

INTEGRATION OF ENVIRONMENTAL REQUIREMENTS INTO THE DECISION-MAKING PROCESS AT THE EARLY STAGE OF BUILDING RENOVATION PROJECT PREPARATION

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Abstract

The renovation of existing buildings requires decisions to be made with limited information on the condition of the building, while simultaneously taking into account environmental requirements arising from legal regulations, funding conditions, and multi-criteria certification systems. The aim of this article is to develop a structured approach to identifying and integrating these requirements into the decision-making process at the early stage of renovation project preparation. The study was conducted using a qualitative analysis of documents and scientific literature. The identified requirements were classified according to their source and basis for application, area of impact, information required for their assessment, required evidence, and stage of identification, and their potential influence on project decisions was then determined. The results were compiled into an environmental requirements integration matrix, and the key information and parameters required for their assessment were identified. The analysis showed that requirements originating from different sources may concern the same areas but differ in the scope of information required, while some data may be used to assess several interrelated requirements. The point at which a requirement is identified does not necessarily coincide with the point at which compliance is demonstrated; therefore, requirements affecting the scope of renovation or the selection of solutions should be identified before the corresponding decisions are made. The proposed approach can support renovation project preparation at an early stage of the decision-making process.

Keywords: building renovation, environmental requirements, decision support, early project stage, information integration

1. INTRODUCTION

The renovation of existing buildings is an important component of the environmental transformation of the construction sector. The need to reduce energy and natural resource consumption, decrease greenhouse gas emissions, and adapt existing buildings to changing technical and environmental requirements means that the range of issues considered in the preparation of renovation projects is

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steadily expanding. This direction is reinforced by European Union climate policy, in particular the European Green Deal [1], the Renovation Wave initiative [2], and the Energy Performance of Buildings Directive (EPBD) [3], which emphasise the importance of renovating the existing building stock for achieving European climate objectives.

The preparation of an existing building renovation project differs from the preparation of a new development. Decisions concerning the extent of intervention, the retention or replacement of existing elements, and the selection of technical solutions are made in relation to a building with specific technical, functional, and material conditions. At the early stage of project preparation, knowledge of the actual condition of the building may be incomplete, while some of the information required to assess alternative options may require further investigation. This issue is reflected in research on decision support in renovation processes. Nielsen et al. identify six areas of such support: setting sustainability objectives, weighting criteria, building diagnosis, generation of alternatives, estimation of their performance, and evaluation of alternative solutions [4]. Kamari et al., in turn, propose a framework supporting decision-making for sustainable renovation, which can be used at an early stage of a project to identify key criteria and, at subsequent stages, to assess and compare alternative solutions [5].

At the same time, decisions made during project preparation may be influenced by environmental requirements originating from different sources. These may arise from regulations concerning the energy performance of buildings [3], the EU Taxonomy [6], the Do No Significant Harm (DNSH) principle applied under specific European Union funding mechanisms [7], and the technical screening criteria established for activities covered by the Taxonomy [8]. Additional requirements may result from the adopted multi-criteria certification system or from the investor's individual assumptions. Individual requirements differ in terms of their basis for application, scope, assessment method, and the type of information and evidence required to demonstrate compliance.

From the perspective of project preparation, not only the scope of an environmental requirement but also the point at which it is identified is important. If a requirement is identified at the project definition stage, it can be taken into account when formulating assumptions and criteria for assessing alternative options [4,5]. If a requirement is identified later, it may be necessary to reassess the adopted solutions, obtain additional data, or supplement the documentation. The issue is therefore not limited to determining which environmental requirements apply to a given project. It is also important to determine at which stage they should be identified, what information is required for their assessment, and which project decisions they may affect.

In the case of existing building renovation, this issue is additionally associated with uncertainty regarding some of the input data. Galimshina et al. indicate that the selection of a renovation strategy is subject to uncertainty resulting, among other factors, from the long service life of a building, while the assessment of alternatives may require their environmental and economic performance to be considered simultaneously [9]. In the approach proposed by the authors, 74 uncertain parameters were analysed, and an integrated LCA and LCC assessment was used to compare renovation strategies [9]. Where a decision is considered between retaining and renovating an existing building and replacing it with a new one, it becomes important to account for environmental consequences throughout the entire life cycle. For this purpose, Huuhka et al. propose the Consequential Replacement Framework, which enables a renovation option to be compared with demolition and the construction of a new building using an LCA approach [10].

The multi-criteria nature of renovation decisions also creates a need to consider different groups of criteria simultaneously. Based on a systematic literature review, Zhu et al. identify the widespread application of Multi-Criteria Decision Making (MCDM) methods to solving complex decision-making problems in construction [11]. These methods can support the comparison of alternative project options;

however, their application requires the prior definition of criteria and the availability of information enabling individual options to be assessed.

The availability of information at the early stage of renovation remains an important research issue. Arregi et al. identify the lack of information about the existing building and the ambiguous definition of project objectives as barriers to decision-making at this stage and propose a tool enabling a preliminary assessment of alternatives based on a limited amount of data [12]. More recent approaches also seek to integrate different sources of information. Radziejowska and Bucoń propose a renovation decision support system combining a BIM model, technical documentation, diagnostic data, and forecasting and optimisation methods [13].

Previous research has focused primarily on defining criteria, assessing and selecting renovation alternatives, and developing decision-support tools [4,5,9–13]. Less attention has been given to the manner in which environmental requirements originating from different sources are integrated with the information and decisions involved at successive stages of renovation project preparation. Of particular importance is determining what information is required to assess individual requirements, at what stage this information should be available, and in which areas its absence or late acquisition may limit the reliable comparison of alternative options.

The aim of this article is to develop a structured approach to identifying and integrating environmental requirements into the decision-making process at the early stage of building renovation project preparation. Within the proposed approach, environmental requirements were classified according to their source, scope of impact on the project, required information and evidence, and the stage of project preparation at which they should be identified. The analysis examined the relationships between environmental requirements, information availability, and project decisions, and identified areas in which the late identification of requirements or insufficient data quality may affect the assessment of alternative renovation options.

2. MATERIALS AND METHODS

The study was conducted using a qualitative analysis of documents and scientific literature concerning the preparation of building renovation projects, environmental requirements, and decision support. The analysis focused on identifying requirements that may influence decisions made at the early stage of preparing renovation projects for existing buildings and on determining the information necessary to incorporate these requirements into the decision-making process.

The research procedure was carried out in four stages. First, sources of environmental requirements relevant to the preparation of building renovation projects were identified. Second, the requirements identified in the analysed documents were organised according to the adopted classification criteria. The information and evidence required to assess individual requirements were then determined, together with the stage of project preparation at which they should be available. In the final stage, the potential influence of the identified requirements on decisions concerning the scope of renovation and the selection of solutions was analysed. The results of the individual stages were compiled into an environmental requirements integration matrix.

2.1. Scope and selection of sources

The research material included regulatory documents, documents specifying funding conditions, and building certification standards from which environmental requirements relevant to the preparation of renovation projects may arise. The sources were selected to include requirements with different bases for application, scopes, and methods of verification.

The regulatory sources included the Energy Performance of Buildings Directive (EPBD) [3], Regulation (EU) 2020/852 establishing the EU Taxonomy framework [6], and delegated acts establishing technical screening criteria for activities covered by the Taxonomy [8,14]. The analysis was extended to include the Do No Significant Harm (DNSH) principle applied under the Recovery and Resilience Facility [7]. The individual sources were analysed with regard to their different functions and scopes of application, without assuming that technical requirements arising from one mechanism automatically apply to projects subject to another mechanism.

In construction practice, various multi-criteria building assessment and certification systems are used, including BREEAM Refurbishment and Fit Out (RFO), LEED, WELL, and DGNB. These systems differ in their structure, scope of criteria, and assessment methods, but may introduce additional requirements affecting the solutions adopted during project preparation. In this study, the analysis was limited to BREEAM RFO and WELL because of the different profiles of the issues they address.

BREEAM RFO was used as an example of a multi-criteria assessment system covering, among other aspects, energy, water, materials, waste, pollution, land use, ecology, and management of the project process [15]. WELL was included as a standard focusing on the impact of the built environment on occupants' health and well-being and on requirements concerning, among other aspects, air and water quality, thermal comfort, light, acoustics, and materials [16]. The analysis of both systems made it possible to extend the scope of the study to requirements that do not arise directly from regulations or funding conditions but may be adopted by the investor as project assumptions and, consequently, may influence decisions made during project preparation.

The second group of materials comprised scientific literature concerning the preparation and assessment of building renovation alternatives, decision support at the early stage of a project, and the influence of data availability and uncertainty on decision-making. The selection of publications focused on studies concerning the renovation of existing buildings and methods enabling the identification, organisation, or assessment of criteria relevant to the selection of a project alternative. Studies concerning early-stage decision support [4,5,12,13], decision-making under uncertainty [9], assessment of the environmental consequences of renovation alternatives [10], and multi-criteria decision-support methods [11] were included.

Regulatory documents, funding conditions, and certification standards were used to identify and classify requirements and to determine the information and evidence needed for their assessment. The scientific literature, in turn, provided the basis for developing the method of linking the identified requirements with information availability, the stage of project preparation, and decisions concerning the selection of a renovation alternative.

2.2. Identification of environmental requirements

For the purposes of this study, an environmental requirement was defined as a condition, criterion, or obligation arising from the analysed documents, compliance with which may require the consideration of specific technical parameters, design or material solutions, the performance of additional analyses, or the preparation of documentation demonstrating project compliance. This approach makes it possible to include requirements of different types and with different bases for application without treating them as equivalent in legal or technical terms.

Identification was carried out separately for each of the analysed sources. In the case of regulations and funding-related documents, the basis and scope of application of a given requirement were first determined, followed by its relevance to the renovation of an existing building. This made it possible to distinguish requirements arising directly from regulations from criteria applicable only when

specific conditions are met, for example those related to the classification of an activity under the EU Taxonomy or the use of a specific funding mechanism.

This distinction was applied in particular to the EU Taxonomy and the DNSH principle. The technical screening criteria established in the delegated acts to Regulation (EU) 2020/852 [8,14] were not treated as a set of requirements automatically applicable to every renovation project. Their function, scope of application, and the environmental objective to which the individual criteria relate were taken into account in the analysis. Similarly, requirements associated with the DNSH principle were analysed in relation to the mechanism from which the obligation to apply the principle arises [7].

In the case of BREEAM RFO and WELL, requirements that may influence decisions made before the scope and technical solutions of the renovation are finally determined were identified. Particular consideration was given to criteria requiring analyses to be carried out at an appropriately early stage, the adoption of specific design parameters, the selection of material or building-services solutions, and the acquisition of data concerning the existing building. Requirements for which the achievement of the required assessment result may depend on decisions made before detailed design begins were also considered. Requirements were included in the subsequent classification if their consideration could influence the scope of renovation, the selection of an alternative, technical or material solutions, or the scope of information required before a decision is made. Requirements relating exclusively to subsequent documentation, construction management, or operation were excluded if they did not influence decisions made at the analysed stage of project preparation.

For each identified requirement, its source, subject matter, and the type of information necessary to assess the possibility of meeting it were recorded. The required evidence was determined separately where its preparation or acquisition could require actions to be undertaken already at the project preparation stage. This made it possible to distinguish the obligation to achieve a specific result from the information needed to make a decision and the documents subsequently required to demonstrate compliance.

2.3. Method for classifying requirements

The identified environmental requirements were classified in a manner that allowed them to be compared irrespective of their source. Due to the different nature of the analysed regulations, funding conditions, and certification systems, no uniform hierarchy of requirements was adopted. Instead, each requirement was described using a set of characteristics relating to its relevance to the preparation of a renovation project.

First, the source of the requirement and the basis for its application were determined. A distinction was made between requirements arising from legal regulations, conditions related to project funding, and the adopted building certification system. This classification was intended to preserve the distinct nature of requirements with different characteristics and did not assume their equivalence or the possibility of directly transferring criteria between the analysed sources.

The requirements were then assigned to the environmental areas to which they related. These included energy and greenhouse gas emissions, water, materials and resource use, waste and the circular economy, pollution, biodiversity, and indoor environmental quality and building use conditions. Where a requirement covered several issues, assignment to more than one area was permitted.

For each requirement, the type of information necessary for its assessment was also determined. This information could relate to the condition of the existing building, functional and operational assumptions, technical parameters of the proposed solutions, properties of materials and products, anticipated energy and resource consumption, or the results of environmental analyses and calculations. This distinction made it possible to determine which requirements can be assessed on the basis of

information available at the beginning of project preparation and which require data obtained only in the course of further analyses or design work. The availability and level of detail of information at the early stage of renovation are identified in the literature as important determinants of the decision-support process [4,12].

The information necessary to assess a requirement was considered separately from the evidence used to demonstrate compliance. Depending on the source and nature of the requirement, such evidence could include the results of calculations or analyses, design documentation, material documentation, test and measurement results, specialist reports, or other documents specified in the relevant assessment system. Distinguishing between input information and evidence of compliance made it possible to determine which data are required for decision-making and which documents are used for subsequent verification.

The classification also included the stage of project preparation at which a requirement should be identified. A functional criterion was adopted: the appropriate stage was considered to be the stage at which identification of the requirement could still influence the analysis of alternatives or the selection of a solution. This stage was not rigidly linked to formal phases of design documentation, because the scope and sequence of preparatory activities may vary depending on the characteristics of the building being renovated. This approach corresponds to the nature of early-stage decision support, in which information availability and the possibility of modifying an alternative change as project preparation progresses [4,5].

As a result of the classification, each requirement was described using five elements: the source and basis for application, area of impact, information necessary for assessment, required evidence, and stage of identification. The classification results were subsequently used to analyse the influence of requirements on decisions made during renovation project preparation. The resulting summary included information and parameters whose availability at the project preparation stage was necessary to assess the possibility of meeting a requirement or could influence the range of alternatives considered and the selection of a solution.

2.4. Method for assessing the influence of requirements on project decisions

The influence of environmental requirements on project decisions was assessed on the basis of their potential consequences for the scope and manner of preparing the renovation. The analysis examined whether consideration of a given requirement could lead to changes in the adopted project assumptions, the selection of a renovation alternative, a technical or material solution, or the need to perform additional analyses or obtain information before a decision is made.

For the purposes of the analysis, groups of decisions were distinguished concerning the scope of renovation, the retention or replacement of existing building elements, the selection of technical and building-services solutions, the selection of materials and construction products, and the adoption of environmental and operational parameters. This classification reflected the nature of decisions made during the preparation of a renovation project and the scope of requirements identified in the analysed sources.

The link between a requirement and a decision was determined on the basis of the content of the requirement, the information necessary for its assessment, and the stage at which it should be identified. A requirement was considered to influence a decision where its consideration could change the range of alternatives under consideration, the criteria used to compare them, or the conditions for adopting a particular solution. A single requirement could be linked to more than one group of decisions if its consequences extended to several areas of the project.

The analysis also considered the relationship between the point at which a requirement is identified and the possibility of incorporating it into the decision-making process. Where information necessary to assess a requirement was not available at a given stage, the need to obtain it before making the decision affected by that requirement was indicated. This made it possible to identify cases in which a lack of data or late identification of a requirement may limit the possibility of comparing alternatives or lead to a reassessment of previously adopted solutions. This approach reflects the importance attributed in the literature to information availability and the sufficiently early identification of criteria in the renovation preparation process [4,5,12].

The results of the impact assessment were combined with the classification presented in Section 2.3 by supplementing the description of each requirement with the group of decisions it may influence. The resulting set of six elements provided the basis for developing the environmental requirements integration matrix presented in the Results section.

3. RESULTS

3.1. Sources and groups of environmental requirements

The analysis showed that environmental requirements relevant at the early stage of renovation project preparation form a heterogeneous set in terms of both their source and the manner in which they are applied. Three basic groups were distinguished in the material analysed: requirements arising from legal regulations, requirements associated with funding conditions, and requirements arising from the adopted building certification system. Distinguishing between the sources proved important for the subsequent analysis, because the mere occurrence of a similar environmental criterion in several documents does not imply the same basis or scope of application.

Within the regulatory group, the requirements primarily concern the energy performance of buildings and the conditions related to the classification of activities under the EU Taxonomy. The EPBD defines the direction of changes in the energy performance of existing buildings and their renovation [3], while Regulation (EU) 2020/852, together with its delegated acts, introduces criteria relating to the six environmental objectives of the Taxonomy [6,8,14]. From the perspective of project preparation, however, their relevance depends on the scope of the project and the basis on which a given criterion applies.

A separate group consists of requirements related to the DNSH principle applied within European Union funding mechanisms. The Regulation establishing the Recovery and Resilience Facility introduces the requirement that measures receiving funding do not cause significant harm to environmental objectives within the meaning of Article 17 of Regulation (EU) 2020/852 [6,7]. In the analysis, these requirements were treated separately from the technical screening criteria of the Taxonomy, because their application arises from a different basis and does not imply the automatic application of the entire set of criteria established for environmentally sustainable activities.

The third group consists of requirements arising from certification systems. The analysis of BREEAM RFO and WELL showed that these systems include requirements relating to multiple environmental areas and parameters associated with building use. BREEAM RFO covers, among other aspects, energy, water, materials, waste, pollution, land use, and ecology [15]. WELL extends the range of issues analysed primarily to indoor environmental parameters associated with occupants' health and well-being, including air and water quality, thermal comfort, light, acoustics, and materials [16].

Irrespective of their source, the identified requirements were assigned to the seven areas adopted in the classification: energy and greenhouse gas emissions; water; materials and resource use; waste and the circular economy; pollution; biodiversity; and indoor environmental quality and building use

conditions. The individual sources cover these areas to varying extents, and some requirements relate simultaneously to more than one of them.

The comparison of sources also indicates that a similar environmental area may be addressed in different ways. Energy-related requirements may concern the energy performance of a building, criteria for the classification of an activity, a funding condition, or scoring within a certification system. Similarly, material-related issues may include life-cycle impacts, efficient resource use, emissions of substances into the indoor environment, or documentation of the properties of products used. For this reason, the subsequent analysis was conducted not only by environmental area but also with regard to the source of the requirement and the information necessary for its assessment.

Table 1. Sources of environmental requirements and key information required for their assessment at the early stage of renovation preparation. Source: author's own elaboration based on [3,6–8,14–16]

Environmental area	Source	Key information/parameters required at the early stage
Energy and GHG emissions	EPBD (regulatory)	energy performance; energy demand and consumption; energy sources; parameters of the building envelope and technical systems; scope of renovation; intended energy performance improvement
	Taxonomy EU/TSC (regulatory)	scope of renovation; primary energy demand (PED) before and after renovation; information required to assess the applicable TSC
	DNSH (condition of the applicable funding mechanism)	nature and scope of the project; information required to assess the potential impact on the climate objective in accordance with the applicable DNSH assessment
	BREEAM RFO (adopted multi-criteria certification system)	energy performance; manner of use; technical systems and energy sources; anticipated energy consumption and emissions
Water	Taxonomy EU/TSC (regulatory)	scope of installation or replacement of water-consuming equipment; type of equipment; water flow/consumption parameters
	DNSH (condition of the applicable funding mechanism)	nature and scope of the project; information required to assess the potential impact on water resources
	BREEAM RFO (adopted multi-criteria certification system)	manner of use; anticipated water consumption; water-consuming equipment; opportunities to reduce consumption and use alternative sources
	WELL (adopted multi-criteria certification system)	water source and quality; potential contaminants; need for testing or treatment
	Taxonomy EU/TSC (regulatory)	scope of retention, replacement, and demolition of elements; type and quantity of materials; potential for reuse and recovery; material properties relevant to the applicable TSC

Materials and resource use	DNSH (condition of the applicable funding mechanism)	use of materials and resources; opportunities to reduce resource consumption and reuse materials
	BREEAM RFO (adopted multi-criteria certification system)	type, quantity, and condition of existing elements; possibility of retaining or reusing them; data for assessing life-cycle impacts of materials
	WELL (adopted multi-criteria certification system)	presence of potentially hazardous substances; composition and emission properties of materials
Waste and the circular economy	Taxonomy EU/TSC (regulatory)	scope of demolition and dismantling; type and quantity of waste; potential for reuse, recycling, and recovery
	DNSH (condition of the applicable funding mechanism)	anticipated waste streams; opportunities for waste prevention, reuse, recycling, and recovery
	BREEAM RFO (adopted multi-criteria certification system)	scope of dismantling; elements that can be retained or reused; anticipated waste streams
Pollution	Taxonomy EU/TSC (regulatory)	presence of potentially hazardous substances; emission properties of materials; potential emission sources during construction works
	DNSH (condition of the applicable funding mechanism)	potential sources and scale of pollutant emissions to air, water, or soil
	BREEAM RFO (adopted multi-criteria certification system)	emission sources; refrigerants; risk of contamination of water and the surrounding environment
	WELL (adopted multi-criteria certification system)	sources of indoor environmental pollution; potentially hazardous substances; emissions from materials
Biodiversity	Taxonomy EU/TSC (regulatory)	location and site development; environmentally valuable features; scope of intervention in the site
	DNSH (condition of the applicable funding mechanism)	location and nature of the project; potential impact on ecosystems, habitats, and species
	BREEAM RFO (adopted multi-criteria certification system)	existing ecological value of the site; features requiring protection; scope of intervention
Indoor environmental quality and building use conditions	EPBD (regulatory)	manner of use; indoor environmental parameters related to energy performance and technical systems
	Taxonomy EU/TSC (regulatory)	emission properties of materials; presence of potentially hazardous substances
	BREEAM RFO (adopted multi-criteria certification system)	air quality and ventilation; thermal comfort; daylight and lighting; acoustics; emission properties of materials
	WELL (adopted multi-criteria certification system)	air quality; ventilation; thermal comfort; light; acoustics; materials and occupant exposure to harmful substances

The comparison showed that assigning requirements originating from different sources to the same environmental area does not mean that they are equivalent. Differences concern both the subject of assessment and the information required to carry it out. For example, in the area of water, requirements may relate to the parameters of water-consuming equipment, total water consumption and opportunities for its reduction, or water quality and conditions of use. Therefore, identification of the environmental area should be supplemented by specifying the source of the requirement and the type of information necessary for its assessment

3.2. Linking requirements to the stages of project preparation

The analysis showed that environmental requirements differ in terms of the point at which they should be identified in the project preparation process. This difference results primarily from the type of information required to assess a requirement and from the possibility of taking its consequences into account when selecting a renovation alternative. In some cases, a requirement should already be known when the project assumptions are being defined, whereas its detailed verification may take place only after the design solutions have been developed.

For the purposes of the analysis, three stages of project preparation were distinguished: project definition, analysis of alternatives, and development of the selected alternative. This division is functional and does not directly correspond to the formal stages of design documentation. It was adopted in order to determine the point at which information about a requirement should be introduced into the decision-making process so that it can still influence the range of solutions under consideration. The adopted sequence of stages and the manner in which environmental requirements are incorporated into the decision-making process are presented in Figure 1.

At the project definition stage, the most relevant requirements are those that may influence the fundamental assumptions of the renovation. These include, among others, the intended level of improvement in energy performance, the extent to which the existing building fabric is to be retained, the adoption of a specific certification system, and environmental conditions associated with the source of funding. Identifying these requirements at this stage may influence the scope of subsequent analyses and the criteria used to compare alternatives.

The analysis-of-alternatives stage includes requirements whose assessment requires the comparison of alternative technical, material, or functional solutions. This group includes, among others, requirements relating to energy consumption, the life-cycle impact of materials and solutions, resource use, water management, and indoor environmental parameters. Introducing these criteria into the analysis of alternatives makes it possible to take their consequences into account before selecting the solution to be developed further.

At the stage of developing the selected alternative, parameters are specified in greater detail and requirements dependent on specific design and material solutions are verified. This applies in particular to the parameters of equipment and building services, the properties of materials and products, detailed results of energy and environmental analyses, and requirements concerning indoor environmental quality. Some evidence of compliance can only be prepared at this stage, even though the requirement itself should have been identified earlier.

The point at which a requirement is identified is therefore not the same as the point at which compliance with it is demonstrated. A requirement may influence the selection of an alternative at the beginning of project preparation, while the data enabling its full assessment or the documents demonstrating compliance are developed as the project progresses.

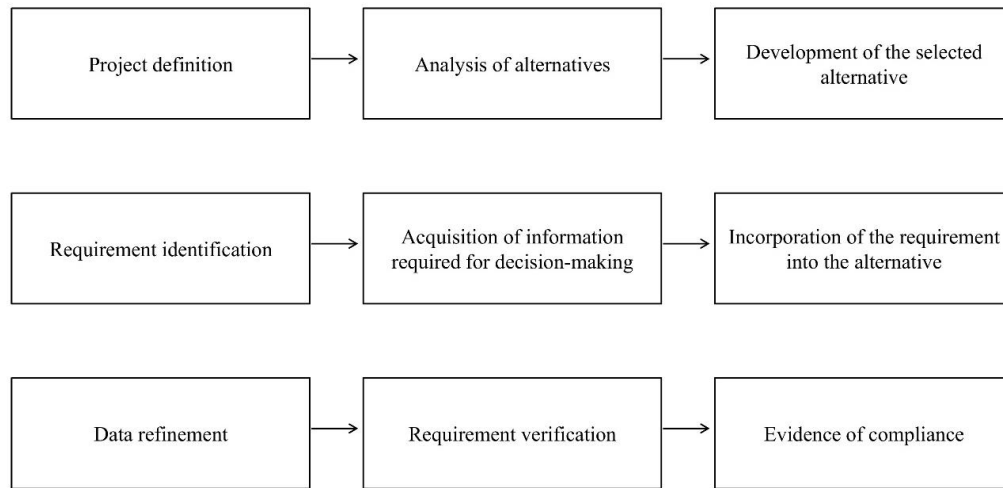


Fig. 1. Stages of incorporating environmental requirements into the renovation project preparation process. Source: author's own elaboration

3.3. Data and evidence requirements

The analysis of the identified requirements showed that the possibility of incorporating them into the decision-making process depends not only on the point at which the requirement itself is identified, but also on the availability of information enabling the consequences of the requirement for the renovation alternatives under consideration to be assessed. The scope of the information required varies depending on the source and subject of the requirement, while some data are relevant to several environmental areas simultaneously.

The first group comprises information concerning the condition of the existing building. This includes, in particular, its technical and energy characteristics, manner of use, existing building services, the type and condition of elements intended to be retained or replaced, and available information on the materials used. These data provide a reference point for determining the possible scope of renovation and assessing the consequences of individual alternatives. Their absence may require assumptions to be made that will need to be verified at a later stage.

The second group comprises assumptions concerning the planned use and expected outcomes of the renovation. These include, among others, the intended energy and environmental parameters, requirements concerning occupant comfort, the anticipated manner of building use, and the adopted certification level where certification forms part of the project assumptions. This information influences the formulation of criteria for assessing alternatives and may determine the scope of further analyses.

The third group includes data concerning the technical and material solutions under consideration. Depending on the requirement, these may include parameters of building envelope elements and building services, energy characteristics of equipment, properties of materials and products, anticipated water and energy consumption, quantities of waste generated, or data used to assess life-cycle environmental impacts. The level of detail of this information increases as the alternative is developed; consequently, a full assessment of some requirements is not possible at the beginning of project preparation.

A separate category comprises the results of specialist analyses, calculations, and assessments. These may include, among others, energy performance calculations, energy and water consumption

analyses, life-cycle assessment, material analyses, climate risk assessment, and analyses concerning indoor environmental parameters. In some cases, such an analysis is necessary to compare alternatives, whereas in others it is used only to confirm the parameters of the solution selected for further development.

At the same time, the analysis indicates the need to distinguish between information used for decision-making and evidence demonstrating compliance with a requirement. The same area may require data already at the analysis-of-alternatives stage, while formal evidence of compliance is produced only after the solution has been developed in greater detail. For example, material properties may constitute a criterion for material selection, whereas manufacturer documentation, an environmental declaration, a certificate, or a test result may subsequently be used to demonstrate compliance with a specific requirement.

As a result, a relationship was identified between three elements of the process: the requirement, the information required for decision-making, and the evidence demonstrating compliance. A lack of information does not mean that the requirement has not been met, but it may prevent the requirement from being reliably taken into account when comparing alternatives. A lack of evidence, by contrast, concerns the ability to demonstrate compliance and may only become apparent at a later stage of project preparation or implementation. Distinguishing between these two situations makes it possible to determine which data should be obtained before a decision is made and which documents may be prepared as the project is developed further.

Table 2. Information and evidence used in the assessment of environmental requirements. Source: author's own elaboration based on the analysis conducted

Type of information	Example scope	Role in the decision-making process	Example evidence of compliance
Condition of the existing building	technical and energy characteristics, building services, materials, condition of elements	determination of the baseline and the possible scope of renovation	survey, audit, test results
Project assumptions	intended use, energy and environmental targets, occupant comfort requirements, multi-criteria certification level	determination of criteria for assessing alternatives	functional programme, investor requirements, multi-criteria certification strategy
Technical solutions	building envelope, building services, equipment, energy parameters	comparison of technical alternatives	calculations, design documentation
Materials and products	technical and environmental properties, emissions, origin	selection of a material solution	manufacturer declarations, EPDs, certificates, test results
Resource consumption and environmental impact	energy, water, waste, emissions, life-cycle impact	comparison of the environmental consequences of alternatives	calculation results, LCA, specialist reports
Indoor environment	air, thermal comfort, light, acoustics	determination of the performance parameters of the alternative	calculations, simulations, specifications, measurement results

3.4. Environmental requirements integration matrix

The compilation of the classification results made it possible to develop a matrix integrating environmental requirements with the decision-making process at the early stage of renovation project preparation. The matrix links the environmental area and example sources of requirements with the information required for their assessment, the stage of identification, the project decisions they may influence, and example evidence of compliance. The structure of the matrix corresponds to the successive elements of the classification adopted in the methodology and makes it possible to trace the relationship between the source of a requirement, the information required for its consideration, and the decision made at the project preparation stage.

The analysis showed that, at the early stage of the decision-making process, requirements whose consequences concern the scope of renovation or the selection of basic technical solutions should be identified first. This applies in particular to requirements related to the energy performance of the building, the extent to which existing elements are retained, resource use, material solutions, and indoor environmental parameters.

The analysis also showed that the information assigned to individual environmental areas is not independent. The parameters of the building envelope and technical systems affect both the energy performance of the building and indoor environmental conditions. Information on the type, quantity, and condition of existing materials is relevant to assessing the possibility of retaining or reusing them, the quantity of waste generated, and life-cycle impacts. In turn, the emission properties of materials link material-related issues with pollution prevention and indoor air quality. This means that some input information may simultaneously affect the assessment of requirements belonging to several areas and more than one decision concerning a renovation alternative. These key interdependencies are represented graphically in Figure 2a by links between the corresponding environmental areas.

In the case of requirements concerning energy and greenhouse gas emissions, information on the energy performance of the existing building, its manner of use, and the intended outcome of the renovation is of primary importance. These data may influence decisions concerning the extent of intervention in the building envelope, energy sources, and building-services solutions. Detailed energy calculations and design documentation may be developed at subsequent stages; however, the basic assessment criteria should be known before an alternative is selected.

Requirements concerning materials, resource use, and the circular economy are more dependent on information concerning the existing building fabric and the possibility of retaining, reusing, or replacing individual elements. Their consideration may influence both the scope of renovation and the subsequent selection of materials and products. In this group, an understanding of the existing building is particularly important because some environmental decisions depend on information about elements that may remain in the building.

Requirements related to water, pollution, and biodiversity may require both information concerning the existing building and its surroundings and the parameters of the proposed solutions. Their influence on the selection of an alternative depends on the scope of renovation. In the case of projects involving sanitary systems, site development, or a change in the manner of building use, these requirements may influence solutions adopted already at the analysis-of-alternatives stage.

A separate group consists of requirements relating to indoor environmental quality and building use conditions. Their assessment requires the definition of intended parameters concerning, among other aspects, air quality, thermal comfort, lighting, and acoustics. These parameters should be taken into account when formulating the renovation assumptions because they may influence architectural, building-services, and material solutions. Their detailed verification, however, takes place as the project is developed.

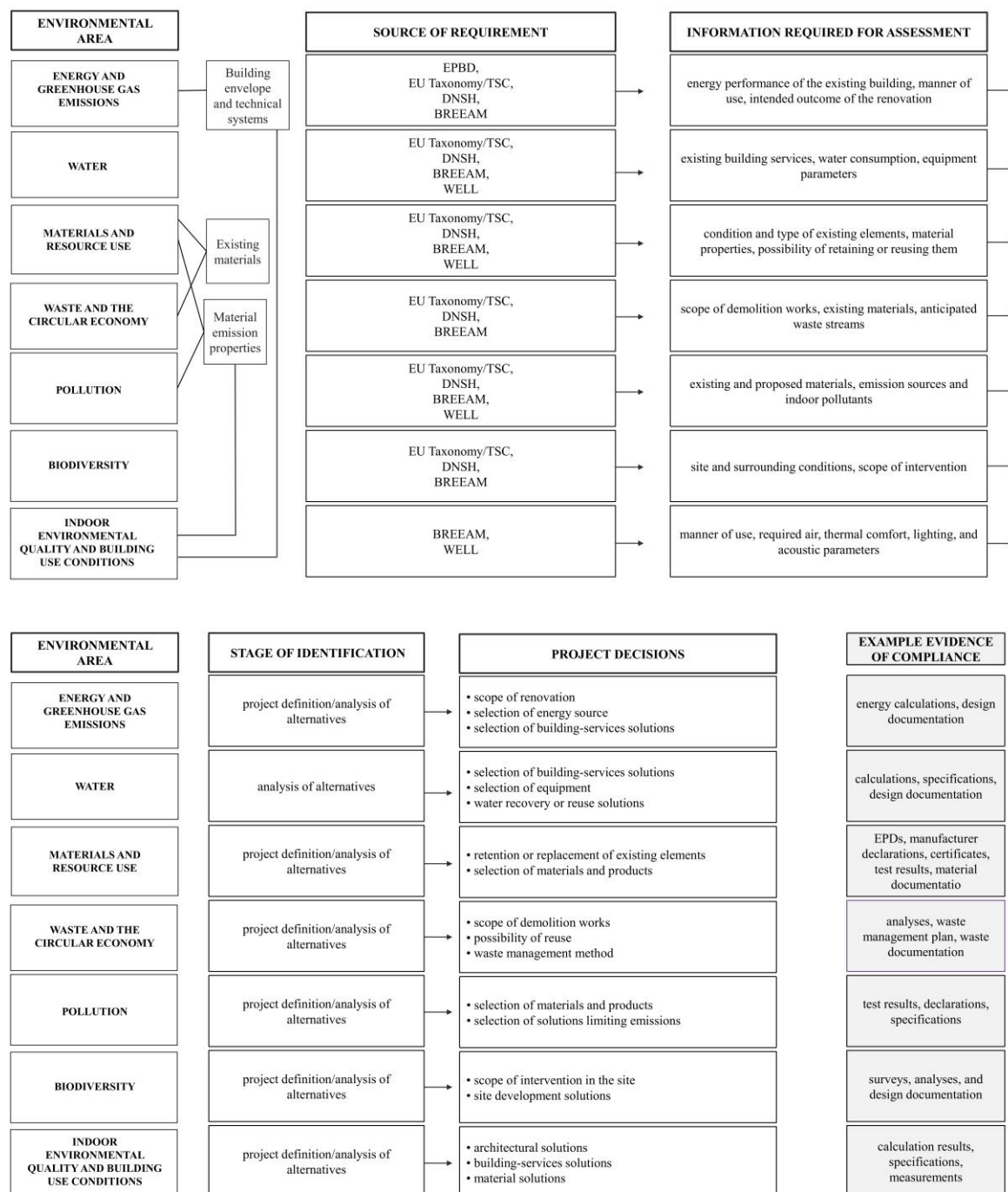


Fig. 2 Matrix integrating environmental requirements with decisions made during renovation project preparation: (a) identification of requirements, information required for their assessment and key interdependencies between environmental areas; (b) linking requirements with project decisions and evidence of compliance. Source: author's own elaboration based on the analysis conducted

A comparison of the individual groups of requirements indicates that the source of a requirement does not in itself determine the point at which it should be taken into account in the decision-making process. Requirements arising from different regulations, funding conditions, or multi-criteria certification systems may influence the same project decision and require partly the same input data. At the same time, similar environmental requirements may be subject to different rules of application and verification. For this reason, their integration into the project preparation process requires information on their source and basis for application to be retained, while simultaneously linking the requirement to the relevant decision and the point at which that decision is made.

Due to the number and diversity of the identified requirements, detailed information and parameters are presented in Table 1, while the matrix is presented at the level of environmental areas. This preserves the readability of the model while taking account of differences between requirements arising from individual sources.

3.5. Application of the approach to renovation projects

The developed approach can be used to structure environmental requirements during renovation project preparation and to determine their relationship with decisions concerning the scope and manner of renovation. The starting point is the identification of requirements applicable to a given project, while retaining information on their source and basis for application. This is particularly important for requirements arising from different regulations, funding mechanisms, and certification systems, which may concern similar environmental issues but are not equivalent in terms of their application and verification.

Once the requirements have been identified, the information required to assess their influence on the renovation alternatives under consideration can be determined. At this stage, it is important to distinguish between data that are already available and information that needs to be supplemented through surveys, investigations, calculations, or specialist analyses. This makes it possible to identify information gaps that should be addressed before a decision dependent on a given requirement is made. In the renovation of existing buildings, this applies in particular to information on the technical and energy condition of the building, existing building services and materials, and the possibilities for retaining or reusing building elements.

The next step is to link the requirement to the decision it may influence. According to the adopted classification, this may concern the scope of renovation, the retention or replacement of existing elements, the selection of technical and building-services solutions, the selection of materials and products, or the adoption of specific environmental and performance parameters. Such an assignment makes it possible to take the requirement into account at a point when alternative solutions can still be compared, rather than limiting its role to the subsequent verification of compliance of the selected alternative.

The matrix can be updated as project preparation progresses and information on the selected alternative is supplemented. This makes it possible to maintain the link between the requirement, the information required for its assessment, and the decision it concerns, despite the increasing level of detail of the data.

In practice, the approach can be used at successive stages of project preparation. Information that is initially unavailable can be supplemented through subsequent analyses, and requirements can be reassessed as the alternative is developed in greater detail. This does not, however, change the need for their sufficiently early identification. If a requirement may influence the scope of renovation or the selection of a solution, it should be identified before the corresponding decision is made, even if the complete documentation demonstrating compliance is not produced until a later stage.

The developed approach does not replace a detailed compliance assessment carried out on the basis of the applicable regulations, funding conditions, or certification system rules. Its function is to structure the relationships between an environmental requirement, the information required for its assessment, the point at which that information becomes available, and the project decision that the requirement may influence. In this sense, the matrix can serve as a tool supporting renovation project preparation by identifying in advance the requirements and information gaps that should be taken into account before an alternative is selected.

4. DISCUSSION

The analysis shows that environmental requirements may influence renovation project preparation earlier than at the stage of verifying the compliance of the adopted solutions. Some of them affect the range of alternatives considered, the criteria for their assessment, and the selection of technical and material solutions. Therefore, not only the content of a requirement is important, but also the point at which it is identified and the availability of information required to assess its consequences. These findings are consistent with previous studies emphasising the importance of the early stage of renovation preparation [4,5,12]. In the present study, the scope of the analysis was extended to include requirements originating from different sources and their relationship with the information required for decision-making and the subsequent demonstration of compliance.

Nielsen et al. [4] distinguish six areas of decision support in the sustainable renovation process, including goal setting, criteria weighting, building diagnosis, generation of alternatives, estimation of their effects, and assessment of alternative solutions. Kamari et al. [5] propose a framework for identifying sustainability criteria and using them to compare renovation alternatives. In both approaches, the sufficiently early identification of criteria influencing the selection of a solution is important. The analysis conducted in the present study additionally draws attention to the origin of these criteria. A requirement taken into account when assessing an alternative may arise from a legal regulation, a funding condition, or an adopted multi-criteria certification system. Each of these sources involves a different basis for application and a different method of verification. Similarity in the subject matter of a requirement is therefore not a sufficient basis for treating requirements originating from different sources as equivalent.

The problem of data availability at the early stage of renovation preparation was indicated, among others, by Arregi et al. [12], who identify the lack of information about the existing building as one of the barriers hindering decision-making. Galimshina et al. [9], in turn, show the importance of data uncertainty in the assessment of renovation strategies. In an existing building, some information concerning the structure, building services, materials used, or the actual manner of use may require additional surveys, investigations, or calculations. From the perspective of the process analysed, however, what is important is not only the extent of the missing data but also their relevance to a specific decision. A lack of information is particularly important when it prevents the assessment of a requirement before the selection of the solution that the requirement may influence.

A particular case of existing building renovation concerns historic buildings and buildings with recognised cultural heritage values. In such projects, decisions concerning improvements in energy performance must take into account not only the expected outcome of the renovation but also the values and features of the building that need to be preserved, as well as constraints on the permissible scope of intervention. This creates additional interdependencies between information on the existing building, regulatory and conservation requirements, possible technical solutions, and decisions concerning the scope of renovation.

Leijonhufvud et al. [18], in analysing the application of EN 16883:2017 to planning energy performance improvements in historic buildings, point to the importance of a systematic and interdisciplinary decision-making process in which solutions are selected on a case-by-case basis, taking into account both energy performance and heritage values. The authors also indicate the need to integrate this approach with existing planning procedures and emphasise the iterative nature of setting objectives and assessing packages of measures [18]. This means that the renovation of historic buildings cannot be considered solely as the selection of measures to improve energy performance, but requires the coordination of different conditions affecting the feasibility of individual solutions.

For historic buildings, this process may be further complicated by the coexistence of regulatory, technical, and financial constraints and the need for specialist knowledge from different disciplines. The key issue is therefore not only the availability of information but also its appropriate linkage with requirements and constraints originating from different sources. A solution that is beneficial in terms of improving energy performance may need to be modified because of the need to preserve heritage values, limitations on interventions in the building envelope or other building elements, or requirements concerning the materials and technologies used. Consequently, information on heritage values, elements requiring preservation, and the permissible scope of intervention should be identified sufficiently early, as it may limit the range of feasible alternatives and influence architectural, building-services, and material solutions.

From the perspective of the approach proposed in this study, the renovation of a historic building is therefore a particularly clear example of a situation in which it is important not only to identify individual requirements, but also to determine the information needed for their assessment, the interrelationships between requirements, and the point at which they should be introduced into the decision-making process. Conservation requirements may in such cases constitute an additional group of conditions affecting the range of available renovation alternatives and the manner in which environmental requirements are assessed. Cultural heritage protection was not, however, a separate subject of the analysis conducted in this study. Extending the proposed approach to include this group of requirements and verifying it in the context of historic building renovation therefore represents a justified direction for further research.

An important element of the adopted classification is the distinction between information required for decision-making and evidence used for the subsequent demonstration of compliance. The results showed that this information may be required at different stages of project preparation. When comparing alternatives, for example, knowledge of the parameters that a material or technical solution should meet may be sufficient, whereas manufacturer documentation, a test result, a certificate, or detailed calculations may be obtained after the project has been developed further. For a decision made at an early stage, the key issue is therefore whether the available data make it possible to assess the consequences of a requirement before a solution is selected. A complete set of documents demonstrating compliance does not always have to be available at that point.

The analysis of the individual sources also showed that different requirements may relate to the same elements of the project being prepared. This applies, among other aspects, to the energy performance of the building, building services, water management, materials, the extent to which existing elements are retained, and indoor environmental parameters. They may therefore influence the same decisions and use partly the same input data. This does not, however, mean that the bases for their application are unified. A particular distinction is required between the technical screening criteria of the EU Taxonomy and the DNSH principle applied under specific funding mechanisms. In the adopted method, the TSC were not treated as requirements automatically applicable to every renovation project, while DNSH requirements were related to the mechanism from which the obligation to apply them arises. Retaining information on the source of a requirement therefore makes it possible to analyse

common consequences for the project process without obscuring the differences between the bases for its application.

The developed matrix combines the environmental area, the source of the requirement, the information required for its assessment, the stage of identification, the decision it may influence, and the evidence of compliance. Its function differs from that of methods used directly to evaluate alternatives. The MCDM methods discussed by Zhu et al. [11] make it possible to compare solutions according to the adopted criteria. The matrix proposed in the present study concerns an earlier stage: it structures the requirements, the information required for their assessment, and the point at which they should be taken into account. It may therefore precede multi-criteria assessment, but it does not replace it.

The solution proposed by Radziejowska and Bucoń [13], which integrates BIM, technical documentation, diagnostic data, and forecasting and optimisation methods, also has a different scope. The matrix presented in the present study is neither a computational system nor a tool for automating the selection of an alternative. Its primary purpose is to structure the requirements and information that should be identified before specific decisions are made. This may be particularly useful at the beginning of project preparation, when the amount of available data is still limited and, at the same time, decisions affecting the further development of the project are being made.

The limitations of the study should be taken into account when interpreting the results. The analysis was qualitative. No weights were assigned and no hierarchy was established for individual parameters or environmental areas, because their relative importance in the decision-making process depends on the characteristics of the building, the scope of renovation, and the requirements applicable to the specific project. Table 1 presents the key information and parameters identified as relevant to the assessment of requirements at the early stage of renovation preparation, while the integration matrix was developed at the level of environmental areas. The adopted level of aggregation enables requirements originating from different sources to be compared, but does not provide a basis for treating the presented results as a complete checklist for demonstrating compliance of a specific project. The scope of requirements should in each case be determined on the basis of the applicable regulations, funding conditions, selected certification system, and investor's assumptions.

A second limitation is that the analysis covers two multi-criteria certification systems, BREEAM RFO and WELL. This selection made it possible to include both a broad range of environmental issues and requirements relating to health and building use conditions; however, the results cannot be generalised to all certification systems.

The importance of information integration at the early stage of renovation also points to the potential role of BIM in collecting and linking data on the existing building with environmental analyses. Lu et al. identify opportunities for integrating BIM with life-cycle assessment (LCA) and life-cycle costing (LCC), distinguishing approaches based on the use of data obtained from the BIM model, their transfer to external tools, and the integration of information directly within the BIM model [17]. In the context of the proposed approach, BIM may therefore support the organisation and use of information needed to assess requirements and compare renovation alternatives, without replacing the decision-making process itself.

The next stage of the research should be the verification of the proposed approach in actual renovation projects. This would make it possible to assess at what stage individual requirements are actually identified, what information is available during the selection of an alternative, and whether the late identification of a requirement leads to a re-analysis or modification of the adopted solution. On this basis, it would also be possible to further refine the matrix, including moving from environmental areas to specific requirements and linking it with multi-criteria assessment methods or digital management of building information.

The proposed approach makes it possible to link environmental requirements with the point at which they are identified, the availability of information, and the decisions made during renovation preparation. It does not introduce a new set of environmental criteria, but structures requirements originating from different sources from the perspective of the project process. It thus makes it possible to shift attention from merely confirming compliance to the earlier identification of requirements that may be relevant to the selection of a renovation alternative.

5. CONCLUSIONS

The analysis showed that incorporating environmental requirements into renovation project preparation requires not only their identification, but also determining the point at which they may influence the decisions being made. Requirements arising from legal regulations, funding conditions, and certification systems may concern similar areas of a project, but differ in their basis for application and method of verification. For this reason, their integration into the project preparation process should retain information on the source of each requirement.

The results indicate that the point at which a requirement is identified does not have to coincide with the point at which compliance with it is demonstrated. If a requirement may influence the scope of renovation, the selection of an alternative, or a technical or material solution, it should be identified before the corresponding decision is made. Detailed verification and the collection of documents demonstrating compliance may take place at later stages of project development. This relationship is confirmed by the results concerning the stages of project preparation.

The distinction between information required for decision-making and evidence used to confirm compliance with a requirement is also important. The absence of complete compliance documentation at an early stage does not necessarily prevent the selection of a solution if information is available that makes it possible to assess its consequences. By contrast, the absence of data required to compare alternatives may limit the possibility of their reliable assessment and lead to the need to reanalyse the adopted solutions.

The developed integration matrix structures the relationships between the source of a requirement, the environmental area, the information required for its assessment, the stage of identification, the project decision, and the evidence of compliance. It can be used as a tool supporting renovation project preparation by identifying requirements and information gaps that should be recognised before an alternative is selected. However, it does not replace a detailed compliance assessment or methods used to directly compare and evaluate alternatives.

Further research should include verification of the proposed approach in actual renovation projects. This will make it possible to assess its application in practice and determine the possibility of further refining the matrix and linking it with multi-criteria decision-support methods and digital management of building information.

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