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APPLICATION OF BIM TECHNOLOGIES IN THE RECONSTRUCTION OF RESIDENTIAL BUILDINGS

ТҰРҒЫН ҮЙЛЕРДІ ЖАҢҒЫРТУДА BIM ТЕХНОЛОГИЯЛАРЫН ҚОЛДАНУ

ПРИМЕНЕНИЕ BIM-ТЕХНОЛОГИЙ В РЕКОНСТРУКЦИИ ЖИЛЫХ ДОМОВ

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energy-efficient retrofit,
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detection, comprehensive
reconstruction,
prefabricated facade
systems, modernization of
residential buildings.

ABSTRACT

The article examines the use of Building Information Modelling (BIM) technologies in the comprehensive reconstruction of multi-apartment residential buildings constructed in the second half of the twentieth century. Ageing building stock and stricter requirements for energy efficiency, seismic safety and urban environmental quality make traditional 2D design approaches inadequate, especially under conditions of multiple design options, limited resources and incomplete data on existing assets. The paper systematizes international experience of BIM-based energy-efficient and seismic retrofit projects and identifies key BIM tools relevant for countries with a developed industrial housing tradition. A method is proposed for adapting these tools to Kazakhstani conditions, considering climatic zoning, regional seismicity and typical residential building structures. The resulting framework, presented as a summary table linking BIM tools to reconstruction tasks and regions, can inform methodological guidelines, prioritization of digitalization measures and the planning of pilot BIM-based modernization projects in Kazakhstan.

Түйінді сөздер:

Ғимараттардың
ақпараттық модельдеуі
(BIM), BIM
технологиялары, энергия
тиімді ретрофит,
сейсмикалық ретрофит,
коллизияларды анықтау,
кешенді реконструкция,
құрастырмалы қасбет
жүйелері, тұрғын үйлерді
модернизациялау.

ТҮЙІНДЕМЕ

XX ғасырдың екінші жартысында салынған жаппай тұрғын үй қорының ескіруі, энергия тиімділігіне, сейсмикалық қауіпсіздікке және қала ортасының сапасына қойылатын қатаң талаптармен бірге, ресурстар шектеулі және бастапқы деректер толық емес жағдайларда дәстүрлі 2D-жобалау тәсілдерінің жеткіліксіздігін айқындайды. Мақалада көппәтерлі тұрғын үйлерді кешенді реконструкциялауда ғимараттардың ақпараттық модельдеу (BIM) технологияларын қолдану қарастырылады. Энергоэффективті және сейсмикалық ретрофит бойынша шетелдік жобалар тәжірибесі жүйеленіп, индустриялық құрылысы дамыған елдер үшін өзекті негізгі BIM-құралдар айқындалған. Климаттық аудандастыруды, өңірлердің сейсмикалық белсенділігін және тұрғын үй қорының типтік құрылымын ескере отырып, бұл құралдарды Қазақстан жағ-



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дайына бейімдеу әдісі ұсынылады. BIM-құралдарды реконструкция міндеттерімен және өңірлермен сәйкестендіретін сводтық кесте түріндегі үлгі әдістемелік ұсынымдар әзірлеуге, цифрландырудың басым бағыттарын белгілеуге және пилоттық модернизация жобаларын жоспарлауға негіз бола алады.

Ключевые слова:

Информационное моделирование зданий (BIM), BIM технологии, энергоэффективный ретрофит, сейсмический ретрофит, выявление коллизий, комплексная реконструкция, сборные фасадные системы, модернизация жилых зданий.

АННОТАЦИЯ

Старение массового жилищного фонда второй половины XX века на фоне ужесточения требований к энергоэффективности, сейсмической безопасности и качеству городской среды делает традиционные 2D-подходы к проектированию недостаточно результативными в условиях многовариантности решений, дефицита ресурсов и неполноты исходных данных. В статье рассматривается применение технологий информационного моделирования зданий (BIM) в комплексной реконструкции многоквартирных домов. Систематизирован зарубежный опыт энергоэффективного и сейсмического ретрофита, выделены ключевые BIM-инструменты, релевантные странам с развитой индустриальной застройкой. Предложен метод адаптации этих инструментов к условиям Казахстана с учётом климатического зонирования, региональной сейсмичности и типовой структуры жилищного фонда. Разработанная схема в виде сводной таблицы, увязывающей BIM-инструменты с типами задач и регионами, может служить основой для методических рекомендаций, развитию цифровизации и планирования пилотных проектов модернизации.

INTRODUCTION

The mass housing stock built in the second half of the twentieth century is currently undergoing a stage of intense physical and functional ageing. A significant share of multi-apartment buildings has been in operation for several decades, leading to the accumulation of structural defects, reduced energy performance, and non-compliance with modern requirements for comfort and safety. Under increasingly stringent regulatory standards and the principles of sustainable development, the comprehensive reconstruction of residential buildings has become one of the key priorities of urban development in major cities of Kazakhstan.

Object of the study - the processes of reconstruction and modernization of multi-apartment residential buildings in the existing housing stock.

Subject of the study - the application of Building Information Modeling (BIM) technologies in the comprehensive reconstruction of residential buildings to improve energy efficiency, seismic resistance, and architectural and spatial quality.

The aim of the study is to systematize international experience in the use of BIM technologies in residential building reconstruction and to develop an approach for their adaptation to the climatic and seismic conditions of Kazakhstan. The aim is related to proving the thesis that the integration of BIM into the practice of housing stock reconstruction provides a qualitatively new level of design coordination, energy performance analysis, and management of reconstruction processes.

Objectives of the study include:

- to analyze international and pilot projects of residential building reconstruction implemented using BIM technologies;
- to identify and describe the main categories of BIM tools used for energy-efficient modernization, seismic strengthening, and schedule and cost management;
- to develop a schematic framework for the recommended application of BIM technologies in Kazakhstan, taking into account regional climatic and seismic factors.

Research methods are based on comparative analysis of international and regional practices, systematization of expert and project data, examination of regulatory requirements, and modeling of reconstruction scenarios using BIM-based platforms.

Research approach relies on the principles of integrating digital technologies into the building life cycle, interdisciplinary coordination of architectural, engineering, and operational solutions, and the concept of sustainable urban development.

Research hypothesis assumes that the implementation of BIM technologies in the reconstruction of Kazakhstan's mass housing stock will optimize the design process, improve the energy efficiency and reliability of buildings, and reduce project duration and costs.

Scientific and practical significance of the study lies in developing a scientifically grounded approach for adapting international BIM tools to Kazakhstani conditions, contributing to the formation of a methodological and regulatory foundation for the large-scale reconstruction of the national housing stock.

LITERATURE REVIEW

To illustrate the potential of the BIM-based approach to the reconstruction and retrofit of the mass housing stock, it is useful to refer to implemented European projects. Within the SINFONIA project, demonstration retrofits were carried out on multi-apartment buildings from the 1960s-1970s, for which information models of the existing buildings were created, prefabricated facade systems were designed and their energy performance was simulated (BUILD UP, 2021). The visual analysis of facades "before" and "after" demonstrates a qualitative change in the architectural appearance of the buildings, which makes it possible to treat such projects as comprehensive architectural and technical reconstruction (Fig. 1).



Figure 1. Results of the modernization of multi-apartment building

Note – compiled by the authors based on (BUILD UP, 2021)

In the MeeFS project, a multifunctional facade system was developed that integrates thermal insulation, solar protection and ducts for building services, and was applied in the retrofit of existing multi-apartment buildings (Fig. 2), (CORDIS EU, 2016). BIM models were used to accurately align modular panels with the existing structure, verify the load-bearing capacity of connection details and assess the energy impact. The implemented cases clearly show how prefabricated facade modules make it possible to address energy efficiency and the renewal of the architectural appearance simultaneously.

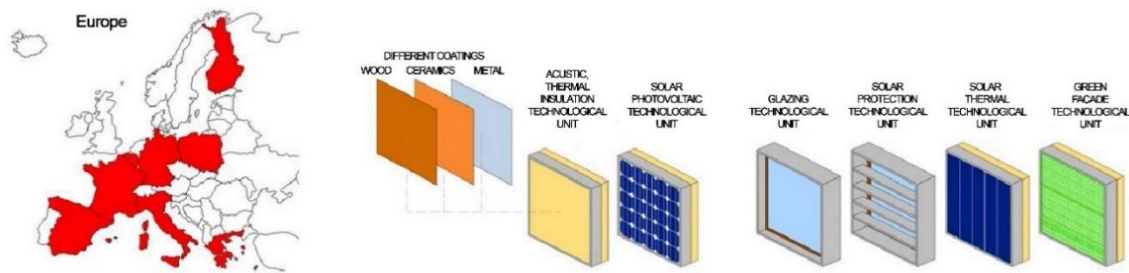


Figure 2. Initial idea for the MeeFS Retrofitting Facade System

Note – compiled by the authors based on (CORDIS EU, 2016)

In studies on integrated seismic and energy retrofit of a reinforced-concrete residential building from the 1970s, the digital model was used to jointly optimize measures for strengthening the load-bearing structure and improving the thermal performance of the envelope, which led to a significant increase in safety levels and a reduction in energy consumption (Paiho, Seppä & Jimenez, 2015)

Formation of the information model of the existing building

One of the fundamental stages in applying BIM technologies to the reconstruction of residential buildings is the creation of an information model that reflects the actual condition of the structures, layouts and building services systems. Unlike new construction, where the model is generated from design documentation, in reconstruction the key task is to integrate archival drawings, results of instrumental surveys, as-built measurements, photographic records and laser-scanning data into a single digital structure (Gholami et al., 2015).

In European demonstration projects of energy-efficient retrofit of multi-apartment buildings, information models were used to significantly refine the real geometry of existing facades, the position of window and door openings, and to capture local deformations and deviations from the original design schemes. This made it possible to correctly design prefabricated facade modules that provide thermal protection and accommodate new service ducts, and to check their fit to the existing structures in advance.

Thus, BIM modelling becomes the starting point for all subsequent stages of reconstruction, reducing the risk of errors associated with discrepancies between design solutions and the actual condition of the building, which is particularly important for residential buildings with a long history of operation and numerous local alterations.

Coordination of design solutions and clash detection

An important area of BIM application in reconstruction is improving the coordination of design solutions and managing clashes between different project disciplines (Fig. 3). The information model serves as a common platform for architectural, structural and building services disciplines, enabling automatic detection of interferences and conflict zones before work starts on site (Muhammad, 2022).

In energy-efficient retrofit projects for multi-apartment buildings, the BIM model was used to coordinate the routing of building services within the new facade layer and the existing structures, as well as to integrate new elements (balcony units, technical cabinets, ventilation ducts) within a limited spatial envelope. Similarly, in comprehensive strengthening projects for residential buildings, the digital model made it possible to align the positioning of strengthening elements with the existing architectural and engineering layout, minimizing interventions in occupied apartments (Lim et al., 2021; Dereje et al., 2021).

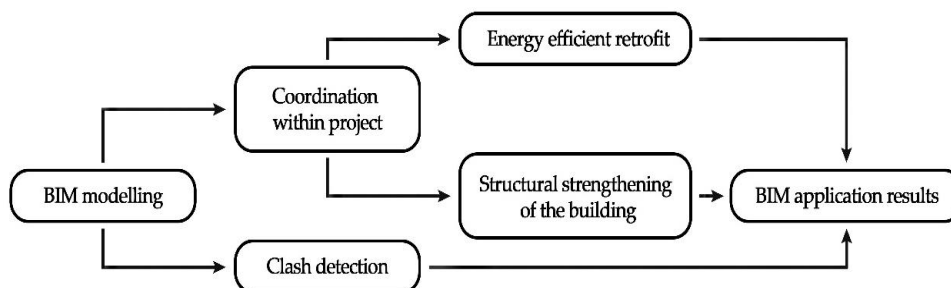


Figure 3. BIM-based coordination in building reconstruction

Note – compiled by the authors

Practical experience shows that the use of a BIM environment for discipline coordination helps reduce the number of design errors and rework, shortens the time needed to agree solutions between project stakeholders and decreases the frequency of unforeseen issues during construction.

Energy-efficient modernization based on BIM models

One of the most developed areas of BIM application in the reconstruction of residential buildings is the analysis and improvement of their energy performance. Within the information model, a detailed description of the building envelope is created, including wall build-ups, parameters of window and door units, thermal bridges and junction details, which makes it possible to use the model as a basis for heat-engineering calculations and energy simulations (Ahmed, Heywood & Holzer, 2023).

In the projects considered, various options were analyzed for external facade insulation using prefabricated modules, replacement of glazing systems and modernization of ventilation and heating systems (Fig. 4) (Pohoryles et al., 2022). The simulation results showed that a combination of external facade retrofit and the installation of energy-efficient windows can provide a significant reduction in heat losses and annual energy consumption, while the integration of heat-recovery ventilation units further decreases building energy use.

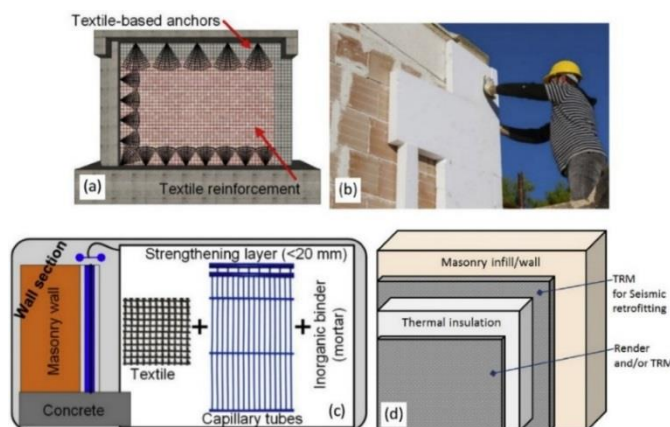


Figure 4. Possible configurations of TRM and energy upgrading solution:

- Infills and RC structure retrofitting with TRM,
- Insulation of a building envelope,
- TRM + capillary heating tubes and
- TRM + thermal insulation material

Note – compiled by the authors based on (Pohoryles et al., 2022)

In these projects, BIM models were used not only to verify thermal performance, but also to assess the techno-economic feasibility of different modernization scenarios, taking into account construction costs and the expected payback period due to reduced operating expenses (4RinEU, 2020).

Use of BIM for seismic performance and structural strengthening

For residential buildings located in seismic regions, assessing seismic performance and developing measures to strengthen load-bearing structures is of critical importance. In studies of integrated seismic and energy retrofit of reinforced-concrete residential buildings from the 1970s, the building information model served as the basis for constructing the analytical model, taking into account the geometry of elements, joints and the distribution of stiffness (Ademovic et al., 2022).

On this basis, different strengthening options were analyzed, including additional reinforced-concrete or steel elements, local strengthening of panel joints, the installation of stiffness belts and other measures (Fig. 5) (Pohoryles et al., 2022). Numerical experiments showed that a well-designed strengthening scheme can provide a significant increase in seismic resistance while simultaneously improving the energy performance of the building through facade insulation and replacement of envelope components.

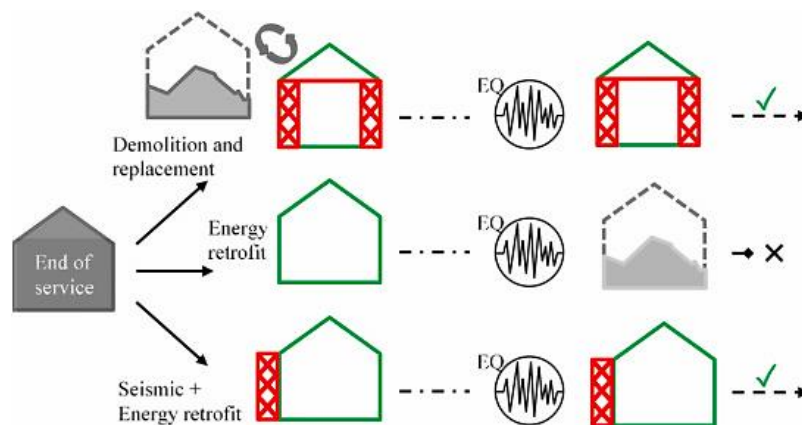


Figure 5. End of service life of buildings: The effect of demolition and rebuilding; energy upgrading and integrated energy and seismic upgrading in zones of seismic hazard

Note – compiled by the authors based on (Pohoryles et al., 2022)

Linking the BIM model with structural analysis software made it possible to evaluate the behavior of the building “before” and “after” retrofit, identify the most effective combinations of strengthening and energy-efficiency measures, and account for technological constraints associated with construction in a built-up urban context. This approach can be adapted to residential buildings in other seismically active regions, where safety and energy efficiency are closely interrelated (Bournas, 2018; Smioldo, 2022).

Economic efficiency and cost management

Building information modelling is increasingly used as a core tool for cost planning, control and optimization in reconstruction and retrofit projects, especially when combined with 4D and 5D dimensions. A BIM model that integrates geometry, element properties and work types enable automated quantity take-off and material schedules, which form the basis for more reliable cost estimates and scenario comparison between alternative retrofit options (Farouk & Rahman, 2025).

In energy-efficient and integrated seismic-energy retrofit projects, linking BIM with 4D schedule models allows visualization of construction phasing and identification of critical activities, which is particularly important for occupied residential buildings where shutdowns and access need careful coordination. The addition of the 5D dimension, in which unit cost data are connected to model quantities and time, supports dynamic cash-flow analysis, continuous comparison of planned and actual costs, and rapid assessment of the cost impact of design changes (Fig. 6) (Pishdad & Onungwa, 2024).

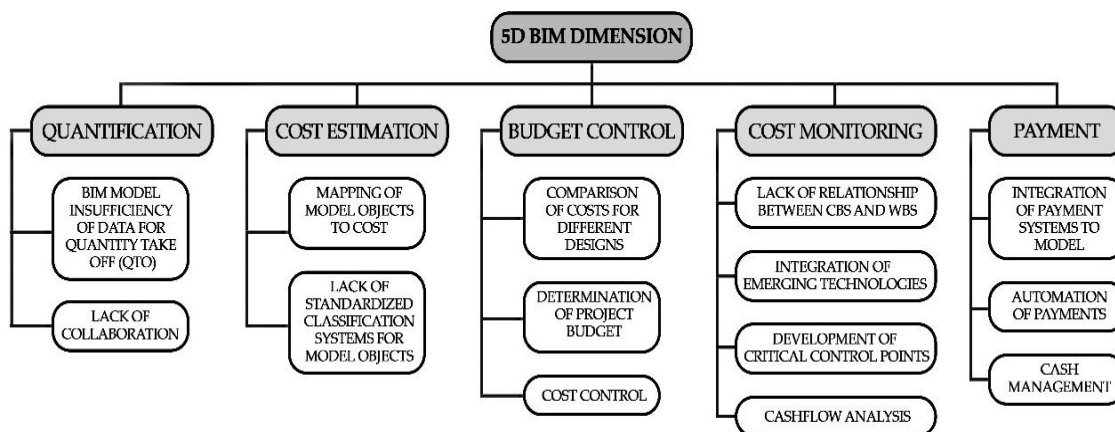


Figure 6. Streamlining the cash management process in construction

Note – compiled by the authors based on a diagram from Pishdad & Onungwa (2024)

The quantitative evidence available in the literature, while context-dependent, demonstrates consistent patterns of efficiency gains from BIM adoption. Studies analysing BIM-based cost optimization of seismic retrofit strategies in reinforced-concrete buildings found that integrated BIM modelling reduced the number of design errors and associated rework costs compared to conventional approaches, with total project cost reductions linked to fewer change orders and shorter coordination cycles (Vitiello et al., 2019). In a case study of bridge construction, BIM adoption based on 4D and 5D modelling was associated with simulated reductions in rework-related time of approximately 70-85% and cost savings in the range of 65-75%, as assessed through Earned Value Management analysis. The authors note that these figures are modelled projections and may vary depending on project scale, scope and implementation context (Elseufy et al., 2026). For residential retrofit projects specifically, the benefit-cost ratio of BIM implementation depends on the scale of the programme and the degree of repetition across similar building typologies: the larger the group of standardized buildings addressed within a single programme, the more favourable the return on investment in parametric libraries and as-is modelling workflows (Vitiello et al., 2019).

Such integrated models also support life-cycle cost analysis, enabling comparison of alternative strengthening and energy-efficiency schemes against the criteria of total economic losses over the building life cycle. Applied to residential building modernization, this approach increases transparency for investors and public authorities and provides a quantitative basis for prioritizing retrofit scenarios and selecting pilot projects (Vitiello et al., 2019).

As-is BIM modelling and laser scanning

For most reconstruction projects, the starting point is the development of an as-is BIM model that captures the actual geometry, construction system and technical condition of the building with a level of detail sufficient for design and analysis. This requires combining heterogeneous sources: archival drawings and specifications, results of visual and instrumental

surveys (opening up structures, testing materials, checking building services), and terrestrial laser-scanning data, which are processed into point clouds and then converted into parametric model elements. Compared to manual measurement, point-cloud-based modelling allows systematic registration of dimensional deviations, deformations of panels and slabs, displacements of joints and local defects, as well as discrepancies between the actual configuration of openings, balconies and engineering routes and the original design documentation. This improves the reliability of the base model and reduces the risk of overlooking critical constraints when developing retrofit solutions (Gholami et al., 2015).

Studies on energy-efficient domestic retrofit indicate that an accurately calibrated as-is BIM model is a prerequisite for robust energy simulations, since thermal performance calculations are highly sensitive to wall build-ups, junction details and real areas of envelope components. In projects such as MeeFS, the as-is model is used to design prefabricated façade modules that must match existing grids of panels, window and door openings and tolerances in slab and wall positions; here, laser scanning helps to define acceptable tolerance ranges and to adjust module geometry before fabrication. Similar approaches are reported in integrated seismic and energy retrofit studies, where the BIM model derived from point clouds provides the geometric basis for analytical models, enabling more realistic assessment of stiffness distribution and the effect of local irregularities on seismic response (Gholami et al., 2015).

From an organizational perspective, the as-is BIM model functions as a shared reference environment for architects, structural engineers, MEP designers and energy specialists, ensuring that all disciplines work with the same verified representation of the existing asset. It facilitates clash detection between new retrofit elements (prefabricated façades, strengthening components, new ducts and risers) and existing structures at an early stage, which is particularly important in densely serviced or occupied residential buildings. Moreover, once the model is populated with attribute data on element conditions, materials and service life, it can support life-cycle analyses and prioritization of measures, linking survey results with cost, energy and seismic performance indicators within a single digital environment (Fig. 7), (D'Angelo et al., 2022).

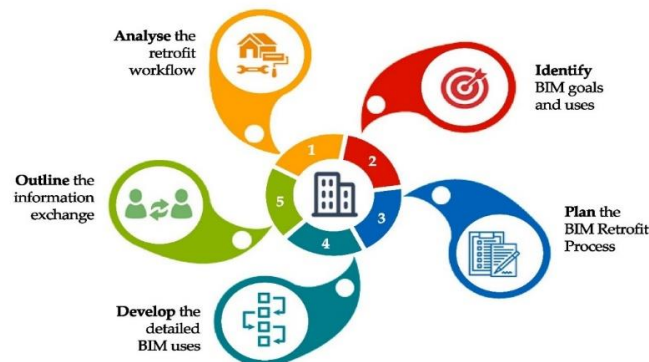


Figure 7. BIM-based BPM (BIM retrofit process) for the retrofit of existing buildings

Note – compiled by the authors based on (D'Angelo et al., 2022)

Parametric libraries of elements

An important aspect of applying BIM technologies to the reconstruction of the mass housing stock is the development and systematic use of parametric libraries that incorporate standard retrofit elements and prefabricated systems as configurable digital objects. Such libraries include façade modules, insulation panels, strengthening components, technical cabinets and service blocks, each defined by a set of parameters (dimensions, materials, thermal characteristics, fixings, allowable tolerances and installation rules), which allows rapid adjustment to specific building typologies and boundary conditions without redesigning

elements from scratch. In the MeeFS project, the multifunctional façade system was implemented as a family of parametric modules with embedded data on thermal performance and integration of building services, enabling designers to generate alternative configurations for different climates and façade layouts while maintaining industrialized production and on-site assembly.

Within SINFONIA and similar European projects, libraries of modular insulation systems, balcony units and technical enclosures are used to assemble retrofit solutions for typical residential blocks, with parameter sets reflecting local climatic loads, regulatory requirements and attachment details to existing structures. The use of parametric libraries substantially accelerates the preparation of reconstruction projects, as quantity take-off, energy performance indicators and, in some cases, cost data can be updated automatically when parameters change, which supports multi-variant analysis at early design stages. For the mass housing stock, these libraries also create preconditions for scaling: once a set of validated parametric solutions has been developed and tested on pilot buildings, it can be replicated across large groups of similar houses with controlled adaptation to regional climatic and seismic conditions, thereby reducing design time, uncertainty and unit costs of modernization (Fig. 8).

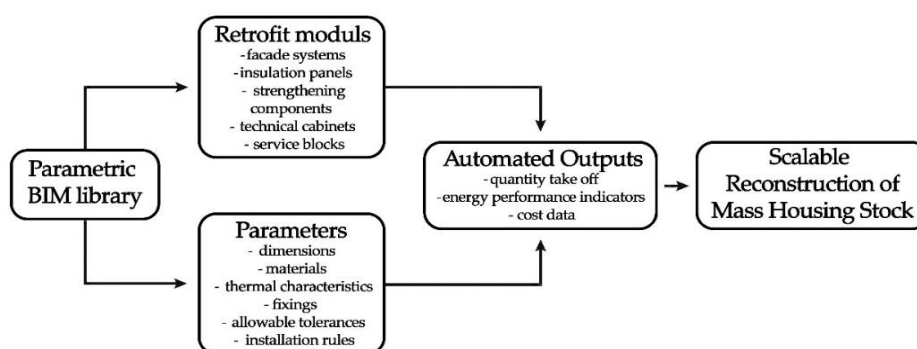


Figure 8. Workflow of parametric libraries in BIM-based reconstruction projects

Note – compiled by the authors

MATERIALS AND METHODS

The study has an overview-analytical character and is based on the systematization of publications and reports on international residential building reconstruction projects using BIM technologies (MeeFS RETROFITTING, SINFONIA, 4RinEU, etc.), as well as scientific works on integrated seismic and energy retrofit. The synthesis of these materials made it possible to identify key categories of BIM tools: as-is BIM modelling and laser scanning, energy modelling, coordination of design solutions and clash management, integration with seismic analysis, 4D schedule modelling, 5D cost modelling, parametric libraries of elements and prefabricated facade systems.

On the basis of a comparative analysis of these categories in terms of the types of tasks addressed (energy efficiency, seismic performance, coordination, resource management) and their applicability to the mass housing stock, an expert interpretation was carried out for the conditions of Kazakhstan, which made it possible to develop a summary scheme of BIM tool application in the form of a table.

RESULTS AND DISCUSSION

The analysis of the sources showed that in international practice of residential building reconstruction, BIM technologies are used as a comprehensive decision-support tool at all stages of the asset life cycle. In the projects considered, information models serve as a basis for creating an as-is model of the existing building, refining geometry using laser scanning, performing

energy simulations for different facade retrofit and building services modernization options, and assessing the economic efficiency and payback periods of the proposed solutions. In studies on integrated seismic and energy retrofit, the coupling of the BIM model with analytical schemes makes it possible to simultaneously optimize strengthening schemes for load-bearing structures and thermal insulation measures for the envelope.

Particular attention should be paid to the use of the BIM environment for the coordination of design solutions and clash management. Published case studies on the reconstruction and modernization of highly serviced buildings indicate a significant reduction in rework volumes and delay risks when clash-detection tools in platforms such as Navisworks and similar applications are used systematically. An additional effect is achieved through the implementation of 4D and 5D dimensions, where the information model is linked to construction schedules and cost indicators, increasing planning transparency and enabling the comparison of alternative retrofit scenarios against the criteria of time, cost and resource availability.

Based on the synthesis of the identified BIM tool categories and their functions, a summary table has been developed that presents the application and adaptation of BIM technologies for the reconstruction of residential buildings in Kazakhstan (Table).

Table. Application and adaptation of BIM technologies in the reconstruction of residential buildings in Kazakhstan

BIM technology	Tasks in residential building reconstruction	Potential outcomes	Recommended regions and conditions of application
As-is BIM modelling	Creation of an information model of the existing building, accounting for the actual condition and unauthorized alterations	Reducing errors and obtaining accurate quantities of work and materials	All regions; large cities with a high share of standard multi-apartment buildings (Astana, Almaty, Shymkent, etc.)
Laser scanning (point cloud)	Accurate capture of facade and interior geometry, identification of deviations from design dimensions	Preparing for prefabricated facades and ensuring accurate installation	Dense and complex urban fabric; panel housing estates from the 1960s-1980s
Clash detection	Detection of clashes between structures, pipelines, cable trays and new facade systems	Reducing rework, costs and project duration	All regions (especially for comprehensive modernization of building services and facade insulation in occupied buildings)
Energy-efficient modelling	Assessment of heat losses, selection of insulation thickness, window types and ventilation parameters with heat recovery	Reducing energy consumption and justifying payback	Cold and continental regions (Astana, Kostanay, Pavlodar, Ust-Kamenogorsk, etc.)
4D BIM (BIM + construction schedule)	Simulation of work sequence and duration, planning reconstruction under conditions of building occupancy	Schedule control and minimizing disruption for occupants	Large cities (block-scale reconstruction projects, phased retrofit)



End of Table 1

BIM technology	Tasks in residential building reconstruction	Potential outcomes	Recommended regions and conditions of application
5D BIM (BIM + cost)	Calculation of retrofit scenarios' costs and analysis of budget sensitivity to changes in scope and design decisions	Justifying investments and supporting option selection	All regions (projects implemented under state housing modernization projects)
Integration of BIM with seismic analysis	Generation of analytical models from the BIM model, assessment of building behavior before and after strengthening, selection of seismic strengthening schemes	Enhancing seismic safety at optimized cost	Southern and south-eastern regions (Almaty, Almaty region, Zhambyl region, Turkistan region, etc., with increased seismicity)
Parametric libraries of standard elements	Standardization of facade modules, insulation details, strengthening elements and service blocks for typical buildings	Scaling solutions across groups of similar buildings	Cities with a high share of standard multi-apartment buildings
Common Data Environment (BIM 360 and similar platforms)	Collaborative work of designers, the client and contractors; storage and updating of project and operation data	Improving the manageability of reconstruction projects	All regions (especially when launching municipal or regional projects for comprehensive housing stock modernization)
<i>Note – compiled by the authors</i>			

This representation shows that some BIM tools (as-is modelling, laser scanning, clash detection, energy modelling) can be implemented as priority steps within pilot projects for the reconstruction of multi-apartment buildings, whereas more advanced solutions (4D/5D BIM, integration with seismic analysis, common data environments) are best developed gradually as experience is accumulated and the regulatory and methodological framework is improved.

Limitations of BIM implementation in residential building reconstruction

Despite the significant potential of BIM technologies, their implementation in the reconstruction of existing residential buildings involves a number of constraints that must be considered when planning and scaling the application of digital tools.

The primary barrier is the high initial cost of implementation: expenses for BIM software licences, hardware upgrades, and staff training can be prohibitive for small and medium-sized design organizations, which form the majority of the market in countries at early stages of BIM adoption. Research indicates that the cost of BIM tools and the training of qualified personnel consistently rank among the top barriers to adoption, alongside the high learning curve associated with the transition from traditional 2D workflows.

A second critical constraint is the shortage of skilled professionals with practical BIM experience in reconstruction projects. Unlike new construction, where BIM workflows are increasingly standardized, retrofit BIM requires specialized competencies - in particular, the

ability to process point-cloud data, calibrate as-is models against survey results, and link geometric models with energy and structural analysis tools. In countries of Eastern Europe and Central Asia, the diffusion of such competencies remains limited due to insufficient BIM training programmes, lack of national standards and a low level of mandatory requirements for BIM use in public procurement.

The third group of constraints is regulatory. The absence of approved BIM standards, model-delivery requirements and contractual frameworks governing the use of information models in the reconstruction of existing housing stock increases uncertainty for project participants and reduces incentives for investment in digital tools. In Kazakhstan, as in other post-Soviet countries, the regulatory environment for BIM in reconstruction has not yet been fully formed, which means that the integration of BIM tools must be accompanied by the parallel development of methodological guidelines and pilot regulatory frameworks.

CONCLUSION

The analysis has shown that BIM technologies have significant potential to improve both the efficiency and quality of residential building reconstruction projects. The information model of an existing asset, when complemented by tools for energy and seismic analysis, clash management and other functionalities, can substantially reduce design errors and rework, decrease uncertainty in schedule and cost estimates, and support a more informed selection of retrofit scenarios in terms of energy performance and safety.

For Kazakhstan, with its combination of harsh climatic conditions, seismically active regions and a substantial share of industrial-era housing, the BIM-based approach appears particularly promising. The summary framework for the application and adaptation of BIM tools across the country's regions outlined in this study provides a basis for developing methodological guidelines and pilot comprehensive reconstruction projects. Further research should focus on refining as-is modelling procedures for the most common residential building types, developing parametric libraries of energy-efficient and seismic retrofit solutions, and creating a regulatory and methodological framework governing the use of information models in large-scale housing stock reconstruction.

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