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A Comparative Analysis of Design Criteria Influencing Building Material Selection Across Different Architectural Contexts

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ABSTRACT

The process of selecting building materials is a complex process that is affected by many restrictions, criteria and considerations. Often, the process is carried out spontaneously without considering the design criteria and neglects the building's function. Therefore, it is crucial to identify the key criteria impacting material selection. Design criteria vary based on a building's intended purpose and location, leading to distinct considerations. This study identifies five main design criteria: physical, cultural-social, environmental, economic, and technical. Experts in architecture participated in a survey, with Analytic Hierarchy Process (AHP) used to assign weights to these criteria. The research findings highlight that material select for a building's envelope depend on its function and context. In religious buildings, cultural criteria are vital, regardless of historical or modern contexts. Historical residential buildings prioritize cultural criteria, while modern ones lean toward economic considerations. Commercial buildings have historically been influenced by physical factors but are now more influenced by technical criteria. This study highlights the importance of considering a variety of design criteria when selecting building materials to ensure effective adaptation to the building's use and context.

1. INTRODUCTION

The design of the building has developed over the ages. Previously, buildings design based on building construction traditions that integrated materials, climate, physical constraints as well as cultural practices into forms of architecture to meet individual or group needs. Traditional buildings catered to people's needs, while considering climatic conditions and available materials [1]. The exterior envelope of the building acts as a first line of defense against external environmental factors such as weather, wind and rain [2]. Definition of the building envelope is an intermediate surface between the internal and external environment, consisting of a group of adjacent layers of materials that form a protective cover against climatic conditions and provide safety and privacy for the building [3]. Therefore, the components of the building envelope must be designed and selected in order to achieve the environmental, technical, socio-cultural, aesthetic and economic design criteria to achieve the optimal performance and efficiency of the building [1]. Design criteria are defined as "refer to the specific requirements, guidelines, and principles that inform the creation of an architectural design for a building, structure, or space. These criteria play a crucial role in shaping the final design and ensuring that it meets the intended objectives and functions while adhering to various constraints and standards. Architectural design criteria can vary depending on the project's scope, purpose, location, budget, and other relevant factors" [3, 4]. The criteria help in comparing the buildings' goals with its performance level. Therefore, design criteria are essential to ensure that the building meets the needs and expectations of users [5]. Building materials are no longer mere claddings with a secondary role in influencing the cultural appearance and character of the building but have transformed into essential tools in functionality. This change was reflected in the development of the building envelope's ability to transform the role of the material from a barrier to an important and influential element on the building's design and performance [6].

This research is significant in the field of architecture and design, providing a structured framework for the selecting building materials that takes into account design criteria for different functional patterns and contexts. The aim is to support architects and designers in creating buildings that are functional, environmentally sustainable and culturally integrated. This study is therefore a valuable resource for promoting informed decision-making in this regard.

Against this complex background, our central research question emerges: How do various design criteria influence the selection of building materials for architectural structures, and which of these criteria holds the greatest significance, depending on the building's function and its surrounding context?

Three types of functional buildings were identified as limitations of this study (religious, residential, and commercial), which are the most common types, and because case studies are available for these types within the historical and modern contexts.

The article is structured as follows (see Figure 1): it begins with an introduction, followed by a review of the literature related to the research problem, and a detailed description of the research methodology. Then, we analyze and discuss the results of the research, leading to the conclusion of the article, where we summarize our findings and provide recommendations based on the study's outcomes.

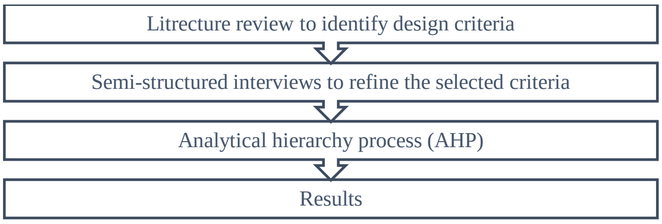


Figure 1. Research structure

2. RELATED STUDIES

2.1 Definition of building materials

William Morris stated in 1892 that "materials are the foundation of architectural engineering; perhaps one will not be mistaken if he defines architecture as the art of appropriate construction using suitable materials" [7]. In the pre-industrial era, the relationship between materials and architecture was primitive. Materials were chosen either due to their availability or their external appearance or durability [8]. In the industrial age, materials science has been separated as a discipline and the role of the engineer as someone who is able to select material rationally. Following Louis Sullivan's principle of "form follows function," architects and industrial scientists proclaimed the idea of "form follows material." Frank Lloyd Wright stated that "every new material means a new form and a new use if it is used according to its nature" [9]. This means that materials have transformed from being a means of construction to a method of work and thinking [8].

Every construction project includes the selection of building materials or the means used in the selection process, as the material selection process is the most important stage in product design. The material selection process is a complex and delicate task determined by an enormous number of choices of building materials [10]. The core design process is very important to the long-term success of engineering projects [11]. During the selection process for the building material, the architect takes into account a set of criteria related to the economic cost, performance and efficiency of the material, such as durability, hardness, maintainability, sound insulation and resistance, in addition to looking for the aesthetics criteria of the material and its acceptance by the community, while minimizing the negative effects on the building environment [12].

2.2 Determining the criteria for selecting building materials

This section aims to define design criteria impacting material selection, illustrate their interconnections, and establish the groundwork for analysis using the Analytic Hierarchy Process (AHP) with expert input.

Design criteria are necessary to ensure that the project meets the needs and expectations of users. Successful design relies on multiple criteria, depending on the viewpoints of the project participants [5]. These criteria must achieve two main purposes [3]:

- Guiding the design process.
- Assessing the project's success.

In this part, we will review a wide range of studies on criteria for selecting building materials. These studies examine critical aspects of design criteria in the selection of building materials, aligning with the objectives of this research. The study by Wastiels and Wouters [12] highlighted the need for identifying and regulating factors that architects take into account when choosing the best materials to complete the project. The study by Ogunkah and Yang [10] addressed design criteria and suggested a framework to make it easier to assess and choose locally sourced or recycled building materials in order to lessen their detrimental environmental impact. By identifying these factors, architects and designers may validate the accuracy of their choices and assess the beneficial effects of both objective and subjective factors in the selection process [10, 13]. In his study, Franzoni [14] made it clear that selecting building materials takes place during the design stage, where the needs of "green buildings" must be addressed by taking into account local construction practices and national/international rules. The study of Akadiri and Olomolaiye [15] proposed a set of factors that may be used to evaluate the elements impacting the selection process. These factors include "comprehensiveness," "applicability," "transparency," and "practical applicability." These variables were thought to be helpful in speeding up the selection of criteria by determining whether they are appropriate and address all pertinent concerns regarding the applicable principles [15]. The design criteria for selecting the materials for a building's facade in terms of maintainability were highlighted in the study of Kanniyapan et al. [2], failure of the facade in the post-construction period can result from neglecting maintenance issues. Sustainability indicators (environmental, technical, social, and economic) are the same criteria influencing the choice of building materials [15-18]. Use of materials from renewable resources, replaceable materials, recyclable materials, or materials that are widely accessible is required to accomplish construction sustainability. The life cycle analysis (LCA) of the material influences the choice of sustainable building materials [18]. Making a selection based on sustainable materials will help decision-makers cut costs and increase project success [13]. Kanniyapan et al. [19] found that despite being a complicated process that depends on the building's post-occupancy stage, which is influenced by several design criteria, choosing materials based on their maintainability helps projects succeed. On the other hand, the study by Saud et al. [20] focused on the criteria of selecting building materials for outside walls in order to increase building efficiency while decreasing the cost. The study of Al-Atesh et al. [21] also defined a number of criteria to consider when choosing environmentally friendly Green Building Materials (GBMs) and compared them to traditional materials. The criteria listed in the table directly relate to our research objective, aiding our understanding of how various design criteria influence building material selections based on function and context.

This serves as the foundation for our analysis of how different factors influence material selection. The "principle" column in the table refers to general concepts or topics. It serves as the main criteria under which a group of sub-criteria falls. This arrangement is intended to facilitate organized comprehension of the multifaceted criteria (see Table 1).

Table 1. Criteria for selecting building materials through the previous studies (author)

No.	Principle	Criteria	Recognized by
1	Site conditions	Building orientation	[12, 19]
		Accessibility	[10, 12, 16, 19]
		Adjacent environment	[12]
		Location	[10]
		Distance	[10, 16]
		Site layout	[10, 19]
		Scale	[10]
		Building orientation	[12, 19]
		Accessibility	[10, 12, 16, 19]
2	Building use	Building function	[10, 12]
3	Socio-cultural aspects	Type	[12]
		Style	[12]
		Aesthetics	[10, 14, 16, 17, 20]
		Local building traditions	[16, 18]
		Compatibility with cultural	[10, 13, 18]
		Communal identity	[10, 18]
		Socio benefit	[15]
4	Environmental aspects	Env. impacts	[10, 13, 15-17, 19]
		Env. Compatibility	[10, 13]
		Health and Safety	[2, 12, 10, 14, 16, 18, 21]
		Climate	[10, 16]
		Resource efficiency	[13, 15, 16, 18, 19, 21]
		Waste minimization	[13, 15, 16, 18, 21]
		Renewable sources	[15, 16, 18, 19, 21]
		Latent energy	[16]
5	Economic aspects	Economic status	[14, 18, 19]
		Availability of materials	[2, 10]
		Life-cycle cost	[10, 13, 15, 17, 19]
		Material embodied energy	[10]
		Affordability	[2, 10, 17, 19]
		Labour cost	[10, 21]
		Energy efficiency	[10, 19]
		Initial cost	[16]
		Maintenance cost	[16, 18, 20]
		Disposal cost	[16]
6	Technical aspects	Durability	[2, 12, 10, 14, 16, 19, 20]
		Thermal performance	[2, 12, 10, 13, 14, 16, 19, 20]
		Mechanical properties	[12]
		Acoustic performance	[2, 12, 14, 16, 17, 20]
		Fire resistance	[10, 12, 16, 19, 20]
		Bldg structure	[10, 17]
		Weather resistance	[10, 16, 19, 20]
		Performance capability	[13-16, 19]
		Clean ability	[2]
		Compatibility and Suitability with other materials	[2, 19]
		Maintainability	[16, 17, 20]
		Weight	[17, 20]
7	Personnel knowledge	Designer expertise	[10, 12]
		User options	[10]
		Creativity	[10, 17]
		Owner’s view	[10, 18, 21]
8	Documentation and details	Material performance documentation	[19]
		Develop guidelines for selecting materials	[19]
		Updated information on materials	[19]

3. STUDY METHODOLOGIES

3.1 Determining the influential criteria in selecting building materials

Previous studies have shown that the process of selecting building materials is considered a Multiple Criteria Decision Making (MCDM) problem. The selection is influenced by a wide range of design criteria, and these criteria change based on the goals of the project. The criteria will be categorized into five groups (physical, socio-cultural, environmental, economic, and technical) based on classifications from related studies and semi-structured interviews with eight experts in the architecture and design field. This classification considers the most comprehensive, incorporating all criteria influencing building material selection (see Table 2). This classification will simplify the pairwise comparison process, which is central to our evaluation methodology. We will use this classification to organize the expert questionnaire and use the Analytical Hierarchy Process (AHP). This will be explained in the following paragraphs.

Table 2. Lists the main design criteria influencing the use of building materials (author)

Design Main Criteria				
Physical Criteria	**Socio-Cultural Criteria**	**Environmental Criteria**	**Economic Criteria**	**Technical Criteria**
Building orientation	Type	Env. impacts	Economic status	Durability
Accessibility	Style	Env. Compatibility	Availability of materials	Thermal performance
Adjacent environment	Local building traditions	Health and Safety	Life- cycle cost	Mechanical properties
Location	Aesthetics	Climate	Material embodied energy	Acoustic performance
Distance	Compatibility with cultural	Resource efficiency	Affordability	Fire resistance
Site layout	Communal identity	Waste minimization	Labour cost	Bldg structure
Scale	Socio benefit	Renewable sources	Energy efficiency	Weather resistance
Building function	Creativity	latent energy	Initial cost	Performance capability
	Designer expertise		Maintenance cost	Clean ability
	User options		Disposal cost	Compatibility and Suitability with other materials
	Owner's view			Maintainability

Table 3. Preference level of criteria [22]

Rating Level	Verbal Judgment or Preference
9	Extremely Preferred
7	Very Strongly Preferred
5	Strongly Preferred
3	Moderately Preferred
1	Equally Preferred
2,4,6,8	Average Values

3.2 Criteria order

The ordering of criteria was determined through semistructured interviews with architecture and design experts. The interviews included questions about criteria that had a significant impact on the select of building materials. Questions cover topics such as the role of design criteria in selecting materials, classifying and ranking criteria within five categories, designer priorities, and criteria's influence on building function and context. Analysis of expert responses determined the relative importance of the criteria and organized and categorized them. Afterward, a questionnaire was distributed to 30 experts (with 21 responses), each possessing a minimum of 15 years of experience in the field of architecture and design. The questionnaire served to evaluate the relative importance of the study's five design criteria (physical, socio-cultural, environmental, economic, and technical). Then We conducted pairwise comparisons of these criteria which is central to the Analytical Hierarchy Process (AHP). For instance, we asked experts to compare the importance of physical criteria relative to socio-cultural criteria, and so on, using a scale from 1 to 9 (see Table 3). This assessment was conducted for each functional building type (religious, residential, and commercial) and within two contexts (historical and modern).

3.3 Decision making model based on Analytic Hierarchy Process (AHP) using expert choice software V.11

The Analytic Hierarchy Process (AHP) is one of the most popular and widely used techniques for assigning weights in Multi-Criteria Decision Analysis (MCDA). It excels in handling complex problems and decision-making in various fields, including material selection [23]. It is equipped to deal with both objective and subjective criteria in the decision-making process [24]. In order to make comparison and selection easier, the AHP technique helps decision-makers organize the problem into a hierarchy of alternatives and evaluation criteria [25]. It assesses each criterion using a hierarchical value tree and pair-wise comparison matrices to assess the performance of each criterion relative to others (see Figure 2).

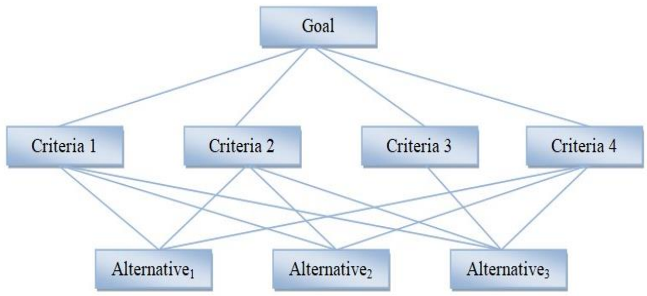


Figure 2. Analytic hierarchy process hierarchy structure [25]

Several studies have employed the Analytic Hierarchy Process (AHP) to determine the weights of criteria and identify the optimal material alternative. Examples include the studies [10, 13, 16, 18, 20, 21, 23].

In this study, the Analytic Hierarchy Process (AHP) was applied using Expert Choice software V.11; it is one of the applications of (AHP) for decision making. It allows for the design of the hierarchical structure of criteria and for pairwise comparisons between the criteria to determine the most influential ones in decision-making it measures the consistency index (CI) of the experts' answers, which must not exceed 0.1. This consistency index is one of the conditions of the hierarchy process that ensures the accuracy of the answers [22]. If CI<0.1, the expert's response is either repeated if possible or excluded.

- We organized a hierarchy of the five proposed criteria (physical, socio-cultural, environmental, economic, and technical).
- Then, we entered pairwise comparisons for these criteria based on the experts' answers through the questionnaire (as explained in the previous paragraph).
- To account for differences in building function and context, we applied the AHP separately for each functional building pattern (religious, residential and commercial) and for both contexts (historic and contemporary). This involves creating different hierarchies for each combination of building type and surrounding context: the first model for religious buildings within the historical context, the second for religious buildings within the modern context, the third for

residential buildings within the historical context, the fourth for residential buildings within the modern context, the fifth for commercial buildings within the historical context, and finally, the sixth for commercial buildings within the modern context.

• We conducted an analysis to determine the relative weight of each criterion within the building's functional type and specific context.

4. RESULT

By consulting with experts, we conducted pairwise comparisons of criteria, thus establishing priorities and evaluating the importance of each criterion. We integrated these results into the Expert Choice software, which employs the Analytical Hierarchy Process (AHP) to determine the weights of all criteria within different contexts.

Weighing a criterion is an important step in understanding its significance in decision-making. These weights, known as Local Weights (LW), are obtained from the Analytical Hierarchy Process (AHP), which is based on expert assessments and pairwise comparisons. The weights indicate the priority of each criterion relative to another criterion, where a higher weight indicates greater importance for that criterion.

These weights are used to prioritize each criterion when evaluating building materials for different functional building types and within different contexts. They serve as a guide for decision-makers in selecting materials that meet the specific requirements of each criteria. This will be clarified further through the succeeding analysis steps.

The functional pattern of the samples was determined through field visits to some of the buildings under study. This determination also involved assessing the surrounding context of each building, considering the physical, socio- cultural, environmental criteria within each context. We consulted with local experts and stakeholders who possessed a deep understanding of the specific site and its surroundings. For historical contexts, we extensively reviewed historical documents and records related to the building and its surroundings. Figures 3-5 show the samples analyzed as part of the study.


(a) Historical context [26]


(b) Modern context (author)

Figure 3. Research samples for religious building


(a) Historical context [27]


(b)Modern context (author)

Figure 4. Research samples for residential building


(a) Historical context [28]


(b) Modern context (author)

Figure 5. Research samples for commercial building

For religious buildings within both ancient and modern contexts, they are influenced by socio-cultural criteria (LW=0.29, LW=0.323, respectively) followed by physical criteria (LW=0.213) in the ancient context, and economic criteria (LW=0.198) in the modern context (see Figure 6).

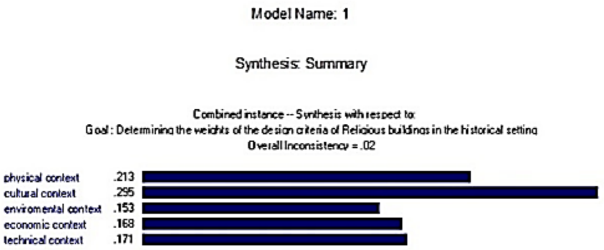
For residential buildings within the historical context, they are influenced by socio-cultural criteria (LW=0.311), followed by physical criteria (LW=0.218). In the modern context, residential buildings are influenced by economic criteria (LW=0.377), followed by technical criteria (LW=0.246) (see Figure 7).

Commercial buildings within the historical context, they are influenced by physical criteria (LW=0.266), followed by economic criteria (LW=0.220). In the modern context, commercial buildings are influenced by technical criteria (LW=0.338), followed by environmental criteria (LW=0.190) (see Figure 8).

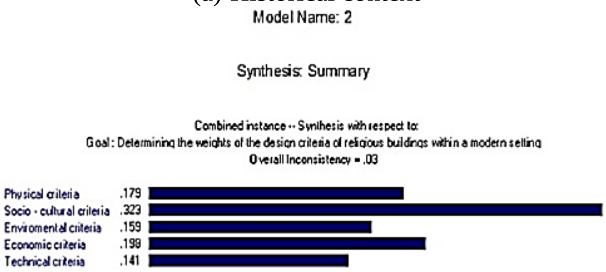
The results of the analysis show that criteria vary depending on the context surrounding the building. In the ancient historical context, socio-cultural criteria have the highest weight and therefore have the greatest influence on decision-making when selection building materials for different functional types. This highlights the essential for designers and architects to prioritize building materials that consider the cultural heritage of the site, ensuring compatibility with the surrounding environment. Ignoring these cultural criteria can lead to contradictory designs that are incongruous with the historical context.

On the other hand, on the contrary, in a modern context, technical and economic criteria are of paramount importance when selection building materials. This indicates that contemporary architectural projects often place a greater emphasis on the technical performance and economic feasibility of building materials. Therefore, architects and designers must use materials that are both technically innovative and cost-effective.

Except in religious buildings, socio-cultural criteria remained influential in both contexts because this type of building is linked to the traditions of society and their cultural heritage.

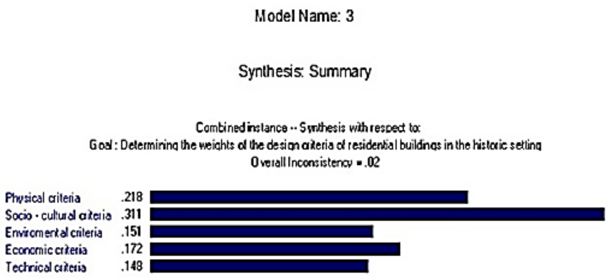


(a) Historical context

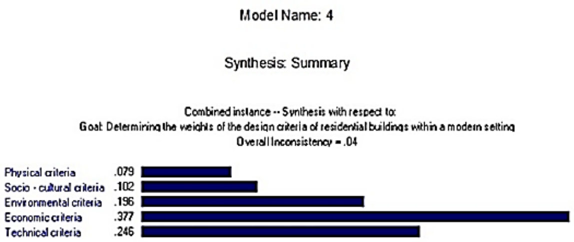


(b) Modern context

Figure 6. Weights of criteria for religious buildings

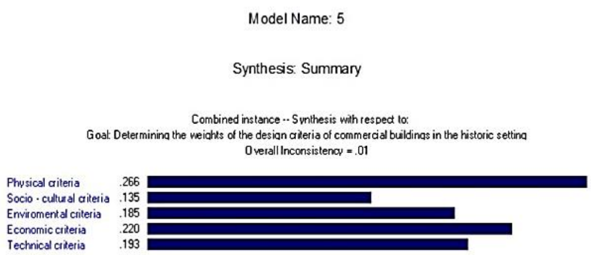


(a) Historical context

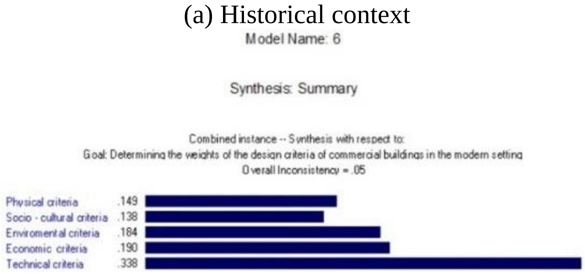


(b) Modern context

Figure 7. Weights of criteria for residential buildings



(a) Historical context



(b) Modern context

Figure 8. Weights of criteria for commercial buildings

5. CONCLUSIONS

The research confirms that material selection is not an isolated process. The study builds upon existing research that has explored criteria for selecting building materials. It attempts to fill knowledge gaps by emphasizing the importance of considering a building's function and context, which is often overlooked. While previous studies have provided valuable insights into specific criteria such as environmental or economic factors, this study integrates these criteria into the broader context of building function and surrounding environment, providing a more comprehensive perspective on material selection. The study identified five main criteria that influence the selection process: material, socio-cultural, environmental, economic and technical criteria. It also confirmed that that the context surrounding a building impacts design criteria, subsequently influencing the choice of building materials. Historical and modern contexts require different priorities in material selection. In a historical context, cultural factors are most important, while in a modern context, technological and economic factors become more important.

The study compares different functional patterns including religious, residential and commercial buildings (the most common types), and provides research examples in local contexts (historical and modern contexts). It is concluded that the function of a building is a key factor in the selection of appropriate building materials, especially in a historical context closely linked to cultural and social values. Preserving cultural heritage remains a top priority. Therefore, architects and designers must consider these factors comprehensively to achieve the desired performance. Additionally, understanding the cultural values of the community is crucial, prompting the prioritization of materials aligned with cultural identity and aesthetic values. In the modern context, technical and economic criteria are significant. Selection materials with advanced technological capabilities and cost-effectiveness are crucial.

Architects and designers can use the results of this study to gain a better understanding of the relative importance of different criteria. This understanding enables them to make more informed decisions when selecting building materials that align with the building's function and context. Also, these findings could be integrated into architectural education. Professors can use the weighting method proposed in this study as a teaching tool to help students understand the complexity of material selection decisions and the significance of considering context in design. Additionally, these insights can help architects communicate effectively with clients by justifying material selections based on specific criteria consistent with the project’s functionality and context. This in turn helps clients understand the reason behind design decisions.

6. RECOMMENDATIONS

The potential areas for future research,

- The specifics of each building type (religious, residential, and commercial) can be delved into to gain a deeper understanding of their different material selection criteria.
- In addition, the research can be extended to a wider range of building types, including educational and healthcare, providing a comprehensive framework

for material selection in different environments.

- Furthermore, the research findings can be applied to bridge the gap between research and practical application in the field of architecture and design.

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