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Research paper

Trends and problems in the sustainable modernisation of residential buildings

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Abstract: Sustainable building modernisation is an important step towards reducing the negative environmental impact of buildings, reducing energy consumption in existing residential buildings, creating more comfortable and functional living conditions, and improving their technical condition. Unfortunately, this is a burdensome, time-consuming and costly process that requires difficult decision-making. They must reasonably enable the intended sustainability goals to be achieved. Bearing this in mind, the article presents research on the issue of modernisation residential buildings. The aim is to provide up-to-date knowledge aimed at supporting modernisation decision-making. A study of the literature shows that research on sustainable modernisation of residential buildings is very extensive and unsystematic. Research areas include issues focused primarily on environmental and economic sustainability goals. More and more research is being conducted towards modernisation that takes into account wider social needs. Recent research points to the need to implement more holistic modernisation scenarios that meet a broader set of sustainability goals and criteria and that involve more stakeholders at earlier stages of modernisation. However, achieving sustainable building goals requires decision support for contrasting objectives when selecting optimal modernisation strategies. Therefore, increasingly better and more efficient tools, methods and decision support systems are being developed that provide systematic approaches for carrying out sustainable building modernisations. Building renovation decisions also require the identification and removal of barriers to modernisation and the skilful management of the various types of knowledge in terms of its creation, processing and use, providing the various stakeholders with appropriately processed knowledge during the residential modernisation stage.

Keywords: modernisation barriers, building assessment, modernisation priorities, modernisation decision support, knowledge management, sustainability in construction

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1. Introduction

Today's housing challenges in retrofitting the existing housing stock stem from the need to take into account sustainability objectives relating to environmental, economic, social and, to a minor extent, technical aspects [1]. A large part of the existing housing stock in Poland and Europe, for various reasons, has not been modernised over the years, with modernisation adapting it to the changes expressed by modern requirements. Negligence due to the loss of technical performance of buildings is a fundamental problem in both renovation and in the broader sense of modernisation, which in the classical sense means upgrading and adapting a building to modern requirements, while in the sustainable sense striving for a balance between the objectives of modernisation.

Sustainable modernisation of buildings, however, primarily implies the need to address energy and environmental issues. This is related to the so-called 'green deal' that is being implemented in many countries, with the primary goal of reducing environmental pollution [2]. The effect of such a policy on the existing building stock is to adapt buildings to new energy standards and radically reduce the energy consumption required during their operation, e.g. through the selection of appropriate technologies and materials [3, 4], the elimination of non-renewable energy sources [5, 6] and a change in the occupants' usage habits.

While modernisation is generally directed towards improving environmental and economic aspects, social sustainability issues are also receiving increasing attention [7, 8]. They have received little attention so far, which has led to creating gaps in support for sustainable modernisation decisions. Nowadays, the social agenda is paying more and more attention to ensuring residents' satisfaction in a broad sense, by improving, among other things, the usable quality of the building (indoor environment) [9–11].

The modernisation of existing residential buildings aimed at achieving sustainable building goals requires support for more efficient decisions [12]. In order to achieve this, appropriate decision support systems are being developed that provide systematic approaches for carrying out sustainable modernisations of buildings. Their aim is to identify the best modernisation measures and implement appropriate measures throughout the building modernisation process [13]. Building modernisation decisions also require the need to integrate different types of information and knowledge generated by different members of the building teams, developing appropriate decision support systems that provide systematic and holistic approaches for carrying out sustainable building modernisations [14–16].

The paper reviews the existing knowledge on barriers to modernisation, knowledge management, building condition assessment methods, and priorities for sustainable modernisation. A selection of concepts, methods, techniques and tools for supporting decisions are presented, followed by a categorisation and identification of their applications in areas where they can support decision-makers.

2. Barriers to modernisation of residential buildings

Sustainable modernisation, despite the undeniable benefits it provides, also encounters difficulties resulting in low performance. The difficulties in achieving sustainable modernisation programmes result from a variety of factors. Ebrahimigharehbaghi et al. [17] found that barriers are already present at the modernisation consideration stage and these are: seeking information and finding a reliable contractor. On the other hand, difficulties in determining the costs of modernisation and the best solutions for increasing the energy efficiency of a building were identified as the main barriers. D'Angelo et al. [18] identified barriers preventing the modernisation of existing buildings, i.e. financial constraints, low user awareness, fragmentation of the supply chain, regulatory uncertainty, lack of technical knowledge and difficult access to modern technology. Dauda and Ajayi [19], on the other hand, identify barriers to building modernisation as cultural, economic, technical (education and skills) and regulatory (legal) factors.

Fořt et al. [20] note that despite the modernisation benefits of a building, a significant barrier is the economic factor constituting the payback period of the investment, while Nägeli et al. [21] consider lack of knowledge to be a barrier about the condition of the building when planning energy efficiency measures. Alabid et al. [22] identified discrepancies between regulations, standards and actual and expected outcomes as the main barriers preventing decision-makers from implementing realistic and achievable carbon reduction plans. Murtagh et al. [23] highlighted factors that building practitioners indicate as discouraging building owners from taking actions to improve energy efficiency. These included increased costs, lack of confidence in technical standards and the regulatory burdens. García-Fuentes et al [24], in their study, identified significant barriers such as fragmentation of the supply chain, lack of information on some solutions and lack of trust in energy savings, and difficult communication between stakeholders.

To understand the barriers associated with policy, process and practice in improving the residential modernisation process Stopps et al [9] identified systemic barriers to improving modernisation processes, including: mandatory standards, encouraging integrated design, improving education and training of practitioners, implementing feedback mechanisms to inform practitioners of successes and failures, and simplifying certification of materials and designs. Farsäter et al. [25] point out that information about the condition of the building and the subsequent modernisation process is not adequately archived and often lost in the later stages of building management. Xue et al. [26] examining the barriers to carrying out residential modernisation indicate the need for improvements in information exchange and consultation, the use of operational experience and financial resources from the private sector, as well as political and financial support from the public sector. Dzulkifli et al. [27] for breaking down barriers and identifying best practices in building maintenance management pay particular attention to issues such as planning and management, staff and competence, technology and technical capabilities. Table 1 classifies the types and factors of barriers to modernisation.

Table 1. Types of barriers and factors preventing modernisation of residential buildings

No.	Type	Factors
1	Economic	long payback period, insufficient funding, poor budget preparation, budget constraints, high cost of effective modernisation solutions.
2	Political	lack or inadequate financial incentives, time constraints for implementing modernisation measures, complicated and difficult procedures for obtaining support, frequent changes in legislation, use of standards and obtaining certifications.
3	Awareness and behavioural	lack of investors' interest, limited access to information, no training and exchange of information, unawareness of the benefits of modernisation, failure to meet investors' expectations, wrong habits and behaviour of residents.
4	Organisational	difficulty in finding suitable contractors, inexperience and poor preparation of management staff, inadequate processing and use of information, difficult communication between stakeholders.
5	Technical	age and type of building and construction technology, lack of reliable decision-support methods, difficult access to modern technology, fragmentation of the supply chain and vulnerability to price fluctuations.

3. Knowledge in the modernisation process

Capturing and improving the flow of information is an essential element for improving the use of resources, processes and projects for both building maintenance and modernisation. Building Information Models (BIM) allow information/knowledge to be captured and used supporting more effective decisions. The use of BIM in building modernisation is becoming increasingly common and is combined with many other methods. Peng et al. [28] proposed an integrated approach of BIM being a database and Data Mining (DM)-based methods to extract useful information from the database for building maintenance. D'Angelo et al. [18], by combining a business process modelling (BPM) technique and implementation of building information modelling (BIM), developed a innovative methodology to support building modernisation. Motawa and Almarshad [29] integrated a maintenance decision support system consisting of two modules: BIM for capturing essential information and Case-Based Reasoning (CBR) for knowledge acquisition. Chen et al. [30] integrate building information modelling (BIM) with multi-criteria modernisation decision support systems. Marmo et al. [31] proposed an extended methodology based on building information modelling (BIM) integrated with facility management (FM) systems to support the management of buildings' maintenance and their operational assessment. Zhao et al [12], on the other hand, presented the use of the new Digital Twin (DT) technology belonging to Architecture Engineering Construction (AEC), in terms of improving the collaboration and communication of information throughout the project life cycle, from the design stage to the operation and maintenance (O&M) one. Rodrigues et al. [32] for the estimation of building life cycle costs of different building maintenance strategies analyses the possibility of using Buildings Life Cycle Management – BLCM, enhanced with information from Building Information Modelling (BIM) and a coefficient method according to ISO 15686. Ding et al. [33] proposed a concept combining Building Information Modelling (BIM) and Reverse Engineering (RE) involving 3D scanning to improve the use of information in modernisation projects. Gonzalez-Caceres et al. [34] show, in turn, that through the use of BIM combined with scanners, smart meters, a complete profile of a building's condition can be obtained, stored and shared, along with a realistic proposal of modernisation measures with their costs and benefits.

In order to improve the flow of data in different areas of the architecture, engineering and construction (AEC) industry, semantic information enrichment technology has gained ground. The use of semantic models has been explored to map and formalise knowledge and support various modernisation tasks. In this regard, Mohamed at al. [35] propose a novel knowledge-based approach for residential maintenance management, which is based on the integration of 'as-is' information with BIM using semantic web technology. Amorocho and Hartmann [36] presented an ontological system that maps modernisation knowledge, taking into account the various requirements and constraints of installing upgrading measures. Lee et al [37], on the other hand, by linking building maintenance ontologies and BIM, developed a systematic approach that used a knowledge mapping method based on a cloud model and grey relational analysis to sort the acquired knowledge in order to improve the efficiency of historic building maintenance management. Examples of the methods used to obtain knowledge and methods to process it in the modernisation of buildings are shown in Figure 1.

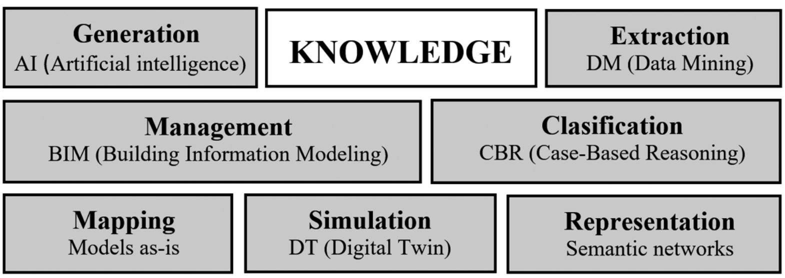

Fig. 1. Actions for and on knowledge using variety of methods

4. Methods for assessing the condition of residential buildings

For the proper maintenance of residential buildings, the assessment of the condition of buildings is crucial. An analysis of the literature shows that assessments are carried out on the basis of different sets of criteria covering environmental, economic, social and technical aspects, using different evaluation methods based mainly on subjective opinions and on complex and time-consuming calculation methods. Building condition assessment systems use a variety of computational methods, ranging from simple mathematical scoring-based methods through multi-criteria rating-based ones to more complex and sophisticated systems based on artificial intelligence-based methods. Jiménez-Pulido et al. [38] indicate that different methods based on different sets of criteria tailored to the actual needs and attributes of existing buildings are increasingly being used to assess and renovate buildings. Faqih and Zayed [39], on the basis of their comparative analysis, noted that the main differences between building element assessment systems are the objectives‘ and scope of the assessment, the different methodologies, tools and aggregation techniques used to arrive at a final assessment of the whole building. In terms of limitations, it was recognised that most of the systems were based on visual observation and subjective interpretation by inspection staff [40]. The problem faced by decision-makers is also to obtain reliable and credible information, as well as the problem of assessing certain criteria of a qualitative nature, as this information is imprecise and problematic to use. Considering that, Karaca et al. [41] proposed Rapid Sustainability Assessment Method assessed the degree of sustainability of existing residential buildings on the basis of redefined environmental, social and economic indicators.

To assess a building and, based on this, determine the extent of repairs needed, MADM (Multiple Criteria Decision Making) methods are used. Lupă?teanu et al. [42] proposed a method (BCA) to assess the technical condition of buildings, based on the general guidelines of the Romanian national standard. Serrano-Jiménez et al. [43], on the other hand, suggested a multi-criteria method based on ten modernisation factors for economic feasibility analysis. The environmental assessment of a building is undoubtedly of key importance for the modernisation measures undertaken. The most accurate method for assessing the potential influence of buildings on the environment is considered to be the LCA analysis, which aims, among other things, to assess and compare different modernisation scenarios [44]. However, multi-criteria methods for assessing the environmental performance of a building have found wider application, and are carried out using GBA (Green Building Assessment) methods. These are multi-criteria sustainable certification systems, such as LEED or BREEAM, the assessment of which for existing buildings is crucial to support environmental transformation. Sadeghi et al [45] proposed an approach based on methods: K-means and fuzzy (AHP), which allows to adjust the ratings of buildings in the various categories evaluated. Alwisy et al. [46], note that building rating systems are problematic to use, as they indicate what needs to be assessed and why, but do not provide answers on how to do it.

Despite recent trends towards considering environmental and economic aspects as part of building sustainability assessments, too little attention has been paid to the need to include social criteria relating to user satisfaction. Santos et al. [7] used a multi-criteria complex approach based on the AHP method to assess the social life cycle of public buildings, focusing on the criterion of health and comfort. Zhao et al [47], on the other hand, used a multi-criteria decision-making method (MCDM) to assess the outdoor environment, taking into account factors, whose weights determined on the basis of residents’ and experts’ opinions. Figure 2 indicates the areas of research in the application of building condition assessment methods.

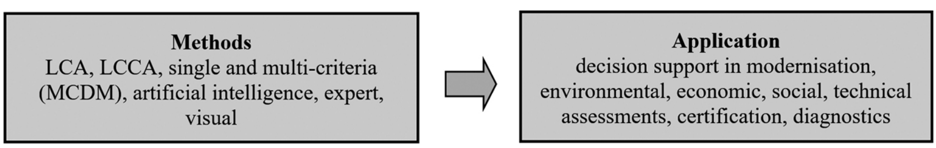

Fig. 2. Application of methods for assessing the building’s condition

5. Priorities of sustainable modernisation

Sustainable modernisation of buildings is a crucial way to solve energy, environmental and social problems. Achieving sustainable building goals is a task that requires the investigation of a large number of modernisation measures and contrasting objectives. As can be seen from the literature review, the objectives of studies targeting modernisation of buildings vary. Very often they focus their attention on reducing the negative environmental impact of buildings and increasing their energy efficiency. There is also a growing recognition of the need to improve the social acceptability of buildings in order to improve quality of life – for example, social sustainability, such as by improving the indoor climate Xue et al. [26]. Recent research point to the need for a broader and multiple perspectives on building modernisation by implementing a holistic approach.

5.1. Improvement of environmental and economic efficiency

Due to the global climate change taking place, reducing the impact of building on the external environment aimed at decarbonising the housing sector has become a key issue. In order to contribute to this goal, Arbulu et al. [2] explored the possibility of using Measurable Progress Indicators (MPIs) which is the main EU legal instrument for measuring decarbonisation progress by European Research and Technological Development (RTD) projects. Hauashdh et al. [5] note that existing buildings have a very high potential to reduce both energy consumption and carbon dioxide (CO_2) emissions through more sustainable and efficient building maintenance strategies and changing building users' behaviour and habits. Feng et al. [48], based on a study of various modernisation and remodelling scenarios carried out using a combination of BIM and LCA with SimaPro software, showed that GHG emissions over the life cycle of an existing building can be significantly reduced by applying measures to improve its energy efficiency. Shirazi and Ashuri [49], on the other hand, in order to find the most energy and environmentally efficient options in terms of environmental impact, analysed and compared the embodied impacts associated with modernisation measures for reducing building energy consumption. However, Fahlstedt et al. [50] pointed out that studies focused solely on CO_2 reduction without including other aspects of modernisation put them at risk of suboptimisation.

In reality, the environmental aspect is rarely the only concern when deciding on modernisation. For a cost-effective and complex modernisation, both environmental and economic aspects are taken into account. The well-known methodologies LCA and LCCA are used for this purpose. Galimshina et al. [51] based on these and multi-objective optimisation using (NSGA-II) developed an approach for finding optimal modernisation scenarios based on climate-friendly and cost-effective modernisation solutions. Whereas Sharif et al. [52] to address environmental and financial issues presented a model using Variational Autoencoders (VAEs) that generates different modernisation scenarios considering total energy consumption and life cycle costs (LCC). Son and Kim [53] used various multi-objective optimisation (EO) algorithms to optimise the opposing goals of minimising energy consumption, CO_2 emissions and modernisation costs and maximising thermal comfort. However, Chang et al. [54] for decision support in the selection of modernisation systems used an optimisation model taking into account multiple objectives, including thermal comfort, energy balance, emissions and economic aspects, also considering the existing form of buildings and uncertainty arising from the performance of the systems.

Quite often, different methods are integrated for targeted studies. Chantrelle et al. [55] used the MultiOpt multi-criteria tool based on a genetic algorithm (NSGA-II) combined with simulation using TRNSYS and economic and environmental databases to optimise modernisation activities taking into account different constraints. Sharif and Hammad [56] used a genetic algorithm (GA) coupled with an energy consumption simulation tool to find the optimal building modernisation scenario considering energy consumption, environmental impact, taking into account budget constraints. Murray et al. [57] used simulation methods in combination with clustering methods and multi-objective optimisation to determine the optimal set of modernisation measures to minimise costs and reduce CO_2 emissions. Kadri´c [58], through the use of a methodology (RSM) combined with energy simulation tools Energy Plus and Design Builder, estimated and modelled the energy reduction potential of modernisation alternatives. Castro et al [59], on the other hand, used dynamic simulation to identify the most appropriate modernisation measures, while to select the best modernisation solutions they used multivariate optimisation, considering different cost functions. Figure 3 shows the frequently undertaken research topics in terms of environmental and economic aspects.

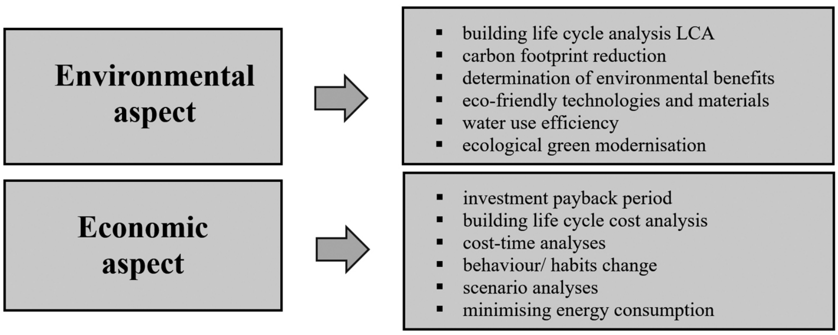

Fig. 3. Research issues related to improving the environmental and economic aspect

5.2. Improving social acceptance

The harmonious development of society in the context of sustainable development aims to meet the needs of the population through appropriate management of building resources. A social sustainability assessment system should be based on different human needs such as health and comfort, safety, culture and heritage, accessibility, etc. Ensuring broadly defined satisfaction with the use of a building is an example of including a social aspect in a sustainable building assessment [11]. Creating a comfortable indoor environmental conditions that satisfies the majority of building users is a fundamental objective of facility management. In order to avoid health risks and discomfort, the European Energy Performance of Buildings Directive (EPBD) mandated member states to promote the modernisation of existing buildings contributing to a healthy indoor environment and improved indoor comfort in buildings. Unfortunately, despite a large amount of research, so far no universally accepted method of assessing indoor environmental quality (IEQ) levels has been developed for improving the maintenance of buildings. To fill this gap, Wargocki et al [10] presented the TAIL rating classification scheme as part of the energy certification method of the EU ALDREN project, which aims to ensure the overall satisfaction of the residents with regard to the indoor environment: quality of the thermal and acoustic environment, indoor air and lighting. Mejjaouli and Alzahrani [60], on the other hand, analysed the possibilities of building modernisation, using Mixed Integer Linear Programming (MILP), to achieve economic benefits, keeping in mind thermal comfort and recommended lighting levels. Other innovative research focused on improving indoor environmental quality was presented by Nimlyat et al [61], who developed a conceptual framework model, based on structural equations (SEM), for assessing IEQ scores and residents' satisfaction in hospital buildings. Ismaeel et al [62] identified critical criteria and sub-criteria based on a questionnaire – Relative Importance Weight (RIW), and then using the Structural Equation Model (SEM) for improving building maintenance they analysed IAQ and symptoms of Sick Building Syndrome (SBS). And Awada and Srour [11], using a Genetic Algorithm (GA)-based method, investigated the relationship between potential opportunities for building modernisation and improved IEQ conditions for a comfortable indoor environment. Figure 4 shows the most common research issues for improving social acceptance.

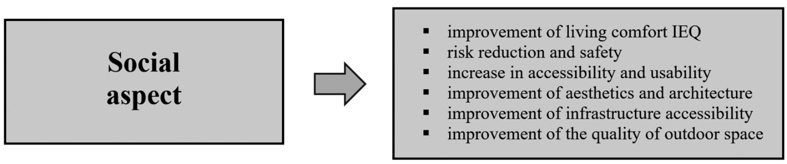

Fig. 4. Research issues considered to improve social acceptance

5.3. Maintenance of technical performance

Maintaining the technical performance of residential buildings is a key element of building sustainable development. Innovative approaches primarily promote a long-term view of the problem of building maintenance by providing appropriate methods and strategies. Therefore, Kwon et al. [63] developed an efficient and effective tool for predicting repair time in the long term, which used methods, i.e. case-based inference (CBR), genetic algorithm (GA), multiple linear regression (MLR) and fuzzy AHP. And Nägeli at al. [21] presented a method for cost-optimal scheduling of building maintenance and modernisation, combining a bottom-up approach for modelling building assets in terms of cost, energy and GHG reductions with a MARS method for optimising the scheduling of maintenance activities. Al-Smadi et al. [64] for minimising the total maintenance cost as well as maximising the building condition used a multi-objective optimisation performed using a particle swarm algorithm, which is based on degradation curves according to a Weibull distribution. Paulo et al [65], on the other hand, used a building management system (BdMS) based on a genetic algorithm and Markov chains to develop a maintenance plan that ensures the lowest cost of implementation while maintaining an acceptable level of building degradation.

The decision to repair or replace building components is a major problem for the building manager. According to Abdi and Taghipour [66], making decisions based on deterministic values is inappropriate because they may change due to factors such as the quality of maintenance. Keeping this in mind, Farahani et al. [67] proposed a systematic approach based on a condition-deterioration model, which was used to compare the cost-effectiveness of different maintenance/repair schedules for building elements to determine the interval between conservation activities. Ferreira et al. [68] presented a maintenance methodology based on a probabilistic approach, implemented through a stochastic maintenance model based on a Petri net (PN), in which the schedule of activities is determined based on the state of the components. Taillandier et al [69] bring the building maintenance problem down to a multi-year plan of maintenance activities optimised simultaneously in terms of various criteria related to building maintenance objectives (quality of service, customer satisfaction, regulatory compliance, etc.) while maintaining a predetermined budget. Liu et al. [70], in response to the use of reactive building maintenance strategies, attempted to explore a preventive maintenance approach, for which they developed an optimisation method to support maintenance decisions, based on the building deterioration rate and considering budget constraints. Cho et al [71] analyzed the uncertainty of repair times for various finishing work in residential buildings based on probability theory to determine effective maintenance strategies. The choice of modernisation measures is also related to the need to solve problems in which property owners have to decide which modernisation measures to invest in first, as well as how to schedule modernisations over time [72, 73]. A summary of research topics aimed at maintaining the technical performance of buildings is presented in Figure 5.

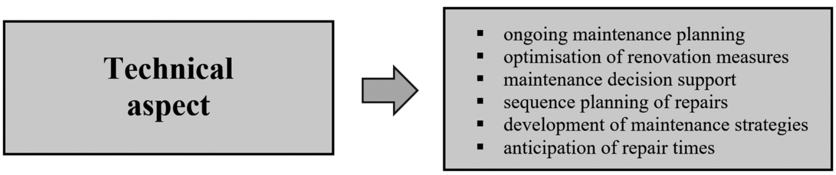

Fig. 5. Research issues in housing maintenance

5.4. Modernisation from a holistic perspective

The sustainable modernisation of existing buildings is increasingly being considered altogether, based on all aspects of sustainability (environmental, economic, social and technical). However, a review of recent studies has shown that most of the decision support systems developed do not take into account the full multidimensional complexity of the residential buildings being assessed. Ahmad and Thaheem [74] claim that the holistic view of sustainability developed so far does not sufficiently take into account different aspects, creating gaps in the analytical support needed for sustainable decision-making. Moschetti et al [75] recognise the need to overcome the traditional focus of modernisation projects in addition to improving the energy efficiency of buildings in a holistic perspective taking into account the social aspect, e.g. in terms of improving quality of life. Bi and Little [8], in a multi-scale holistic approach to solve complex social challenges systematically at the building and city scale, paid attention to social factors, i.e. health and comfort, improvement of air quality and minimisation of energy consumption. Hong et al. [76] developed a holistic approach including monitoring, diagnosis and modernisation to reflect unexpected changes in the climate and energy environment, as well as in energy policies and technologies within a new 'urban body' paradigm. Serrano-Jiméneza et al. [77], with the objective of promoting sustainable modernisation of housing stock, propose the Architectural and Psycho-environmental Assessment Method for Modernisation (APRAM) as a decision support system that takes into account the architectural requirements and social perceptions of residents.

A holistic view of social sustainability in residential buildings and making sustainable modernisation decisions is not limited to improving the building itself, but also includes other issues. Jensen et al [14] presented a simple holistic tool, RENO-EVALUE, to support decision-making in the early stages of modernisation projects. It takes into account different stakeholders' interests and covers project organisation, economics and the modernisation process focusing on essential aspects of modernisation projects, i.e. prioritizing and making decisions. Kamari et al. [16] remark that when making decisions and communicating with relevant stakeholders, holistic issues related to meeting sustainability goals are not comprehensively addressed. Dealing with the full complexity of sustainable modernisation involves implementing a holistic multimethodology for sustainable modernisation. An example of a holistic approach that takes into account even more complexity in modernisation decision-making is the PARADIS decision support system developed by Kamari et al. [15]. It allows the generation and assessment of optimal and holistic modernisation scenarios based on building information modelling (BIM) and provides a framework for an approach that combines methods from Soft Systems Methodologies (SSM) with Multiple Criteria Decision Making (MCDM), through which different stakeholders can be involved in the decision-making process. A diagram of the holistic approach including the influence of stakeholders expressed by organisational factors on modernisation decisions is shown in Figure 6.

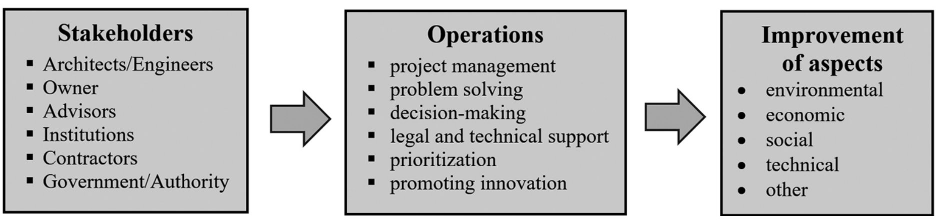

Fig. 6. Stakeholder influence on the decision-making process in a holistic approach

6. Summary and conclusions

In this article, a systematic review of the existing literature on sustainable modernisation of residential buildings was carried out and contemporary research trends were identified. The literature was analysed in terms of scientific and practical knowledge on key issues related to supporting sustainable modernisation of buildings. The literature review shows that modernisation research is very often multi-faceted, unsystematic and diverse which makes it difficult to qualify. The author pointed out that the boundaries of research are evolving from technology (building information acquisition and modelling) to management issues (mainly human experience, multi-objective optimisation and multi-stakeholder interests). In terms of applied modernisation decision-support tools, their applicability in areas where they can support decision-makers, i.e. setting sustainability goals, weighting criteria, diagnosing and estimating building performance, generating alternative modernisation strategies, were categorised and highlighted. In addition, current challenges, barriers, obstacles and problems associated with modernisation were given attention.

The study analysed in this article addresses various aspects of modernisation. Much of it focuses exclusively on solving individual problems related to, for example, reducing the environmental impact of modernisation or improving the energy performance of modernised buildings. It also emphasises the need to pay attention to societal needs that concern issues related to the quality of the indoor environment of buildings as well as its surroundings. Such individual studies do not fully fulfil the concept of sustainable modernisation, the fundamental aim of which is modernisation in the context of a number of cumulative and balanced objectives for improving environmental, economic and social aspects. Recent research increasingly highlights the need to develop holistic methodologies for building retrofitting, which could serve as decision support for sustainable modernisation projects and help stakeholders (building professionals and building users) to prioritise and make decisions in the early stages of projects to develop the best compromise modernisation solutions.Studies that present such approaches point the way for future research contributing to improvements in collaboration between stakeholders in modernisation projects.

Acknowledgements

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Kierunki i problemy zrównoważonej modernizacji budynków mieszkalnych

Słowa kluczowe: bariery modernizacji, ocena budynków, priorytety modernizacji, wspomaganie decyzji modernizacyjnych, zarządzanie wiedzą, zrównoważony rozwój w budownictwie

Streszczenie:

Zrównoważona modernizacja budynków mieszkalnych dotychczas rozumiana, jako odpowiedzialna za wdrażanie energooszczędnych i ekologicznych rozwiązań technologiczno materiałowych, obecnie rozpatrywana jest znacznie szerzej i ma na celu wypracowywanie rozwiązań modernizacyjnych zapewniających równowagę w osiągnięciu celów środowiskowych, ekonomicznych, społecznych oraz innych [1]. Działania jakie realizowane są w ramach tego procesu mają na celu zmniejszenie negatywnego oddziaływania budynków na środowisko i zużycia energii w istniejących budynkach mieszkalnych, stwarzanie bardziej komfortowych i funkcjonalnych warunków do zamieszkania, a także poprawę ich stanu technicznego. Jednak, pomimo że w ostatnich latach nastąpił duży postęp w kierunku wdrażania polityki zrównoważonego rozwoju w zakresie renowacji i modernizacji istniejących budynków, to w wielu krajach wciąż napotyka się na wiele problemów i barier związanych z jej wdrożeniem. Na podstawie przeprowadzonych badań literaturowych, których celem było określenie problemów i kierunków zrównoważonej renowacji i modernizacji budynków mieszkalnych, zauważa się ogromne zróżnicowanie tematyczne prowadzonych badań. Badania mają charakter multidyscyplinarny i często obejmują różnorodne dziedziny badawcze, takie jak: inżynieria lądowa, środowiskowa, architektura, informatyka oraz inne narzędzia i usługi. Jak dotychczas najwięcej badań prowadzono w zakresie środowiskowych i ekonomicznych priorytetów zrównoważonego rozwoju. Środowiskowe koncentrowały się przede wszystkim na dostarczaniu rozwiązań pozwalających zmniejszyć negatywne oddziaływanie budynku na środowisko zewnętrzne. W przeważającej większości badań aspekt środowiskowy rozpatrywany jest łącznie z innymi ściśle z nim skorelowanymi, takimi jak: energooszczędność i ekonomika modernizacji i utrzymania budynków. Celem tych badań jest dostarczenie efektywnych strategii konserwacji budynków, radykalne zmniejszenie zużycia energii potrzebnej podczas ich eksploatacji poprzez stosowanie odpowiednich technologii materiałowych [11], rezygnację z nieodnawialnych źródełenergii [3, 4], a także zmianę nawyków użytkowych mieszkańców. Coraz więcej badań prowadzonych jest również w kierunku modernizacji uwzględniającej szeroko rozumiane potrzeby społeczne. Zaspokojenie potrzeb mieszkańców poprzez zrównoważony rozwój społeczny oparty o różne potrzeby człowieka, takie jak zdrowie i wygoda, bezpieczeństwo, kultura i dziedzictwo, dostępność itp., ma na celu zapewnienie szeroko rozumianej satysfakcji z użytkowania budynku i stanowi jeden z ważniejszych celów zarządzania obiektem. W kontekście modernizacji budynków poruszany jest również aspekt techniczny, który ma duże znaczenie z uwagi na starzejący się zasób budynków mieszkalnych. W badaniach nad tym problemem zwraca się uwagę na potrzebę utrzymania odpowiednich parametrów budynku, zachowanie jego pierwotnych funkcji oraz zapewnienie niskich kosztów utrzymania. W najnowszych badaniach wskazuje się także na potrzebę wdrażania bardziej holistycznych scenariuszy modernizacji, które obejmują szerszy zestaw kryteriów zrównoważonego rozwoju i pozwalają realizować określone cele, angażując większą liczbę interesariuszy we wczesnych etapach procesu modernizacji. Modernizacja istniejących budynków mieszkalnych ukierunkowana na osiągnięcie celów zrównoważonego budownictwa wymaga wsparcia w podejmowaniu bardziej efektywnych decyzji. Istnieje duża liczba narzędzi, metod, modeli wspomagających podejmowanie decyzji modernizacyjnych oraz systemów oceny budynków w tym certyfikacji pod kątem zrównoważonego rozwoju. W obliczu wielu możliwości wyboru sposobu modernizacji budynków, głównym proble-

mem jest identyfikacja tych, które są bardziej efektywne i niezawodne w długim okresie czasu i które w największym stopniu przyczynią się do rozwiązywania problemów środowiskowych, ekonomicznych i społecznych[8]. W tym celu opracowywane są odpowiednie systemy wsparcia decyzji, które dostarczają systematycznych całościowych podejść dla przeprowadzenia zrównoważonych modernizacji budynków. Ich celem jest określanie najlepszych środków modernizacyjnych oraz wdrażanie odpowiednich działań w całym procesie modernizacji. Skuteczność modernizacji uzależniona jest również od identyfikacji i likwidacji barier uniemożliwiających jej realizację oraz konieczność integracji i umiejętne korzystanie z różnego rodzaju informacji i wiedzy tworzonej przez różnych członków zespołów budowlanych. W artykule dokonano przeglądu istniejącego stanu wiedzy w zakresie barier modernizacji, zarządzania wiedzą, metod oceny stanu budynku, priorytetów zrównoważonej modernizacji. Przedstawiono wybrane koncepcje, metody, techniki oraz narzędzia służące do wspomagania decyzji renowacyjnych, a następnie skategoryzowano i wskazano ich zastosowania w obszarach, w których mogą one wspierać decydentów.

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