10223 Vilnius, Lithuania; augustinas.maceika@vilniustech.lt

² The Faculty of Fundamental Sciences, Vilnius Gediminas Technical University, Sauletekio Ave. 11, LT-10223 Vilnius, Lithuania; olga-regina.sostak@vilniustech.lt

* Correspondence: andrej.bugajev@vilniustech.lt

† These authors contributed equally to this work.

Abstract: This study focuses on evaluating modular house construction projects, which is a critical segment within sustainable building practices. Despite the significant advantages of modular construction, such as enhanced resource efficiency and reduced environmental impact, existing research often overlooks its unique attributes and constraints. Our objectives were to identify crucial parameters for a comprehensive evaluation of modular construction, particularly emphasizing sustainability, and to explore how an advanced conversational AI tool, ChatGPT, can assist in modular building assessments. We employed the Delphi method to define these parameters and integrated ChatGPT to develop a robust assessment methodology. This approach allowed us to harness AI-driven insights to enrich the evaluation process. Our findings suggest that ChatGPT delivers high-quality results comparable to those produced by experts in modular building assessments. ChatGPT formulated a detailed description of the evaluation scale for each criterion, effectively outlining the guidelines for evaluating modular house projects. To illustrate the effectiveness of our proposed methodology, we applied it to a real-world modular house project in Lithuania, demonstrating how this approach can significantly contribute to advancing sustainable construction practices.

Keywords: modular building; project evaluation; ChatGPT; conversational AI; generative AI; artificial intelligence; Delphi method; MCDM; sustainability



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1. Introduction

The modular building [1] has become an increasingly popular construction method due to its numerous advantages such as cost savings, speed of construction, and flexibility in design. A modular building offers cost savings by reducing material waste, benefiting from economies of scale, and optimizing labor, and its speed of construction stems from simultaneous processes and predictable timelines [2]. Flexibility in design comes from customization, adaptability, and stringent quality control in a factory setting [3]. In the context of this research, we will refer to a modular building as a structure composed of standardized modules fabricated off-site in a factory or manufacturing facility and assembled on-site. These modules, made from materials like metal, wood, or plastic, include complete sections of a building, such as rooms with integrated floors, roofs, and walls. Modular buildings provide quick and efficient assembly or disassembly, flexibility, and high-quality control. They can be used for both temporary and permanent structures, including residential housing, commercial buildings, mobile offices, and temporary housing. Modular construction (MC) has been identified as a possible remedy that significantly enhances productivity, accelerates building timelines, and diminishes the substantial ecological footprint of the construction industry. Despite being embraced in several countries across the globe, its widespread use is still hindered by numerous interconnected obstacles. For instance, in Germany—a country with a strong off-site construction (OSC) market—MC

is still not widely adopted by housing corporations. This is unexpected, especially given its crucial role in rapidly providing housing in areas experiencing severe shortages, and according to the research [4], results show that barriers concerning the market (supply and demand), the industry's attitude, and the process (B8) can be regarded as highly relevant factors.

Exploring the customer decision process for modular building projects, especially in the residential sector, reveals a complex network of decision-making factors. These factors, ranging from design aesthetics and functionality to cost-effectiveness, sustainability, construction timelines, and customization options, are pivotal in understanding customer preferences in modular housing projects (for illustration, see Figure 1). Prior studies have not fully captured or understood these intricacies.



Figure 1. Modular building example (generated by ChatGPT 4.0 [5]).

The significance of these factors varies for each customer, influenced by their individual needs, preferences, and values. This variation highlights the diverse considerations in modular housing selection, including sustainability. Sustainability, while one of many factors, plays an increasingly important role in customer choices, reflecting a broader societal shift toward environmentally conscious living. In this context, 'weights' refer to the importance or priority of each factor in decision-making process. For some, sustainability and energy efficiency may be paramount, aligning with their commitment to eco-friendly living. Others might prioritize different aspects such as budget or design.

Understanding these varying weights is crucial for professionals in the modular housing industry, including developers, architects, and marketers. It enables them to tailor their offerings to meet the diverse preferences of customers, while also considering the environmental impacts of their projects. This approach helps bridge the gap between individual customer needs and the collective goal of sustainable development.

As a key component of evaluation methodology, an evaluation scale must be established to provide a standardized method of evaluating and comparing different residential modular building projects. Such a scale enables customers to make informed decisions by evaluating various projects against uniform criteria. This is particularly significant given that traditional methods like the Analytic Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) can achieve better performances due to a less biased evaluation—some criteria undergo direct evaluation using instructions accompanied with an evaluation scale.

The goals of this research were to identify and quantify the key factors influencing the customer's selection of residential modular building projects, determine their relative importance, and establish the evaluation scale. Furthermore, in our study, we aimed to demonstrate how to utilize generative AI tools such as ChatGPT [5] to cover the lack of data from experts. While there are many well-known methods that are like the Delphi

methods. The main task for ChatGPT is to complement experts output, which is needed for both the research itself and the successful application of its outcome for practical cases in the future.

The objective of this research was modular house projects in a project evaluation context. The main scientific hypothesis of this research is that ChatGPT can be efficient enough to provide high-quality results by creating a description of the evaluation scale that complements and speeds up the expert's work and reduces the description to corrections using the limited one-shot learning technique, i.e., when the model is given a single example from which to infer how to perform a task.

1.1. The Background of the Research

In our research on the assessment of modular construction projects, we placed a strong emphasis on evaluating customer preferences and establishing evaluation scales. This approach aligns with innovative methodologies used in various industries. For instance, studies on mobile phone selection and the energy-sustainable renovation of building envelopes employ the Analytic Hierarchy Process (AHP) for decision making, a method that is also crucial in our assessments of modular buildings [6,7]. Further emphasizing the importance of robust analytical frameworks, research on building energy modeling at an urban scale resonates with our focus on sustainability and efficiency in modular construction [8].

These shared methodologies manage complexities across different construction disciplines, including energy efficiency in building renovations and infrastructure management based on multicriteria approaches [9,10]. The latter, employing a two-phase AHP and the TOPSIS method, mirrors our approach to modular construction, where balancing various stakeholder interests and efficient resource allocation is crucial. In our work, as an illustration, we used a weighted method, which also required determining the relative values of the evaluated factors.

Further parallels are found in research focused on value management (VM) in construction and the prioritization of social assistance candidates, emphasizing the need for structured decision-making models [11,12]. A recent study on improving the seismic performance in modular buildings, particularly focusing on prefabricated steel modules with multi-tuned mass damper floor systems, directly complemented our research in modular construction [13]. This study's innovations in enhancing structural integrity and resilience are integral to our goals of ensuring that modular buildings are not only efficient and environmentally friendly but also structurally robust and safe.

The exploration of regenerative circularity in the built environment and asset management in asset-intensive industries offers further insights. Studies focusing on sustainability assessment tools and strategic plans for identifying critical assets mirror our efforts in incorporating sustainability and adaptability into modular construction [14,15]. Additionally, the significant roles of knowledge, awareness, and environmental consciousness in adopting green practices in construction organizations underline the importance of fostering such attributes among stakeholders, which is a key aspect in advancing sustainable modular building methods [16].

Technological integration also plays a pivotal role. Studies on the effective use of Building Information Modelling (BIM) in the AECO industry, as well as structural design optimization (SDO) using BIM and optimization algorithms highlight the integration of technologies to enhance user experience and support sustainability [17,18]. These principles are crucial not just in smart infrastructure but also in the evolving field of modular construction.

Finally, the insights from sustainability transition studies in the construction industry resonate with our findings in modular construction, emphasizing the importance of technological and organizational factors, the role of information sharing, and the influence of social media and key opinion leaders in technology adoption [19].

Collectively, these various studies underscore the importance of multi-criteria decision making, stakeholder engagement, technological integration, and sustainability in advancing the field of modular construction. The integration of modern methodologies and innovations from related fields can significantly enhance modular building projects.

A comprehensive comparison between traditional on-site and modular off-site construction methods was conducted to understand their environmental impact. Using three representative single-family houses in Okanagan, British Columbia, Canada, a cradle-to-gate life cycle assessment was performed. Data related to materials, transportation, and energy were collected, and environmental impact measures were calculated. The comparisons indicated that neither method was definitively more environmentally friendly. However, the study suggested that implementing certain strategies like optimal design and reducing material and worker transportation could minimize environmental impacts. The study provided a foundation for future life cycle assessment studies on new building projects [20].

Recent research introduced a framework to assess the economic sustainability of single-family modular houses over their life cycle. It involves selecting economic performance criteria, developing indicators, and using multi-criteria decision analysis to create economic sustainability indices. The framework was applied to two modular houses in British Columbia, Canada, with results showing excellent overall economic sustainability. However, certain areas required improvement. The framework can guide decisions on construction methods and pinpoint areas needing enhancement in a modular building's life cycle [21].

Modular buildings feature streamlined construction processes, precise resource utilization, predictable scheduling, adherence to building codes, rigorous quality control, and sustainability measures like resource efficiency and energy efficiency. The higher speed of construction, better productivity and workmanship, cost savings, higher safety, higher product control and quality, and less negative environmental impacts are the most noticeable advantages of modular construction [2]. These characteristics enhance efficiency, compliance, and sustainability compared to traditional construction methods.

Integrating ChatGPT and similar large language models (LLMs) into construction research offers new possibilities and challenges, a notion supported by a study that critically assessed GPT models in the industry [22]. This research revealed the potential of GPT models to enhance various project life cycle stages, identified challenges, and created a prototype for material optimization. These findings underscore the relevance of our work in applying ChatGPT for modular house project evaluation, highlighting the untapped potential of LLMs to revolutionize construction management and sustainability efforts. GPT models have also been proved applicable in construction scheduling based on specific project requirements; however, the technology still has limitations, and further development is needed before it can be widely adopted in the industry [23].

Summarizing everything said above, we showed the context and the background of this research—there are several opportunities for pioneering the incorporation of generative AI technology into the construction field. Thus, the current research is dedicated to continuing the topic that was extensively discussed in [22] by presenting a new concrete way to incorporate generative AI technology into construction industry, more specifically into the project planning phase when project assessment is performed, and the hard work of a competent expert is required.

1.2. The Role of ChatGPT in This Research

Besides the utilization of ChatGPT to improve the text (with careful revision, without the creation of new knowledge), which is an obvious direct application (for the current text as well) of ChatGPT, in our study, we demonstrated how to utilize generative AI tools such as ChatGPT to cover the lack of data from experts. Thus, the main task for ChatGPT in the current research context was to complement experts output, which is needed for both the research itself and the successful application of its outcome for practical cases in

the future. Implementing an AI tool like ChatGPT as a knowledge expert is particularly beneficial in navigating the challenges presented in [24]. Given the challenges in collecting and interpreting data, especially from small surveys that may be subjective, an AI like ChatGPT can provide a clear and unbiased perspective based on data.

It can process vast amounts of information from a wide range of sources to provide valuable insights, mitigating some of the subjective bias inherent in human responses. Moreover, in an industry where professionals are pressed for time, ChatGPT can handle vast amounts of data swiftly and efficiently, relieving the burden from human experts. It can effectively analyze information and provide comprehensive reviews in much shorter time if we compare it to a human analyst. Importantly, while the framework proposed in [24] relies on continuous benchmarking processes that may take years to develop a comprehensive database, an AI like ChatGPT can expedite this process. It can swiftly review, revise, and recalibrate benchmark values and tweak performance scales in real time, adapting to site-specific socio-economic and geographical conditions. This offers a more efficient, adaptable and dynamic approach to benchmarking in the emerging modular construction industry. In conclusion, in our research, ChatGPT provided an efficient, objective, and comprehensive analysis of data for benchmarking in the modular building industry, making it an invaluable tool for such research.

The following are the progressive steps involved in the ChatGPT framework [5]:

1. **Interactive Dialogue Structure:** ChatGPT's interactions resemble a structured discussion. Using this dialogue framework, ChatGPT can respond to follow-up queries, correct mistakes it has made, refute false assertions, and decline inappropriate requests.
2. **Data Collection and Reward Model Training:** ChatGPT is built on GPT-3.5, a language model that employs deep learning to generate human-like writing. The process includes collecting comparison data and training a reward model to evaluate the generated content.
3. **Sampling and Policy Initialization:** The database is sampled to obtain a fresh prompt. The supervised policy serves as the initialization for the proximal policy optimization (PPO), guiding the policy to produce a result.
4. **Reward Determination and System Update:** A reward is determined by the reward model for the generated output, utilizing proximal policy optimization. The reward is then used to update the policy, contributing to the iterative improvement of the system.

Our research mirrors the complexities mentioned in [25] regarding selection and evaluation by experts, the necessity of multi-aspect viewpoints, and the need to avoid inconsistency in responses when developing sustainability-type questionnaires. To navigate these challenges, we propose the use of ChatGPT. ChatGPT, a sophisticated AI developed by OpenAI, was designed to generate human-like text based on the input it receives. By integrating ChatGPT into our process, we were able to mitigate some of the issues associated with human variability and bias. As an AI, ChatGPT is inherently neutral and consistent, providing reliable input free from the subjectivity inherent to human experts. This AI can also manage the high volume of respondents needed for a robust study. Unlike human researchers, ChatGPT can swiftly process and interpret data from many participants, reducing the time required for data analysis. Moreover, using linguistic variables for assessment, as mentioned in [25], becomes more efficient with ChatGPT. The AI can interpret, relate, and assign fuzzy numbers to linguistic terms, ensuring a more precise and objective assessment. Lastly, the AI excels in questionnaire analysis. It can rapidly analyze filled-out questionnaires, identify patterns, and provide insights, again reducing the time required for this process and increasing the consistency of the results. In summary, integrating ChatGPT into our research process provides an efficient, objective, and reliable approach to overcoming the challenges associated with the evaluation and analysis stages of the construction project.

The rapid advancements in artificial intelligence (AI), particularly in large-scale language models like ChatGPT, have ushered in a new era of digital transformation. With its extensive training data and sophisticated algorithms, ChatGPT has demonstrated remark-

able abilities, especially in generating human-like text across diverse disciplines, facilitating interdisciplinary research, and serving a plethora of use cases ranging from customer service to research collaboration [26,27]. Its potential to democratize scientific research, simplify tasks, and make academic pursuits more effective and time-saving underscores the transformative nature of such AI models [28].

However, as with any powerful technology, the use of ChatGPT is not without its challenges. Concerns about the reliability and accuracy of its outputs, biases inherent in its training data, and its opaque decision-making process have been raised [26,28]. Additionally, there are ethical challenges associated with AI models in research, including data privacy concerns and the potential for unintentional plagiarism.

Yet, the potential of ChatGPT to revolutionize various domains cannot be understated. Its ability to comprehend conversational contexts, generate coherent and grammatically correct language, and adapt across sectors and disciplines positions it as a game-changer in the AI landscape [27]. Moreover, the concept of human-machine collaboration underscores the dynamic interaction between humans and AI, highlighting the need for a holistic understanding of their synergy across cognitive, metacognitive, affective, and social domains [29].

We propose the use of the Multi-Criteria Decision Making (MCDM) Delphi method, complemented by the capabilities of ChatGPT, to evaluate the projects of modular buildings. The Delphi method is a Bayesian parameter inference MCDM method that allows for the estimation of the posterior distributions of model parameters without relying on explicit likelihood functions. This approach is particularly effective in handling the complexities and uncertainties inherent in the evaluation of modular buildings, which can vary widely in design, materials, and construction methods [30].

The Delphi method enables us to gather and refine experts' opinions iteratively to estimate parameters that significantly affect the performance of modular buildings, such as materials used, construction methods, and design choices. Following this, we planned to utilize ChatGPT to further analyze and improve the evaluation of individual criteria for specific modular construction projects. ChatGPT's advanced natural language processing capabilities can assist in interpreting the Delphi method's results, providing nuanced insights and suggestions for each criterion. This can include generating detailed reports, proposing optimization strategies, or even identifying potential areas of risk or innovation based on the aggregated expert opinions [31].

Moreover, ChatGPT can facilitate dynamic interaction with the data, allowing stakeholders to query specific aspects of the modular construction project and receive instant, informed responses. This interactive approach can significantly enhance decision-making processes, ensuring that all considerations are thoroughly evaluated.

The combination of the Delphi method and ChatGPT offers a comprehensive and robust framework for modular building evaluation. While the Delphi method provides a solid foundation through expert consensus, ChatGPT adds a layer of intelligent analysis and interaction, making the evaluation process more thorough and adaptable. This integrated approach not only accommodates the heterogeneity and complexity of modular buildings but also embraces the variability in expert opinions, leading to a more refined and actionable evaluation. Despite the fact that Delphi is quite an old method that was developed in the 1950s by the RAND Corporation to forecast the impact of technology on warfare, its age does not diminish its usefulness. Rather, the Delphi method has proven to be adaptable and valuable across different disciplines, including business, education, health, and public policy. It is particularly useful in situations where individual judgments need to be synthesized into a group consensus and direct communication between experts is not feasible or is undesirable due to potential bias or influence. In recent years, the popularity of this method in scientific articles was significantly increased (Figure 2).

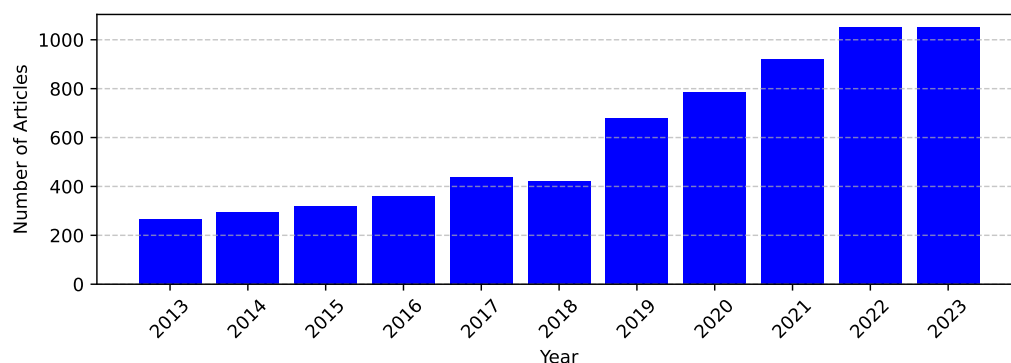


Figure 2. The number of articles by year with the Delphi method. This result was obtained from the Web Of Science platform with an advanced search query, “AK = (Delphi OR Delphi method)”.

In conclusion, integrating the Delphi method with ChatGPT presents a powerful and innovative tool for assessing the performance of modular buildings. This combination allows for a detailed and interactive evaluation of various performance parameters, enhancing the quality and effectiveness of modular building projects through a more informed and data-driven decision-making process.

This study made the following contributions:

- Conducted a comprehensive survey using the Delphi method to identify and select the critical factors affecting customer selection in modular construction projects, demonstrating the importance of expert and consumer input in refining research focus areas within the modular construction domain.
- Introduced an innovative research design that strategically integrates ChatGPT to implement the application of these selected factors by introducing a detailed evaluation scale. This showcases the potential for AI to complement traditional research methodologies by enhancing the precision and relevance of data analysis in the modular construction sector.
- Demonstrates the process of crafting detailed prompts to guide ChatGPT, ensuring the generation of relevant and accurate information for the development of an evaluation scale specifically tailored to modular construction projects. This highlights the meticulous approach required to effectively utilize AI tools in academic research.
- Calls for the development of sophisticated AI-driven tools tailored to the construction industry, capable of navigating complex consumer decision-making processes and sustainability considerations. This contribution emphasizes the need for further exploration into the integration of AI in enhancing sustainable housing development strategies, while also acknowledging the foundational work conducted without AI assistance.

The remainder of this paper is structured as follows. Section 2 describes the methodology of the research. Section 3 discusses how the methodology was applied to the case study. Section 4 presents the results of the proposed research methodology applied to the real case in Lithuania. Finally, Section 5 presents and discusses the results from the case study. Section 6 provides concluding remarks and proposes future research areas.

2. The Methodology of this Research

In this section, we present the methodology of this research, i.e., how we addressed the problem of evaluation. More specifically, we address the evaluation of each criterion for evaluation separately.

2.1. Factors for Evaluation

In the pursuit of evaluating the multifaceted dimensions of modular housing projects, our research identified a series of critical factors that influence their success and

sustainability. To contextualize these factors within the broader academic and practical discourse, we conducted a comprehensive review of the existing literature. Table 1 presents the culmination of this effort, listing each identified factor alongside references to the works of other researchers who have investigated similar themes. This alignment not only validates our research approach but also situates our findings within the ongoing dialogue on modular construction, bridging the gap between our study and the broader body of knowledge in the field. These factors are the input criteria for the first round of the Delphi method. The factors presented in Table 1 are defined in more detail in Sections 2.2.1–2.2.14.

Table 1. Factors and corresponding references.

Factor Number and Name	Sources
B1.1. Construction time	[21,32–34]
B1.2. Design costs	[21,34]
B1.3. Construction costs	[21,32,34,35]
B1.4. Building lifespan	[21,32,33]
B1.5. Amount of investment	[34,36]
B1.6. Building guarantee lengths	[30]
B1.7. Exploitation costs	[21,35]
B1.8. Modular building adaptivity	[21]
B1.9. Traceability of products and works	*
B1.10. Design time	[21,34]
B1.11. Maintenance costs	[21,32]
B1.12. Disposal costs	[21]
B1.13. Investment risk	[21]
B1.14. Compatibility of elements from different manufacturers	*
B2.1. Geometry and configuration	[30,33,37,38]
B2.2. Aesthetic design	[30,32,35,37–39]
B2.3. Functionality	[32,33]
B2.4. Energy efficiency class	[30]
B2.5. Heating and ventilation	[32,37,39]
B2.6. Insolation and light	[37,39]
B2.7. Sound isolation	[37]
B2.8. Amenities	[37,39,40]
B2.9. The quality of the modular house, the completeness of the work, the delivery and the preparation of the documentation	*
B2.10. The area	[33,37,38]
B2.11. Number of floors	[33,38]
B3.1. The usual (permanent residence) location	[34]
B3.2. Protection against burglary and theft	[30]
B3.3. A good view from the window, the presence of greenery around	*
B3.4. The situation of the neighborhood (friendly, safe environment)	[21,34,40]
B3.5. Compliance with the status of the resident	[34]
B3.6. Adaptation to the lifestyle	[32,34]
B4.1. Geographical location	[33,35,37,40]
B4.2. Site availability	[38]

Table 1. *Cont.*

Factor Number and Name	Sources
B4.3. Distance from the city center	[36,38,40]
B4.4. Parking lot and other infrastructure	[39]
B4.5. Swimming pool, garden	[36,39]
B4.6. Public and private service facilities	[36,38,39]
B4.7. City structure and development	[36]
B5.1. Compliance with the strategy of renting, selling or living in	[34]
B5.2. Compliance with the situation on the labor market and labor supply	[21,40]
B6.1. Recyclability of elements	[21,32,41]
B6.2. Absence of negative effects on humans	[21,32,41]
B6.3. No negative impact on nature	[21,41]
B6.4. Production from renewable sources	[21,35,41]
B6.5. Eco-friendly operation	[42]
B6.6. Ecological production	[21,41]
B6.7. Environmental friendliness of transportation	[21,43]
CB5. Preliminary price	[30,34]
CB6. Compliance with norms and standards	[30]

* These factors were obtained from respondents during the first round of the Delphi method.

2.2. Ranking Criteria

Here, we present the criteria for the ranking of different factors for the modular building project evaluation. Every criteria is ranked with a number from 1 to 5 (also known as the Likert scale). A higher numerical value corresponds to a more favorable project attribute. Specifically, the scale is defined as follows:

1. Poor—The project significantly lacks the desirable attributes of the given criterion.
2. Fair—The project displays basic features of the criterion but falls short of a satisfactory standard.
3. Good—The project meets the expected standards for the criterion, representing an average performance.
4. Very Good—The project exceeds the average standards, showing enhanced attributes of the criterion.
5. Excellent—The project excels in fulfilling the criterion, showcasing exemplary performance and attributes.

This ranking system was designed to provide a quantitative measure of each project's characteristics, facilitating a comprehensive evaluation based on predefined criteria. It can be used in two general ways to implement the evaluation of each factor of the project:

1. Evaluate each factor for each object using some expert opinion-based evaluation procedure.
2. Set up an evaluation scale with defined criteria for each rank of each factor.

The second way is not available for all factors, as it must involve the subjective opinion based on the factor's definition (e.g., "A good view from the window"). However, where it is appropriate, the defined criteria for each rank (which lets us define the scale) could improve the evaluation process in speed and robustness, eliminating the subjectivity. The main barrier of such an approach is the need to perform the expensive work of an expert with high competence, and, as it was mentioned before already, we intend to reinforce the expert with ChatGPT.

The scale values represent a consensus-driven approach to appraising the multifaceted aspects of modular construction projects, ensuring a standardized evaluation process. The

ranking scale (along with detailed descriptions for each rank) was proposed by ChatGPT and was verified by the expert. According to the expert, no major changes were required; however, some minor inconsistencies were identified. More specifically, there were some overlapping ranges of parameters in the scale for evaluations. Thus, it was decided to correct the output provided by ChatGPT without some major reiteration by ChatGPT—according to the expert, the corrections finalized the result. Thus, in the points in Sections 2.2.1–2.2.14, the results were obtained using appropriate prompts with ChatGPT, and details with the original prompts and output are provided in Appendix A.

2.2.1. Construction Time

The ranking of construction time is based on the predicted time that is needed for the construction of the building. Modular buildings generally have shorter construction times compared to traditional or classical buildings. The precise construction time can vary depending on several factors, including the complexity and size of the project, the manufacturing capabilities of the modular construction company, site preparation requirements, and the level of customization desired. However, in general, modular buildings tend to be constructed more quickly due to the following reasons:

- **Off-Site Construction:** Modular buildings are constructed in a factory-controlled environment, allowing for simultaneous work on site preparation and building fabrication. This off-site construction approach reduces construction time significantly.
- **Parallel Work Processes:** With modular construction, site preparation tasks, such as foundation construction or utility connections, can proceed concurrently with the fabrication of modules in the factory. This parallel work process accelerates the overall construction schedule.
- **Streamlined Production:** Modular buildings follow standardized designs and construction processes. The manufacturing process in a factory environment allows for efficient assembly line production, with skilled workers specializing in specific tasks. This streamlined production process minimizes delays and improves construction speed.
- **Reduced Weather Dependency:** Since the majority of the modular building construction takes place in a controlled factory environment, it is less affected by adverse weather conditions that can cause delays in traditional construction. This factor helps maintain consistent construction schedules and reduces the overall project timeline.

As a result of these and some other factors, when compared to more conventional construction methods, modular construction can result in savings of 50% (time), 30% (materials), and 25% (waste), thus achieving significant economic savings [44]. However, it is important to note that the exact building time can still vary depending on the specific project requirements and circumstances.

On average, modular buildings can be constructed in a shorter timeframe compared to traditional or classical buildings. While the exact duration can vary depending on the size and complexity of the project, as well as other factors, here is a general comparison:

- **Modular Buildings:** The construction of modular buildings typically takes less time compared to traditional construction methods. Depending on the size and complexity of the project, modular buildings can often be completed in a range of a few weeks to a few months. Smaller modular structures, such as single-family houses or small office buildings, can often be completed in a matter of weeks. Larger modular buildings, such as multi-story commercial structures, may take a few months to complete.
- **Traditional/Classical Buildings:** The construction timeline for traditional buildings is typically longer due to the sequential nature of the construction process. It involves various stages, including site preparation, foundation construction, framing, interior and exterior finishing, and other installations. The duration of construction for traditional buildings can vary significantly depending on the size, complexity, and construction methods used. On average, the construction of traditional buildings can take several months to over a year, depending on the project scope.

It is important to note that these estimates are general and can be influenced by project-specific factors. Both modular and traditional construction methods have their own advantages and considerations, and the choice between them should be based on factors such as project requirements, budget, site constraints, and timeline preferences.

Construction times can vary widely based on the size and complexity of the building, the number of workers, local regulations, and many other factors. Rough estimates are provided in Table 2.

Table 2. Time ranges for construction.

Rank	Traditional Construction Time (Months)	Modular Construction Time (Months)
1	[24,36)	[12,18)
2	[18,24)	[9,12)
3	[12,18)	[6,9)
4	[9,12)	[4,6)
5	[6,9)	[3,4)

2.2.2. Amount of Investment

The ranking of cost-related factors is based on the predicted costs that are needed for the construction of a building. Projecting costs, construction costs, and the amount of investment are related to the financial aspects of a construction project, but they represent different aspects of the overall expenses. Here is a breakdown of each term:

Projecting Costs: Projecting costs, also known as design or planning costs, refer to the expenses incurred during the initial stages of a construction project. These costs typically include architectural and engineering fees, site surveys, soil testing, permit fees, and other expenses related to the design and planning phase. Projecting costs are associated with developing the project concept, conducting feasibility studies, creating design plans, and obtaining necessary approvals and permits. These costs are incurred before the actual construction begins and are part of the overall project budget.

Construction Costs: Also known as hard costs, these are the expenses directly associated with the physical construction of the building. These costs include materials, labor, equipment, subcontractor fees, construction permits, site preparation, foundation work, structural components, interior and exterior finishes, mechanical and electrical systems installation, and any other construction-related expenses. Construction costs represent the largest portion of the overall project budget and are directly related to the actual construction work.

Amount of Investment: The amount of investment refers to the total capital or financial resources needed for the construction project. It includes both projecting costs and construction costs, along with other related expenses. The amount of investment is the total sum required to initiate and complete the project, covering all the planning, design, and construction activities. It includes costs for land acquisition, design and planning fees, construction costs, contingency funds, financing expenses, professional fees, marketing expenses (if applicable), and any other costs associated with the project. The amount of investment represents the overall financial commitment required to bring the construction project to completion.

In summary, projecting costs are the expenses incurred during the design and planning phase, construction costs are the expenses directly related to the physical construction work, and the amount of investment is the total capital required for the entire project, encompassing both projecting costs and construction costs, along with other associated expenses.

In addition to projecting costs and construction costs, the amount of investment for a construction project may include several other related expenses. These expenses can vary depending on the project scope, location, and specific requirements. Here are some common examples of other related expenses that may be included in the amount of investment:

Land Acquisition: the cost of purchasing or acquiring the land on which the construction project will be built. This can include the purchase price of the land, legal fees, surveying costs, title searches, and any necessary site preparations.

Financing Expenses: costs associated with obtaining financing for the project, such as loan origination fees, interest payments, loan guarantee fees, and other financing-related expenses.

Contingency Funds: an allowance for unforeseen circumstances or changes that may arise during the construction process. Contingency funds are set aside as a buffer to cover unexpected expenses or project modifications.

Professional Fees: fees paid to professionals involved in the project, such as architects, engineers, project managers, consultants, and legal advisors. These fees can vary based on the size and complexity of the project.

Insurance and Bonding: costs associated with insurance coverage for the project, including builder's risk insurance, liability insurance, and any necessary performance or payment bonds.

Utilities and Infrastructure: expenses related to connecting the project to essential utilities such as water, electricity, gas, and sewer systems. This can include fees for utility hookups, the installation of infrastructure, and any necessary upgrades or extensions.

Permitting and Regulatory Costs: fees associated with obtaining permits, licenses, and complying with local building codes and regulations. This can include building permits, environmental impact assessments, zoning fees, and inspections.

Marketing and Sales Expenses (if applicable): costs associated with marketing and promoting the project, such as advertising, sales commissions, model unit construction, and staging.

Administrative and Overhead Costs: general administrative expenses related to project management, office space, utilities, accounting, legal services, and other operational costs.

It is important to note that the specific expenses included in the amount of investment can vary depending on the nature and scale of the project. It is recommended to consult with financial advisors, project managers, or construction professionals to accurately assess and estimate the full range of expenses that should be considered in the amount of investment for a particular construction project.

Table 3 lists five intervals of price bounds for projecting costs, construction costs, and the amount of investment for both traditional and residential modular buildings, ranked from the most expensive to the cheapest.

Table 3. Different types of costs for different types of buildings (\$/sq.m).

Rank	Traditional Projecting	Modular Projecting	Traditional Construction	Modular Construction	Total Traditional	Total Modular
1	[540,648)	[486,594)	[5400,6480)	[4860,5940)	[6480,7560)	[5940,7020)
2	[432,540)	[378,486)	[4320,5400)	[3780,4860)	[5400,6480)	[4860,5940)
3	[324,432)	[270,378)	[3240,4320)	[2700,3780)	[4320,5400)	[3780,4860)
4	[216,324)	[162,270)	[2160,3240)	[1620,2700)	[3240,4320)	[2700,3780)
5	<216	<162	<2160	<1620	<3240	<2700

2.2.3. Building Lifespan

The lifespan of a building is dependent on many factors including the quality of construction, the materials used, and the ongoing maintenance. Here are five ranks from the shortest to longest lifespan, considering both traditional and modular buildings:

- Rank 1—Very Short Lifespan:** temporary modular buildings such as event tents or emergency shelters (1–5 years). These structures are designed for immediate use and are not built to last. They serve their purpose in disaster-struck areas, temporary events, or short-term accommodation needs.

2. **Rank 2—Short Lifespan:** portable cabins or temporary classrooms (6–20 years). These are often seen in construction sites, schools, or as temporary offices. They are made more durable than the very-short-lifespan buildings but are not meant for very long-term use.
3. **Rank 3—Average Lifespan:** prefabricated houses or manufactured houses (21–60 years). These houses are built in factories and then assembled on-site. They are designed for longer-term use and can withstand weather conditions better than temporary structures.
4. **Rank 4—Long Lifespan:** permanent modular houses with high-quality materials (61–100 years). These houses are built to last, using quality materials and construction techniques that ensure their longevity. They are intended to serve as full-time residences for decades.
5. **Rank 5—Very Long Lifespan:** High-end, architect-designed modular houses (101+ years). These houses are designed and built with exceptional attention to detail, using high-quality, durable materials. With proper care and maintenance, they can last for over a century, similar to traditionally constructed houses.

2.2.4. Building Warranty Lengths

The warranty lengths of the buildings were ranked using ChatGPT. The obtained ranking data for traditional and modular buildings are presented in Table 4.

Table 4. Rankings for modular building warranty lengths.

Rank	Traditional Building Warranty (Years)	Modular Building Warranty (Years)
1	≤ 2	≤ 2
2	[2,5)	[2,5)
3	[5,10)	[5,10)
4	[10,20)	[10,20)
5	20+	20+

Building warranty length refers to the period during which the builder or manufacturer of a building is responsible for repairing or resolving certain defects and issues that may arise after construction. Here is a detailed breakdown:

- **Nature of Warranty:** This covers defects in materials, workmanship, structural issues, and major systems. Specific coverage varies by warranty.
- **Duration:** This ranges from a few years to several decades, depending on the type of warranty and covered components.
- **Types of Warranties:** These include the following:
 - **Limited Warranties:** These cover specific elements for a defined period.
 - **Structural Warranties:** These focus on structural integrity, including foundations, and load-bearing parts.
 - **Home Builder Warranties:** These are for new residential buildings, varying in length and coverage.
- **Importance:** This protects against costly repairs due to construction defects and serves as a quality assurance measure.
- **Transferability:** Some warranties can be transferred to new owners, enhancing property value.
- **Limitations and Exclusions:** Not all issues are covered; exclusions vary by warranty.
- **Claim Process:** This requires filing a claim within the warranty period for assessment and resolution.

2.2.5. Building Exploitation Costs

Modular building exploitation costs are provided in Table 5, they refer to the ongoing expenses associated with operating and maintaining a modular building after its construction and installation. These costs can vary depending on factors such as the size and purpose of the building, its location, the level of usage and occupancy, and the specific requirements for maintenance and utilities. Some common components of modular building exploitation costs include the following:

Utilities: These include expenses for electricity, water, heating, cooling, and other utilities necessary for the functioning of the modular building. The cost will depend on the energy efficiency of the building and the local utility rates.

Maintenance and Repairs: Regular maintenance, inspections, and repairs are essential for preserving the condition and functionality of the modular building. This includes tasks such as cleaning, painting, HVAC system maintenance, plumbing repairs, and general upkeep.

Insurance: Modular buildings, like any other structures, require insurance coverage to protect against potential risks such as property damage, liability claims, or accidents. The insurance premiums will depend on factors such as the building's value, location, and intended use.

Property Taxes: Modular buildings are subject to property taxes, which are typically based on the assessed value of the building and the local tax rates. The tax rates may vary depending on the jurisdiction.

Security and Safety Measures: Expenses related to security systems, surveillance equipment, fire alarms, and safety protocols are essential for ensuring the protection of the modular building and its occupants. This includes costs for security personnel, monitoring services, and periodic safety inspections.

Cleaning and Waste Management: Regular cleaning services and waste disposal are necessary for maintaining cleanliness and hygiene within the modular building. The costs will depend on the size of the building, the frequency of cleaning, and the waste management services utilized.

Property Management: If the modular building is part of a larger property or complex, there may be additional costs associated with property management services, such as administrative fees, maintenance coordination, and tenant communication.

It is important to note that the specific exploitation costs for a modular building can vary significantly depending on various factors mentioned earlier. It is recommended to consult with professionals or property management experts who can provide a more accurate estimate based on the specific circumstances of the modular building in question.

These costs include building maintenance, utilities, property taxes, and other ongoing expenses associated with the building exploitation. Note that the actual cost can vary greatly depending on the specific property, its location, usage, and many other factors.

Table 5. Ranking of exploitation costs.

Rank	Traditional Building Exploitation (USD/sq.m/year)	Modular Building Exploitation (USD/sq.m/year)
1	[65,86)	[54,76)
2	[43,65)	[32,54)
3	[22,43)	[16,38)
4	[11,22)	[5,16)
5	<11	<5

2.2.6. Modular Building Adaptivity

Modular building adaptivity refers to the flexibility of the building design to be changed or adjusted over time based on varying needs. This could include the ability to add or remove modules, rearrange internal layouts, or even relocate the entire building.

Here are five ranks, from lowest to highest, considering aspects such as design flexibility, ease of modification, and cost of changes:

1. **Rank 1—Poor:** The building design allows for very minimal or no changes in layout or use over time. Major alterations would require significant structural changes, high costs, and lengthy timeframes.
2. **Rank 2—Fair:** The design permits some minor changes, such as small interior modifications, without major structural alterations. However, these changes may still involve considerable costs and time.
3. **Rank 3—Good:** The building design incorporates a moderate level of flexibility. It allows for changes in room layouts or usage with relative ease and at moderate cost. However, larger scale changes may still be challenging or costly.
4. **Rank 4—Very Good:** The design allows for significant flexibility. Large-scale changes in layout or use can be achieved at moderate cost and in a reasonable timeframe. The building may also have features that facilitate easy modifications, such as standardized connections between modules.
5. **Rank 5—Excellent:** The building design provides for maximum adaptability. It allows for significant changes, including the addition or removal of modules, changes in layout or use, or even the relocation of the building with relative ease, minimal cost, and within short timeframes. The design may incorporate specialized features that enhance adaptability, such as quick-release connections or adjustable structural elements.

2.2.7. Traceability

Traceability in the context of modular building construction refers to the ability to track the progress of a job or project, the parts used, and the workers involved, often for the purpose of quality assurance, record keeping, and regulatory compliance.

Here are five ranks, from lowest to highest, considering the ability to track the various stages of production, quality control measures, and labor tracking:

1. **Rank 1—Poor:** minimal or no systems in place for tracking job progress, components used, or workers involved; no digital record keeping; and limited or no documentation of job stages.
2. **Rank 2—Fair:** basic tracking systems in place, possibly manual record keeping or rudimentary digital systems. Documentation may not be consistent or comprehensive, and quality control measures may be lacking.
3. **Rank 3—Good:** digital tracking systems in use, with the regular documentation of job progress, components, and labor. Quality control measures are employed, but they may not cover all aspects of the project or all stages of construction.
4. **Rank 4—Very Good:** advanced digital tracking systems in use, with comprehensive and regular updates on job progress, components, and labor. Quality control is integrated into the tracking process, with most aspects of the project covered.
5. **Rank 5—Excellent:** state-of-the-art digital tracking systems in use, with real-time updates on job progress, components, and labor. Quality control measures are fully integrated into the tracking system, covering all aspects of the project at all stages of construction. Traceability is considered in the design stage and is a key component of the construction process.

2.2.8. Geometry and Configuration

Assessing building geometry and configuration objectively is a complex task that involves several criteria, including spatial efficiency, accessibility, lighting, thermal comfort, and acoustics. This method is based on the book of Markus and Morris [45]. Each of the following five ranks is associated with an increasing level of efficiency and comfort:

1. **Rank 1—Poor:** The configuration and geometry of the building significantly reduce the spatial efficiency. It is challenging to move around due to the poor layout. It

has inadequate natural lighting and ventilation, resulting in poor thermal and acoustic comfort.

2. **Rank 2—Fair:** The building has some issues with spatial efficiency, layout, and accessibility. While there is some allowance for natural light and ventilation, these are not optimized, affecting thermal and acoustic comfort to a certain degree.
3. **Rank 3—Good:** The building offers satisfactory spatial efficiency with a layout that facilitates ease of movement. There is a balance of natural and artificial light, and sufficient ventilation to ensure adequate thermal and acoustic comfort.
4. **Rank 4—Very Good:** The building's geometry and configuration contribute to high spatial efficiency. The layout allows for ease of movement and good accessibility. Natural light and ventilation are effectively used to enhance thermal and acoustic comfort.
5. **Rank 5—Excellent:** The building's geometry and configuration demonstrate optimal use of space, with a layout that ensures easy movement and excellent accessibility. Natural light and ventilation are optimized to provide excellent thermal and acoustic comfort, meeting and exceeding all design standards.

2.2.9. Aesthetic Design

Assessing the aesthetic design of a building is a subjective task as it largely depends on individual preferences. However, it is possible to use certain objective criteria based on architectural theories and principles, such as proportion, harmony, rhythm, contrast, and unity. In the following, each of the five ranks is associated with an increasing level of aesthetic appeal [46]:

1. **Rank 1—Poor:** The design does not consider principles of proportion, harmony, rhythm, contrast, and unity. The building does not evoke a positive response and lacks visual appeal.
2. **Rank 2—Fair:** The design reflects a basic understanding and implementation of the aesthetic principles but lacks cohesiveness. Some elements may appear disconnected or disjointed.
3. **Rank 3—Good:** The design shows a balance of aesthetic principles with a noticeable sense of proportion, harmony, and rhythm. The building's design evokes a generally positive response.
4. **Rank 4—Very Good:** The design effectively incorporates aesthetic principles, resulting in a visually appealing structure. Proportion, harmony, rhythm, contrast, and unity are clearly exhibited in the design, evoking a strong positive response.
5. **Rank 5—Excellent:** The design demonstrates an exceptional understanding and application of aesthetic principles. The building's design is highly appealing, evoking a strong emotional response and effectively blending proportion, harmony, rhythm, contrast, and unity to create a compelling and memorable aesthetic experience.

Please note that aesthetic appeal can be highly personal and vary greatly among different people and cultures. Therefore, this is a generalized guide that may not apply to every case.

2.2.10. Energy Efficiency Class

Usually, the following classes are used for standard construction projects: A++, A+, A, B, C, D, E, F, and G. We split these into the following five groups, and since A++ is used as an important requirement for many construction projects in the Euro zone, we put it into a separate category:

1. **Rank 1:** G and F;
2. **Rank 2:** E and D;
3. **Rank 3:** C and B;
4. **Rank 4:** A and A+;
5. **Rank 5:** A++.

2.2.11. Heating and Ventilation

The ranking of ventilation is based on the type of the ventilation being used in the project.

1. **Natural Ventilation System:** This system relies on passive air flow through doors, windows, and other openings. It does not consume energy for operation but lacks control over air quality and can result in energy losses due to unregulated thermal exchange with the outdoor environment. A typical example might have manually operated windows and vents without any mechanical ventilation components.
2. **Standard Mechanical Ventilation System:** This system mechanically brings fresh air into the building and expels stale air, offering a more controlled ventilation than natural ventilation. However, it lacks energy efficiency as it does not recover heat from the outgoing air. The system might include fans for supply and removal, with simple filters and basic control mechanisms.
3. **Improved Standard Mechanical Ventilation System:** This is an upgraded version of the standard mechanical ventilation system that includes a heat recovery unit with a moderately efficient heat exchanger, an electric heater, fans, and higher-grade filters. This system improves energy efficiency by pre-heating the incoming air with the outgoing air. It may also have a basic system for managing combustion air, with static controls for various components.
4. **Advanced Mechanical Ventilation System with Heat Recovery:** This system includes a high-efficiency heat recovery unit, more energy-efficient fans, and advanced filters. It offers improved control mechanisms, such as demand-controlled ventilation based on CO₂ levels or occupancy sensors. It also provides more reliable combustion air management, eliminating the need to manually open windows or other openings. This system represents a significant upgrade in energy efficiency and control compared to the previous system.
5. **State-of-the-Art Mechanical Ventilation System with Energy Recovery:** This system not only recovers heat but also humidity, providing additional energy savings and improved indoor air quality in climates where humidity control is a concern. It uses high-performance components throughout and employs advanced control systems that dynamically adjust ventilation based on various factors. For example, it may include a very high-efficiency energy recovery unit, variable speed fans, superior filters, and smart controls that adapt to changes in indoor and outdoor conditions.

The systems are ranked from 1 (least efficient) to 5 (most efficient). The third system is a moderately upgraded version of a standard mechanical ventilation system and is roughly comparable in efficiency to the system we provided, assuming some improvements in heat recovery and control systems.

2.2.12. Insolation and Light

The ranks for insolation and light are the following:

1. **Rank 1—Poor Quality:**
 - Traditional Building: Natural light ratio <1:10, Artificial lighting <50 lx.
 - Modular Building: Natural light ratio <1:10, Artificial lighting <50 lx.
2. **Rank 2—Basic Quality:**
 - Traditional Building: Natural light ratio 1:10, Artificial lighting 50–74 lx.
 - Modular Building: Natural light ratio 1:10, Artificial lighting 50–74 lx.
3. **Rank 3—Moderate Quality:**
 - Traditional Building: Natural light ratio 1:8, Artificial lighting 75–99 lx.
 - Modular Building: Natural light ratio 1:8, Artificial lighting 75–99 lx.
4. **Rank 4—Good Quality:**
 - Traditional Building: Natural light ratio 1:6, Artificial lighting 100–150 lx.
 - Modular Building: Natural light ratio 1:6, Artificial lighting 100–150 lx.

5. Rank 5—Excellent Quality:

- Traditional Building: Natural light ratio >1:6, Artificial lighting >150 lx.
- Modular Building: Natural light ratio >1:6, Artificial lighting >150 lx.

2.2.13. Sound Isolation

The rankings for sound isolation quality in buildings (for both traditional and modular buildings) are the following:

1. **Rank 1—Minimal Sound Isolation:** Traditional/Modular Building: Sound Reduction Index (SRI) <30 dB;
2. **Rank 2—Basic Sound Isolation:** Traditional/Modular Building: Sound Reduction Index (SRI) 30–39 dB;
3. **Rank 3—Moderate Sound Isolation:** Traditional/Modular Building: Sound Reduction Index (SRI) 40–49 dB;
4. **Rank 4—Good Sound Isolation:** Traditional/Modular Building: Sound Reduction Index (SRI) 50–60 dB;
5. **Rank 5—Excellent Sound Isolation:** Traditional/Modular Building: Sound Reduction Index (SRI) >60 dB.

2.2.14. Security

In context of residential modular houses, security refers to protection against burglary and theft. The system provided to ChatGPT as an example involved GSM/GPRS connectivity, sound alarms, text notifications, app-based controls, zone-specific sensors, magnetic contacts, and motion/glass impact detectors. It showed a high level of sophistication and comprehensive coverage; therefore, the system was ranked as a 4 on a scale from 1 to 5. Here is an overview of security systems for modular buildings from the simplest to the most advanced:

1. **Basic Security System:** This system consists of minimal intrusion detection components, which could include simple door and window contacts, along with a couple of motion detectors. There is a basic control panel with a local siren for immediate vicinity alerts, but the system lacks any form of remote monitoring or notification.
2. **Intermediate Security System:** This system upgrades the basic system by integrating basic remote monitoring functionality through a wired telephone connection or simple internet connection. This could include door and window contacts, multiple motion detectors, and a control panel with a basic digital display. Notifications could be achieved through dial-out phone calls or simple text messages to predefined numbers.
3. **Advanced Security System:** This system encompasses a wider range of detection methods such as door and window contacts, multiple motion detectors, and glass break detectors. It provides remote monitoring functionality through a Wi-Fi connection, which allows the user to monitor and control the system with a smartphone application. Automated notifications are provided through text and email alerts. The system may also have some level of integration with other smart house systems.
4. **Comprehensive Security System:** Building upon the advanced system, this security system includes additional intrusion detection components such as video surveillance and biometric access controls. It provides remote monitoring through both Wi-Fi and GSM/GPRS for redundancy and notifications, including voice calls, text messages, and emails. The system has a high level of integration with a smart house automation system and includes advanced features like timed arming and disarming, geofencing, and customized notifications.
5. **State-of-the-Art Security System:** The most comprehensive security system includes all features from previous systems but adds more sophisticated measures. It might include facial recognition, artificial intelligence for threat detection, smart locks, and full integration with a house automation system. The system may provide cloud storage for video surveillance footage, advanced tampering detection measures, and a

backup power supply. The notifications could include a real-time video feed to mobile devices, and multi-factor authentication could be used for system access.

3. The Application of the Methodology

In this section, we describe the main methods that were applied to the case study of a project evaluation in Lithuania. The methodology applied in this study consists of the following main steps:

1. **Establishment of Factors:** In utilizing the Delphi method, factors related to the successful implementation and efficient operation of modular houses were identified. In using the Delphi method, the evaluation was usually performed using two rounds. The list of factors used in different rounds is provided in Tables 6 and 7. During the first round, an evaluated list of these factors, prioritized based on relevance and impact, was compiled.
2. **Selection of Evaluable Factors:** From the compiled list, factors suitable for evaluation using a scoring system were selected. We used a threshold value of 3.3 to separate the representative factors for the second round according to the technique presented in [47], i.e., all factors with scores (obtained according to [48]) that are greater or equal than the threshold value 3.3 were passed to the second round (see Tables 6 and 7). Thirty respondents took part in the first and second Delphi rounds, which is the recommended number of respondents [49].
3. **Determination and Interpretation of Scale Values:** The interpretation of values for the scale of factors was performed with the assistance of ChatGPT. The process involved describing each factor using the prompt-and-response method, which facilitated the assignment of a numerical value to represent its importance. This approach allowed for consistent evaluation across different aspects of modular housing implementation. Each value was evaluated to understand its significance in the context of modular housing. The interpretations provided insights into their collective contribution to the project's success.
4. **Analysis of ChatGPT Method:** The application of the obtained scale to specific example let us evaluate the advantages and disadvantages of using the ChatGPT method. The conclusions highlight the method's strengths in handling complex evaluations and identify areas for potential improvement or caution. The findings are succinctly presented, offering valuable insights into the application of ChatGPT in research methodologies.

In Tables 6 and 7, the '+' and '−' symbols denote whether the according factor was included or not, respectively, in the survey in the corresponding round of the Delphi method. As it can be seen from these tables, many factors were excluded from the final round because of the lack of interest from the respondents. As it can be clearly seen, the sustainability-related factors were among the excluded ones; the users tended to seek the best ratio of price and benefit for themselves. Perhaps including some information about some attractive conditions, e.g., stimulating toward sustainable solutions, would make some positive shifts in the attractiveness of such solutions. The inclusion of such information was not considered in the current research; however, the current result reveals the problem of the priorities of the respondents participating in the survey, i.e., the sustainability factors have low importance. Another important note, sustainability increasing solution support is often implemented through requirements for projecting companies rather than end users, e.g., as it is performed with newer requirements for residential buildings in Lithuania. The energy performance class of new buildings must be not less than A++ if the construction works will start after the 2021 1st of January [50]. Additional statistics are presented—the means of evaluations were calculated, and the standard deviation SD was determined.

Table 6. Factor presence in different rounds part 1.

Round 1				Round 2			
Factor Code	Mean	SD	Score	Factor Presence	Mean	SD	Factor Presence
B1.1.	4.2	0.925	3.693	+	4.233	0.774	+
B1.2.	4.267	0.907	3.716	+	4.1	0.885	+
B1.3.	4.833	0.379	4.606	+	4.3	0.837	+
B1.4.	4.767	0.43	4.582	+	4	0.91	+
B1.5.	4.267	1.015	3.362	+	4.267	0.868	+
B1.6.	4.133	1.137	3.305	+	4.367	0.718	+
B1.7.	4.6	0.498	4.524	+	4.3	0.794	+
B1.8.	3.53	0.973	3.466	+	4.167	0.874	+
B1.9.	-	-	-	—	3.933	0.828	+
B1.10.	3.667	1.155	3.141	+	-	-	—
B1.11.	4	0.983	3.28	+	-	-	—
B1.12.	2.867	1.196	2.866	+	-	-	—
B1.13.	4.067	1.048	3.291	+	-	-	—
B1.14.	-	-	-	-	-	-	—
B2.1.	3.733	0.944	3.536	+	3.833	0.986	+
B2.2.	3.933	1.048	3.591	+	3.533	1.167	+
B2.3.	4.633	0.615	4.196	+	4.133	0.9	+
B2.4.	4.5	0.938	3.446	+	4.567	0.817	+
B2.5.	4.433	0.858	3.431	+	4.4	0.86	+
B2.6.	4.067	0.868	3.656	+	4.1	0.96	+
B2.7.	4.333	0.922	4.073	+	3.867	1.196	+
B2.8.	4.4	0.77	3.773	+	3.967	1.033	+
B2.9.	-	-	-	—	4.3	0.837	+
B2.10.	3.867	0.937	3.237	+	-	-	—
B2.11.	3.6	1.07	3.137	+	-	-	—

Table 7. Factor presence in different rounds part 2.

Round 1				Round 2			
Factor Code	Mean	SD	Score	Factor Presence	Mean	SD	Factor Presence
B3.1.	3.933	0.907	3.609	+	3.667	1.269	+
B3.2.	-	-	-	—	4.367	1.066	+
B3.3.	-	-	-	—	3.8	1.157	+
B3.4.	3.867	1.008	3.232	+	-	-	—
B3.5.	3	1.114	2.914	+	-	-	—
B3.6.	3.6	0.969	3.144	+	-	-	—
B4.1.	4.1	0.845	4.004	+	3.7	1.208	+
B4.2.	4.333	0.711	4.091	+	3.933	1.081	+
B4.3.	3.367	1.033	3.056	+	-	-	—
B4.4.	4	1.145	3.25	+	-	-	—
B4.5.	2.533	1.196	2.757	+	-	-	—
B4.6.	3.6	1.07	3.137	+	-	-	—
B4.7.	3.533	1.106	3.109	+	-	-	—
B5.1.	3.733	1.173	3.161	+	-	-	—
B5.2.	3.567	1.073	3.116	+	-	-	—
B6.1.	2.833	1.289	2.829	+	-	-	—
B6.2.	3.9	1.213	3.212	+	-	-	—
B6.3.	3.733	1.081	3.172	+	-	-	—
B6.4.	3.233	1.357	2.963	+	-	-	—
B6.5.	3.6	1.249	3.1	+	-	-	—
B6.6.	3.3	1.236	3.005	+	-	-	—
B6.7.	3.033	1.326	2.893	+	-	-	—
CB5.	4.433	0.679	4.126	+	4.433	0.728	+
CB6.	4.267	1.015	3.362	+	4.067	0.868	+

Workflow Diagram

The whole evaluation process can be summarized in a workflow diagram. In this section, we provide the workflow diagram of the proposed evaluation process. It is presented in Figure 3. Detailed descriptions of the steps are as follows:

1. **Start.** The beginning of the evaluation process.
2. **Initial Data Collection.** Collect practical examples of modular buildings to serve as the initial dataset.
3. **Application of the Delphi Method.** Engage a panel of experts to apply the Delphi method, iterating through rounds to refine and determine key criteria and their relative weights for evaluating modular buildings.
4. **ChatGPT Involvement for Data Expansion and Analysis.**
 - Provide ChatGPT with a representative set of sample data from the collected examples.
 - ChatGPT uses this dataset to generate additional contextual information and data aligned with the refined criteria from the Delphi method.
5. **Evaluation Scale Development Using ChatGPT.** Develop an evaluation scale based on the information generated by ChatGPT, in alignment with the criteria and weights established through the Delphi method.
6. **Expert Verification of the Evaluation Scale.**
 - An expert verifies the evaluation scale to ensure its accuracy and validity.
 - If serious flaws are detected, the process returns to the ChatGPT Data Expansion and Analysis stage (Step 3), including the description of the flaws for ChatGPT to address.
7. **Final evaluation.** Conduct the final evaluation of modular buildings using the developed and verified evaluation scale.
8. **End.** The conclusion of the evaluation process.

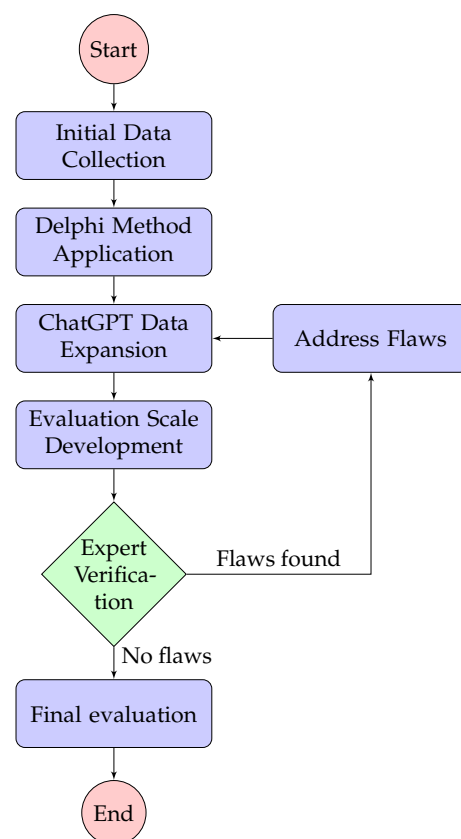


Figure 3. Workflow diagram illustrating the evaluation process.

It is important to note that, as it was mentioned before, the initial scale for ranking, suggested by ChatGPT, was confirmed by the expert without any modifications. It was acknowledged as adequate and accurate for fulfilling the goals of this study.

4. Case Study: The Modelling of Investor's Behaviour

The Description of the Case

In this section, we briefly introduce the case of a project evaluation in Lithuania and the application of the previously described methodology to this case.

It depends on concrete method and objectives how these estimates will be used. The simple approach is to compute the sum of the estimates in order to obtain the project estimation; in the provided case, the sum is equal to 403. However, the interpretation of this result is out of the scope of the current research; it usually depends on the context of the data being analyzed.

In using the Delphi method, certain factors were evaluated based on the ranking description provided by ChatGPT, while others were assessed based on the opinions of customers and experts. Table 8 presents the distribution of factor evaluators; most factors were evaluated using the scale that was provided by ChatGPT, and another approach was used in cases where objectiveness of opinion was necessary. In other words, the whole evaluation procedure is simplified, leaving only necessary factors for the user to evaluate. It is important to note that the data were limited to a single detailed project example; thus, the one-shot learning technique was applied.

Table 8. The approach for the evaluation of different factors.

Factor Group Number and Name	Factor ID	The Approach for Factor Evaluation
B1. Economic factors that are related to the construction and efficient operation of a modular house	B1.1	ChatGPT
	B1.2	ChatGPT
	B1.3	ChatGPT
	B1.4	ChatGPT
	B1.5	ChatGPT
	B1.6	ChatGPT
	B1.7	ChatGPT
	B1.8	ChatGPT
	B1.9	ChatGPT
B2. Factors that are related to the architectural implementation and efficient operation of a modular house	B2.1	Customer's opinion
	B2.2	Customer's opinion
	B2.3	Customer's opinion
	B2.4	ChatGPT
	B2.5	ChatGPT
	B2.6	ChatGPT
	B2.7	ChatGPT
	B2.8	Customer's opinion
	B2.9	Customer's opinion
B3. Factors that are related to the psychological and social needs of a modular house resident	B3.1	Customer's opinion
	B3.2	ChatGPT
	B3.3	Customer's opinion
B4. Factors that are related to the location of a modular house	B4.1	Customer's opinion
	B4.2	Customer's opinion
CB5. Preliminary price of a modular house	CB5	Customer's opinion
CB6. Compliance of the modular house with norms and standards	CB6	Expert's opinion

A one-story, 60-square-meter modular house project was selected as the case study. This project accounts for investments in not only the house, its construction, and furnishing but also the purchase of the plot of land for construction.

The evaluation results for this illustrative project are shown in Table 9. The score of each factor is multiplied by its weight. The weighted scores are provided in the last column of Table 9. This evaluation method is beneficial for comparing individual projects to determine the best option for the customer.

Table 9. The factor evaluation.

Factor	Data for Evaluation	Score	Weight	Estimation
B1.1	Up to 8 weeks	4	4.23	16.93
B1.2	EUR 1000	5	4.10	20.50
B1.3	EUR 12,000	4	4.30	17.20
B1.4	100 years	4	4.00	16.00
B1.5	Total USD 169,430, including additional investment in the amount of USD 117,590	5	4.27	21.33
B1.6	5 years	2	4.37	8.73
B1.7	USD 3240 per year (including the depreciation of the house, land taxes, and utility bills)	2	4.30	8.60
B1.8	It is possible to adapt the house to the most diverse needs of the residents	3	4.17	12.50
B1.9	The house is carefully designed, manufactured by certified professionals using certified materials	3	3.93	11.80
B2.1	One-story house, 60 m ² , with external dimensions 9735 × 6080 m and 2480 mm high	4	3.83	15.33
B2.2	The house is finished in natural wood, and the roof is covered with profiled sheet	4	3.53	14.13
B2.3	The functionality of the house is good	4	4.13	16.53
B2.4	A++ class	5	4.57	22.83
B2.5	A heat pump with a boiler and house design ensures even heating and efficient ventilation	4	4.40	17.60
B2.6	Up to 150 lx lighting in the living rooms and kitchen, up to 300 lx in the bathroom, corridors, and auxiliary rooms	4	4.10	16.40
B2.7	C class (55–60 dB.)	4	3.87	15.47
B2.8	All the necessary amenities and communications are connected	5	3.97	19.83
B2.9	The price includes the elements of the house, the value-added tax, delivery to the location, assembly, and connections	4	4.30	17.20
B3.1	The location of the house is familiar to the customer, and the environment is suitable for living	5	3.67	18.33
B3.2	Traditional protection with sensors	1	4.37	4.37
B3.3	The plot is located in an array of gardens, surrounded by greenery, and the plot is landscaped	5	3.80	19.00
B4.1	The plot of the house is located in an array of gardens, the environment is clean, and the neighbors are familiar	5	3.70	18.50
B4.2	The place is easily accessible by car, but the public transport connection is poor	4	3.93	15.73
CB5	USD 51,840 (The price includes the elements of the house, the value-added tax, delivery to the location, assembly, and connections)	4	4.43	17.73
CB6	The evaluated house was designed and built by certified professionals, in accordance with the requirements of the Eurocodes, using certified materials	5	4.07	20.33

Several key considerations are highlighted in this evaluation as follows:

1. The scores for certain factors were assigned based on the subjective judgment of the evaluator, as the evaluation of these factors is inherently subjective. Specifically, these factors include B2.1, B2.2, B2.8, B2.9, B3.1, B3.3, B4.1, B4.2, CB5, and CB6.
2. Evaluating a single project in isolation does not suffice for a comprehensive final evaluation. A comparative analysis involving multiple projects is required for such an evaluation. Consequently, the final evaluation should be contextualized within a decision-making framework, although this aspect falls beyond the scope of the current research.
3. The evaluation of factor CB6 demands specific expertise, necessitating the involvement of an expert in some cases. In this particular instance, the evaluator possessed the necessary competence to assess this factor independently.
4. For the remaining factors, evaluator bias is significantly reduced, thanks to the implementation of a standardized scale, which is an important achievement and a notable contribution of our publication. This scale, meticulously developed with the assistance of ChatGPT, ensures a more objective and consistent evaluation process across different evaluators and contexts.

5. Discussion

In examining the customer priorities for modular houses, it is evident that sustainability-related factors that directly impact the house's operating economics and living conditions, such as energy efficiency class, are given precedence. This focus reflects a growing consumer awareness of the immediate benefits of sustainable features, particularly in terms of cost savings and enhanced living comfort. As our research emphasizes the importance of sustainability and efficiency in modular construction, the findings from a study on Building Information Modeling (BIM) [51] become particularly relevant. This study identified key drivers for BIM adoption that parallel our identified factors for modular building selection, highlighting innovation in construction practices as critical for both fields (Modular Construction and BIM).

Our findings on modular construction, emphasizing efficiency and sustainability, complement recent research that identifies critical challenges in BIM implementation. The solutions and methodologies we propose could be instrumental in addressing these BIM-related challenges, offering valuable insights for their resolution [52]. However, it is crucial to recognize that factors indirectly related to customer needs, like carbon emissions during the production, transportation, and construction phases, tend to be less emphasized. This oversight presents a significant challenge in the sustainable development of the modular housing sector. This suggests a need for manufacturers, transport companies, and builders to proactively address these broader environmental impacts, even if they are not top-of-mind for consumers. Their involvement is vital in ensuring the overall sustainability of the sector, extending beyond immediate customer concerns.

The divergent views of experts, customers, and other stakeholders in modular housing also pose challenges. Resolving these discrepancies requires a strategic approach to find common ground and compromises. In this context, tools like ChatGPT can be instrumental. By providing a wide array of information and facilitating dialogue, ChatGPT can aid in resolving conflicts and support more sustainable decision-making processes.

In addressing consumer behavior, it is observed that while consumers recognize the importance of sustainable practices and often expect them to be standard, this does not necessarily translate into brand loyalty or a preference for companies with the lowest environmental impact. This contradiction, highlighted in [53], reveals a gap between consumer ideals and their willingness to incur additional costs for sustainability. This paradox in consumer behavior underscores the complexity of integrating sustainability into business models and the need for innovative strategies that align consumer expectations with sustainable practices without imposing prohibitive costs. Addressing this paradox is beyond the scope of our current study but represents a critical avenue for future research. Expanding on strategies to bridge this gap—whether through targeted educational programs, incentives for sustainable living, or enhanced marketing strategies that better communicate the long-term benefits and cost savings of sustainable features—could provide valuable insights. This gap underscores the need for a multidisciplinary approach, combining insights from environmental psychology, marketing, and construction management to develop effective strategies that align consumer behavior with sustainable construction practices. We leave this as an important area for further exploration, urging researchers to delve into the complexities of consumer decision-making processes to foster a more sustainable modular housing market.

In our investigation into modular construction, we encountered the need for optimization in project management, a theme also central to a recent study on time–cost optimization in construction projects. This study introduced a modified dynamic oppositional learning TLBO (MDOLTLBO) algorithm to enhance the efficiency of finding optimal solutions [54]. The innovative approach taken to refine the population initialization and search space in this study parallels our efforts in developing an evaluation scale for modular building projects, where optimizing decision-making processes is key. The application of such advanced optimization techniques in both contexts underscores their importance in streamlining complex construction projects.

In this paper, we aim to provide a comprehensive overview of the advantages and disadvantages of using ChatGPT, drawing from the recent literature to highlight its potential benefits, challenges, and areas for future exploration.

Advantages of using ChatGPT for building project evaluation include the following:

1. **Broad Information Access:** ChatGPT can draw upon a vast range of information pertaining to the factors being evaluated. This allows for comprehensive insights and analyses.
2. **Scaled Evaluation:** ChatGPT can categorize the values of the evaluated factors according to a predefined scale, providing a detailed description for each point on the scale. This covers the need for the expert to create a described scale suitable as a part of the evaluation instructions.
3. **Rapid Responses:** Queries posed to ChatGPT are answered swiftly, streamlining the analysis process and saving time. Thus, a similar approach might be efficient in other similar studies as well.
4. **Quality Language Output:** Responses from ChatGPT are articulated in coherent and professional language, making the information easily digestible. In this sense, ChatGPT being a language model means that there is no drawbacks in the language quality context.
5. **Consistency:** Unlike human experts, ChatGPT provides consistent answers over time, ensuring that evaluations are not influenced by factors like fatigue, mood, or personal bias.

Disadvantages of using ChatGPT for building project evaluation include the following:

1. **Precise Prompting Required:** Formulating precise prompts is essential when interacting with ChatGPT. This often necessitates collecting detailed information about each subject under investigation, i.e., expertise for correct prompts is needed, and it can be seen as a partial replacement of expertise in the field in which the evaluation is being conducted.
2. **Accuracy Concerns:** While ChatGPT is informed by a vast amount of data, its responses may occasionally be imprecise or not entirely relevant. Users may need to spend time verifying and, if necessary, correcting these responses. An expert verified the ChatGPT output in our case.
3. **Subjective Limitations:** ChatGPT is not equipped to provide answers that rely on the subjective opinions of specific individuals, be it the customer, expert, or any other stakeholder. For criteria that implies a subjective assessment by its nature, the assessment must still be conducted by the customer.
4. **Knowledge Cutoff:** ChatGPT's knowledge is not continuously updated. Therefore, it may not be aware of very recent trends, studies, or best practices in the building industry post its last training cut-off. In particular, this is important in the case of data that are very sensitive to changes over time; thus, this did not have a big negative impact in our case.
5. **Lack of Context Awareness:** Unlike human experts who can adjust their assessments based on nuanced understanding and context, ChatGPT might not always catch subtle project-specific intricacies. While this can be mitigated to some extent with precise and detailed prompting, it does not entirely replace the depth of understanding that a human expert might have.
6. **Unavailability of references to the source of knowledge:** It is impossible to track the original source of different parts of ChatGPT-generated knowledge; moreover, ChatGPT does not take responsibility for its output.

It is important to note that the knowledge that was generated by ChatGPT is not considered a unique output that is needed for research; we used it for demonstration purposes. The main result is the proven fact of the ChatGPT-generated knowledge's suitability to cover (in the target domain) the needs of a complex professional evaluation procedure.

6. Conclusions

In this research, we explored the feasibility and effectiveness of employing ChatGPT in the evaluation of factors critical to the implementation and operation of modular houses. Our findings reveal several key insights:

1. **ChatGPT as a Tool for Scale Description:** ChatGPT has proven to be an efficient tool for articulating detailed descriptions for each score on a rating scale, significantly facilitating the scoring process for standardized evaluations. However, its utility is somewhat limited for factors requiring subjective judgments from experts or customers.
2. **This research showed the consumer behavior paradox toward sustainability,** highlighting the discrepancy between proclaimed sustainable values and actual purchasing behaviors—it was clearly observed after the Delphi method application in current research.
3. **Precision in Prompting and Verification:** The success of utilizing ChatGPT hinges on the precision of the prompts provided and the subsequent verification of its outputs against established knowledge. Despite ChatGPT's capacity to provide insightful responses, these may not fully capture the intricacies of consumer preferences and market dynamics. Adjusting prompts to better reflect the nuanced considerations of sustainability and cost implications in consumer choices is essential.
4. **Potential for Broader Application in Factor Generation:** Beyond evaluating predefined factors, there exists an opportunity to leverage ChatGPT in generating and refining the list of factors itself. Such an approach could offer novel insights into the paradox of consumer behavior toward sustainability, harnessing ChatGPT's ability to amalgamate diverse perspectives and identify emerging trends in sustainable living practices. In current research, the factors were curated using the Delphi method and interviews with potential modular house users. In a broader sense, this research contributes to the possible incorporation of modern large language models into the field of MCDM.
5. **Enhancing Decision-Making Sustainability:** ChatGPT's role extends to supporting more sustainable decision-making processes by providing stakeholders with access to a broad spectrum of information, reflecting current opinions and trends. Its application can facilitate the identification of optimal compromises, help bridge information gaps, and reduce uncertainties, particularly in reconciling cost, sustainability, and consumer preferences. This capability is invaluable in addressing the consumer behavior paradox, underscoring the importance of informed and balanced decision making in promoting sustainable modular housing solutions.
6. **The evaluation scale provided by ChatGPT was based on detailed single-example data (one-shot learning) that the large language model was fed.** Unfortunately, there is no convenient way for the user to access the exact information about data sources used by ChatGPT. However, the validation of results by an expert in the current research showed that the knowledge behind the output was sufficient, and only minor flaws needed to be addressed. Thus, the main research hypothesis about ChatGPT's ability to efficiently solve the evaluation scale establishment problem was confirmed. The information generated by ChatGPT itself should not be viewed as an original part of the knowledge in this research; however, it is both for demonstration purposes and as proof of possible suitability in the context of the methodology. In other words, it was used to demonstrate how to use ChatGPT to simplify expertise tasks for an expert who only needed to validate and correct the output.
7. **The other important output of this research is the transparent demonstration of prompts that led to satisfactory results.**

Future Directions: The outcomes of this study highlight the significant potential for leveraging advanced AI tools like ChatGPT in the modular construction sector and beyond. These tools not only enhance assessment methodologies but also provide deeper insights into consumer behaviors and sustainability preferences. Future research should aim to develop AI-driven tools that are specifically designed for the broader construction industry.

These tools should be adept at navigating the intricate dynamics of consumer decision making and the multifaceted aspects of sustainability. Pursuing such advancements is crucial for closing the current gaps and promoting a more sustainable framework in modular housing development and other construction domains.

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Appendix A. The Conversation with ChatGPT

Appendix A.1

Here, we provide an exported conversation with ChatGPT [5] as an important part of our investigation.

Prompt:

This is a ventilation system for modular building: “A separate mechanical ventilation system is designed in the house. Ventilation unit with heat recovery (rotary heat exchanger ef.85%), electric heater (1.0 kW 1), fans (2×0.2 kW 1), filters (ePM2.5 65%) for supply (ePM10 50%) for removal and control automation kit. The ventilation unit is provided in the technical room of the existing building. In the rooms, the air is distributed through round galvanized sheet ducts and is supplied to the rooms and removed through the supply and removal ceilings. Air flow control flaps are installed in the required places. Duct tightness class not lower than B. Air intake and exhaust ducts are insulated with thermal insulation. During the use of the fireplace, when additional air supply is required for combustion, the vent chamber reduces to compensate for the air supply air flow 80% (up to $384 \text{ m}^3/\text{h}$), exhaust air flow 20% (up to $96 \text{ m}^3/\text{h}$), $288 \text{ m}^3/\text{h}$ remains for air compensation. If the amount of air for combustion support is insufficient, the window is opened. For the hood in the kitchen, the duct from the hood goes to the exhaust zone of the vent chamber AHU-1, bypassing the chamber elements, air removal $450 \text{ m}^3/\text{h}$, without speed adjustment. An air flow closing-opening valve is installed on the duct in the hood, which must open when the hood is running and close when the hood is off”, please rank its’ efficiency from 1 to 5 (from worst to best) and provide alternative systems with the rest of 4 ranks. The answer’s result should be the list of 5 ranked and named systems along with their description. Provide the answer in LaTeX.

ChatGPT:

Given that this model has a knowledge cutoff in September 2021 and the performance of ventilation systems greatly depends on factors such as the exact layout and usage of the building, this will be a hypothetical ranking based on generalized understanding of such systems and their efficiency as of the last update. However, before the ranking, let’s analyse the provided system.

The provided system includes a heat recovery ventilation (HRV) unit, which is excellent for energy efficiency, and the 85% efficiency of the rotary heat exchanger is quite good. However, the reliance on opening a window if the combustion support is insufficient may lead to energy losses and impact overall performance. Similarly, the absence of speed adjustment for the kitchen hood exhaust could limit the system’s adaptability to different conditions. Let’s assign this system a rank of 3 for now.

Now, let's fill the other four ranks with some generalized system types. Please note, this is a simplified representation and the efficiency of actual systems would depend on numerous specific factors, including but not limited to their precise configuration, usage patterns, the specific building in question, and local climate conditions.

1. **Natural Ventilation System:** This is the most basic form of ventilation that relies on the natural flow of air through windows, doors, vents, and other openings. While it has no energy costs for operation and can be adequate for some settings, its performance can be inconsistent and it is generally less efficient than mechanical systems in terms of air quality control and energy management.
2. **Standard Mechanical Ventilation System (without heat recovery):** This system mechanically brings fresh air into a building and expels stale air. While it provides more consistent air exchange than a natural ventilation system, it can lead to significant energy losses as the incoming air must be heated or cooled to match the desired indoor temperature.
3. **Mechanical Ventilation System with Heat Recovery (as provided):** The system in question fits here. The addition of a heat recovery unit greatly improves energy efficiency by pre-heating (or pre-cooling) the incoming air with the outgoing air. However, the specific design provided has a few limitations as mentioned above.
4. **Improved Mechanical Ventilation System with Heat Recovery:** This is similar to the provided system but with a few improvements. It could include speed adjustment for the kitchen hood exhaust, a more sophisticated system for managing combustion air that doesn't rely on opening a window, and perhaps some additional energy-saving measures such as demand-controlled ventilation based on CO₂ levels or occupancy sensors.
5. **State-of-the-art Mechanical Ventilation System with Energy Recovery:** This goes one step beyond the previous category by not only recovering heat, but also humidity. An energy recovery ventilation (ERV) system can transfer moisture as well as heat between the outgoing and incoming air streams, which can provide additional energy savings and improve indoor air quality in climates where humidity control is a concern.

Again, please note that these are very generalized descriptions and real-world performance can vary significantly based on many factors.

Prompt:

You said "(as provided): The system in question fits here". In previous answer, however, I need full answer with all 5 ranks and full description of third rank in a style as it was not mentioned by me before.

ChatGPT:

I see, you want a reworked version of the given system ranked at 3, with new descriptions for all five systems. Please note that the specific efficiency of each system can vary widely based on the exact configuration and use conditions. However, here's a hypothetical ranking of ventilation systems for modular buildings:

1. **Natural Ventilation System:** This system relies on passive air flow through doors, windows, and other openings. It does not consume energy for operation but lacks control over air quality and can result in energy losses due to unregulated thermal exchange with the outdoor environment. A typical example might have manually-operated windows and vents without any mechanical ventilation components.
2. **Standard Mechanical Ventilation System:** This system mechanically brings fresh air into the building and expels stale air, offering a more controlled ventilation than natural ventilation. However, it lacks energy efficiency as it does not recover heat from the outgoing air. The system might include fans for supply and removal, with simple filters and basic control mechanisms.
3. **Improved Standard Mechanical Ventilation System:** An upgraded version of the standard mechanical ventilation system that includes a heat recovery unit with a

moderately efficient heat exchanger, an electric heater, fans, and higher-grade filters. This system improves energy efficiency by pre-heating the incoming air with the outgoing air. It may also have a basic system for managing combustion air, with static controls for various components.

4. **Advanced Mechanical Ventilation System with Heat Recovery:** This system includes a high-efficiency heat recovery unit, more energy-efficient fans, and advanced filters. It offers improved control mechanisms, such as demand-controlled ventilation based on CO₂ levels or occupancy sensors. It also provides more reliable combustion air management, eliminating the need to manually open windows or other openings. This system represents a significant upgrade in energy efficiency and control compared to the previous system.
5. **State-of-the-Art Mechanical Ventilation System with Energy Recovery:** This system not only recovers heat but also humidity, providing additional energy savings and improved indoor air quality in climates where humidity control is a concern. It uses high-performance components throughout and employs advanced control systems that dynamically adjust ventilation based on various factors. For example, it may include a very high-efficiency energy recovery unit, variable speed fans, superior filters, and smart controls that adapt to changes in indoor and outdoor conditions.

The systems are ranked from 1 (least efficient) to 5 (most efficient). The third system is a moderately upgraded version of a standard mechanical ventilation system and is roughly comparable in efficiency to the system you provided, assuming some improvements in heat recovery and control systems.

Prompt:

Consider this modular building security system: “The security alarm system is designed to transmit burglar alarm, fire alarm and system technical signals to the keyboard and/or to the user’s phone with the help of the GSM/GPRS module and/or to the manufacturer’s software installed on the PC. In any case, a warning about unauthorized access to the protected premises or a violation of the system is announced by sound sirens and text messages to the liquid crystal display on the control panel - keyboard. The location of the control panel is selected in the technical room and protected so that it cannot be accessed without triggering an alarm signal when the security system is in storage mode. To control the system (turn it on/off), a control panel—keyboard—is provided at the main entrance to the premises. Information about the protected zones and the current state of the system can be seen on the display screen of the remote control and in the manufacturer’s app, which is available on both mobile devices and PCs. System elements are protected against unauthorized opening/removal 24 h a day. Security alarm sensors are designed in such a way that there are only sensors of the same room in one zone. Magnetic contacts are designed for window and door protection. Combined motion/glass impact sensors are designed to protect the volume of the premises and to protect the windows from breaking. An outdoor siren is provided for the security system in the facade part of the building, and an indoor siren is provided for the keyboard. Wireless motion detectors compatible (of the same manufacturer) with the ESIM384 centrale are designed in the auxiliary building”, please rank its’ efficiency from 1 to 5 (from worst to best) and provide alternative systems with the rest of 4 ranks. The results should be the list of 5 ranked and named systems along with their description. I need full answer with all 5 ranks and full description in a style as it was not mentioned by me before. Provide the answer in LaTeX.

ChatGPT:

Given that I don’t have access to real-time data, this will be a hypothetical ranking based on generalized understanding of such systems as of the last update. The ranking will be focused on factors such as security, redundancy, control, automation, and connectivity.

Your provided system involves GSM/GPRS connectivity, sound alarms, text notifications, app-based controls, zone-specific sensors, magnetic contacts, and motion/glass impact detectors. It shows a high level of sophistication and comprehensive coverage,

therefore, I'd rank this system as 4 on a scale of 1 to 5. Let's create an overview of security systems for modular buildings from the simplest to the most advanced.

1. **Basic Security System:** This system features minimal intrusion detection components, such as simple door/window contacts and a couple of motion detectors. It lacks advanced monitoring, notification, and control capabilities. It might include a simple siren for local alerts but does not provide remote monitoring or control functionality.
2. **Standard Security System with Basic Connectivity:** An upgrade to the basic system, this includes more sensors and introduces basic remote monitoring functionality, possibly via a phone line or a simple Internet connection. It might include door/window contacts, several motion detectors, and a control panel with basic display capabilities. Notifications could be limited to phone calls or simple text messages.
3. **Advanced Security System with Smart Capabilities:** This is a more comprehensive system that includes a wider range of sensors (door/window, motion, glass break) and introduces smart capabilities. It might feature Wi-Fi connectivity for remote monitoring/control via a smartphone app, automated notifications (text/email), and some level of integration with other smart home systems.
4. **Comprehensive Security System with GSM/GPRS Connectivity (as provided):** The provided system fits this category. It includes a wide range of sensors (magnetic contacts, combined motion/glass impact), offers remote monitoring/control via GSM/GPRS, and provides alerts via multiple channels (siren, text notifications). It offers app-based control and displays system state information on a remote control. It also features protective measures against unauthorized tampering.
5. **State-of-the-Art Security System with Advanced Automation and Integration:** This system builds on the previous category by incorporating additional advanced features. It could include advanced intrusion detection components (video surveillance, biometric access controls), AI-based threat detection, and full integration with a smart home automation system. It might also feature advanced tamper detection measures, backup power supply, and multiple communication channels for redundancy (Wi-Fi, GSM/GPRS, landline). Notifications could include voice calls, texts, emails, and app notifications.

The systems are ranked from 1 (least efficient) to 5 (most efficient). The fourth system is the one you provided, demonstrating a comprehensive security setup with a good balance of intrusion detection components and communication channels.

Prompt:

Again, you said "(as provided): The provided system fits this category". In previous answer, however, I need full answer with all 5 ranks and full description in a style as it was not mentioned by me before.

ChatGPT:

My apologies for misunderstanding your request earlier. Now, I understand you want a complete ranking, where the system you described is not directly used as one of the points of comparison but could be equivalent to one of the ranked systems in terms of functionality. Here is a hypothetical ranking of security systems:

1. **Basic Local Security System:** This is a simple system with only local alarm capabilities. It includes basic intrusion detection components like door/window contacts and a few motion detectors. However, it lacks advanced monitoring, remote notification, and control capabilities. The system has a local siren for alerts but does not offer remote monitoring or control functionality.
2. **Intermediate Security System with Connectivity:** This upgraded system includes more sensors and offers basic remote monitoring, likely through a phone line or simple internet connection. It comprises door/window contacts, motion detectors, and a control panel with basic display functions. Notifications are delivered via phone calls or basic text messages.

3. **Advanced Security System with Internet Connectivity:** A more comprehensive system, this includes a variety of sensors, such as door/window contacts, motion detectors, and glass break detectors. It introduces internet connectivity, allowing remote monitoring and control through a smartphone app. Notifications are delivered through automated text and email alerts.
4. **Comprehensive Security System with GSM Connectivity:** This sophisticated system includes an array of sensors, such as magnetic contacts, combined motion/glass break detectors, and advanced monitoring capabilities. It offers remote monitoring and control via GSM/GPRS, with alerts delivered through multiple channels such as sirens and text notifications. The system features app-based control and displays the system state information on a remote screen.
5. **State-of-the-Art Security System with Advanced Features:** Building upon the comprehensive system, this state-of-the-art security setup includes additional advanced features. These could include video surveillance, biometric access controls, artificial intelligence-based threat detection, and integration with other smart home systems. The system includes advanced tamper-detection measures, a backup power supply, and redundant communication channels (Wi-Fi, GSM/GPRS, landline). Notifications are delivered through a variety of channels, including voice calls, texts, emails, and app alerts.

In this revised ranking, your described system would likely fall around the “Comprehensive Security System with GSM Connectivity” level, although the specific features might not exactly match.

Prompt:

I need 5 intervals of building time bounds for 5 ranks (from longest to shortest) for both: traditional and modular buildings. Provide the answer in LaTeX.

ChatGPT:

Sure, let's discuss some general time frames for the construction of traditional and modular buildings, ranked from longest to shortest. Keep in mind that construction times can vary widely based on the size and complexity of the building, the number of workers, local regulations, and many other factors. These are rough estimates and should not be used for precise planning.

Rank	Traditional Building Time (Months)	Modular Building Time (Months)
1	24–36	12–18
2	18–24	9–12
3	12–18	6–9
4	9–12	4–6
5	6–9	3–4

In this table, Rank 1 represents the longest building times, while Rank 5 represents the shortest. For both traditional and modular buildings, the time frames are reduced as we move from Rank 1 to Rank 5. Generally speaking, modular buildings can be constructed in a shorter time frame compared to traditional buildings due to the advantages of factory production, concurrent site work, and reduced weather-related delays.

Prompt:

I need 5 intervals of building costs bounds for 5 ranks (from the most expensive to cheapest) for both: traditional and modular buildings. Provide the answer in LaTeX.

ChatGPT:

Costs in construction can vary considerably depending on factors such as location, design complexity, labor costs, materials used, the local real estate market, and more. As such, providing specific cost ranges can be challenging and potentially misleading. However, for the purpose of this exercise, let's discuss relative cost levels in very general terms for both traditional and modular buildings.

It's also important to note that while modular construction can offer some cost savings due to efficiencies in the building process, the cost of the finished building can be similar to traditional construction depending on the final design, finish choices, site work required, and other factors. The figures below are for illustrative purposes only and represent a range of potential costs per square foot in a hypothetical scenario.

Rank	Traditional Building Cost (\$/sq.ft.)	Modular Building Cost (\$/sq.ft.)
1	\$400–\$500	\$350–\$450
2	\$300–\$400	\$250–\$350
3	\$200–\$300	\$150–\$250
4	\$100–\$200	\$100–\$150
5	Below \$100	Below \$100

Please remember, the values are purely for illustrative purposes. Real costs may vary dramatically based on the factors mentioned earlier. Modular construction can be cheaper in some scenarios but not in all cases. It is always advisable to consult with construction professionals to get accurate estimates for your specific project.

Prompt:

Please, consider the Euro zone, use Euros and International System of Units.

ChatGPT:

Thank you for the clarification. As per your request, here's a hypothetical breakdown of costs in the Eurozone, in Euros per square meter. This ranking is from the most expensive to the least. Note that these costs can vary widely depending on the factors mentioned previously.

Rank	Traditional Building Cost (€/sq.m)	Modular Building Cost (€/sq.m)
1	5000–6000	4500–5500
2	4000–5000	3500–4500
3	3000–4000	2500–3500
4	2000–3000	1500–2500
5	Below 2000	Below 1500

Again, these figures are hypothetical and for illustrative purposes only, and actual costs can vary greatly. It's always advisable to consult with construction professionals for precise estimates based on your specific project.

Prompt:

I need 5 intervals of price bounds for 5 ranks (from the most expensive to cheapest) for both: traditional and residential modular buildings. Please do separate ranking for: projecting costs, building costs, amount of investment. Consider the Euro zone, use Euros and International System of Units. Provide the answer in LaTeX.

ChatGPT:

Given the wide range of factors that can affect the cost of construction, it's challenging to provide precise costs. Variables such as location, materials, labor, design complexity, local regulations, and market conditions can significantly impact the overall cost.

However, for the sake of this exercise, let's discuss very general potential costs for both traditional and modular residential buildings in the Euro zone, broken down by project costs, building costs, and total investment. These figures are hypothetical and meant for illustrative purposes.

Please note that "projecting costs" often refers to the cost of architectural design and engineering work, while "building costs" generally refers to the actual construction costs.

Rank	Traditional Projecting (€/sq.m)	Modular Projecting (€/sq.m)	Traditional Building (€/sq.m)	Modular Building (€/sq.m)	Total Investment (€/sq.m)
1	500–600	450–550	5000–6000	4500–5500	5500–6600
2	400–500	350–450	4000–5000	3500–4500	4400–5500
3	300–400	250–350	3000–4000	2500–3500	3300–4400
4	200–300	150–250	2000–3000	1500–2500	2200–3300
5	Below 200	Below 150	Below 2000	Below 1500	Below 2200

Please remember that these figures are highly estimated, and actual costs can vary significantly. To get accurate estimates for a specific project, it’s always advisable to consult with construction professionals.

Prompt:

Correct your answer considering this definition of amount of Investment: The amount of investment refers to the total capital or financial resources needed for the construction project. It includes both projecting costs and building costs, along with other related expenses. The amount of investment is the total sum required to initiate and complete the project, covering all the planning, design, and construction activities. It includes costs for land acquisition, design and planning fees, construction costs, contingency funds, financing expenses, professional fees, marketing expenses (if applicable), and any other costs associated with the project. The amount of investment represents the overall financial commitment required to bring the construction project to completion. Also, provide different data for modular and traditional buildings.

ChatGPT:

Thank you for providing a more detailed definition. Based on this, let’s adjust the potential costs for both traditional and modular residential buildings. The projections still account for variables such as location, design complexity, materials, labor, and other costs. The final “Amount of Investment” column now also includes hypothetical costs related to land acquisition, professional fees, contingency funds, and other associated expenses.

Please note that these figures are hypothetical, and real costs can vary widely.

Rank	Traditional Projecting (€/sq.m)	Modular Projecting (€/sq.m)	Traditional Building (€/sq.m)	Modular Building (€/sq.m)	Total Investment (€/sq.m)
1	500–600	450–550	5000–6000	4500–5500	6000–7000
2	400–500	350–450	4000–5000	3500–4500	5000–6000
3	300–400	250–350	3000–4000	2500–3500	4000–5000
4	200–300	150–250	2000–3000	1500–2500	3000–4000
5	Below 200	Below 150	Below 2000	Below 1500	Below 3000

As always, consult with construction professionals for precise estimates based on your specific project.

Prompt:

Total Investment must be provided for modular and traditional buildings separately, i.e., two columns instead of single.

ChatGPT:

I apologize for misunderstanding your request earlier. Here is the corrected table with separate “Total Investment” columns for both traditional and modular residential buildings.

Rank	Traditional Projecting (€/sq.m)	Modular Projecting (€/sq.m)	Traditional Building (€/sq.m)	Modular Building (€/sq.m)	Total Investment (Traditional) (€/sq.m)	Total Investment (Modular) (€/sq.m)
1	500–600	450–550	5000–6000	4500–5500	6000–7000	5500–6500
2	400–500	350–450	4000–5000	3500–4500	5000–6000	4500–5500
3	300–400	250–350	3000–4000	2500–3500	4000–5000	3500–4500
4	200–300	150–250	2000–3000	1500–2500	3000–4000	2500–3500
5	Below 200	Below 150	Below 2000	Below 1500	Below 3000	Below 2500

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