CHEMICAL ENGINEERING TRANSACTIONS
VOL. 113, 2024

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Jeng Shiun Lim, Bohong Wang, Guo Ren Mong, Petar S. Varbanov

ISBN 979-12-81206-14-4; **ISSN** 2283-9216

DOI: 10.3303/CET24113103

A Renovation Framework for Energy Efficient Dilapidated Building Retrofitting in Kazakhstan

Elmira Tazhentayeva[a], Anees Ahmed Vighio[b], Kamaliah Mohd Saha[b,*], Murat Rakhimov[a], Rozana Zakaria[c], Thong Jia Wen[b], Askhat Rakhimov[a], Zhanara Rakhimova[a], Yedil Imanov[a], Kamilya Maikotova[a]

[a]Faculty of Architecture and Civil Engineering, Albykas Saginov Karaganda Technical University, Karaganda City, 100027, Kazakhztan
[b]Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
[c]Faculty of Artificial Intelligence, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
kamaliah@utm.my

Dilapidated buildings hinder energy conservation and sustainability by consuming excessive energy, harming the environment, and providing poor living conditions. In Kazakhstan, many buildings are dilapidated as they were built since the Soviet era and so suffers substantial heat loss in winter and heat gained in summer due to poor thermal insulation thereby increasing the cost of space heating and cooling for human comfort. This study proposes a ten-step renovation framework to minimize thermal energy loss by retrofitting dilapidated buildings in Kazakhstan, preserving their architectural history while enhancing energy efficiency. It draws from existing literature on building reconstruction and discusses the performance of thermal insulation materials in improving building envelopes.

1. Introduction

A dilapidated building is a structure that has fallen into a state of disrepair, often as a result of neglect or the ravages of time. These buildings are characterized by significant wear and tear, both in terms of their structural integrity and overall living conditions. The most pressing issue in Kazakhstan is dilapidated residential buildings that affect many communities across the country. These buildings are characterized by significant wear and tear, both in terms of their structural integrity and overall living conditions. Many buildings in the country were constructed during the Soviet era, the country's buildings and structures use a lot more energy than those in other countries. Energy-efficient insulation was not taken into consideration when these buildings were constructed according to the building codes and standards of the time (Cherenkova et al., 2016). The consequences of dilapidated residential buildings entail far-reaching problems. Collapsing structures pose a threat to the safety and well-being of residents, as they may be prone to collapse or have inadequate security measures. These buildings often suffer from problems such as leaking roofs, faulty plumbing, electrical problems, and insufficient insulation, resulting in uncomfortable living conditions and increased utility costs for residents (Dosaliev et al., 2018).

The Government of Kazakhstan has recognized the importance of addressing this problem and has initiated various programs and policies aimed at addressing the problem of dilapidated residential buildings. These efforts are aimed at improving the living conditions of residents, ensuring the safety of structures, and improving the overall quality of housing in the country. One of the key approaches used by the government is the reconstruction and modernization of existing residential buildings (Amangeldikyzy et al., 2023). This includes repairing structural damage, upgrading basic systems such as plumbing and electrical wiring, improving insulation, and improving overall livability. It is worth noting that dilapidated residential buildings create significant problems in Kazakhstan, affecting the safety and quality of life of residents.

Its antiquated nature is demonstrated by the fact that about 85 % of Kazakhstan's current housing stock does not meet current standards for thermal insulation. Building facade condition is another common source of issues.

Paper Received: 16 May 2024; Revised: 22 August 2024; Accepted: 5 November 2024
Please cite this article as: Tazhentayeva E., Vighio A.A., Mohd Saha K., Rakhimov M., Zakaria R., Wen T.J., Rakhimov A., Rakhimova Z., Imanov Y., Maikotova K., 2024, A Renovation Framework for Energy Efficient Dilapidated Building Retrofitting in Kazakhstan, Chemical Engineering Transactions, 113, 613-618 DOI:10.3303/CET24113103

It becomes imperative to think about implementing policies targeted at isolating these buildings' facades. Improving the thermal insulation of building enclosing structures not only increases their external attractiveness but also reduces heat loss during transmission (Gade et al., 2018). By reducing heat loss within the building, the need for heat energy from the heat supply source to compensate for these losses is reduced. According to Ivanova, thermal insulation helps to reduce energy consumption inside buildings, which ultimately leads to lower heating costs (Ivanova, 2016).

The importance of reducing energy consumption in the residential sector is undeniable. The significant costs and long payback periods usually associated with energy-efficient measures pose a challenge when it comes to selecting the most economically viable options that provide significant energy savings. After carefully evaluating the energy-efficient technologies available in the construction market, we developed an optimization framework. This framework includes an algorithm that helps you make informed decisions about the choice of energy-efficient measures. One of the most profitable energy-efficient measures is reconstruction. In addition to saving energy, efficient renovation will help to improve the economic, social, and environmental quality of buildings (Gade et al., 2018). This study is conducted to develop a Renovation Framework for redundant buildings in Kazakhstan.

2. Dilapidated Buildings: Evidence from Kazakhstan

A large number of dilapidated houses can be found in Kazakhstan's single-industry towns. In Kazakhstan, single-industry towns are specialised areas whose economic existence is largely dependent on one industry or enterprise. These cities arose during the Soviet era when industrialization was concentrated in specific areas. The decision to build such cities was motivated by the need to develop Kazakhstan's abundant natural resources, which include oil, gas, minerals, and heavy industry. The development of single-industry towns was planned to support and accommodate workers and the infrastructure needed for large-scale industrial activities. Their heavy reliance on a single industry makes them vulnerable to fluctuations in global commodity prices, technological changes, and changes in market demand.

In Kazakhstan, the absolute leaders in terms of the share of residents living in single-industry towns are the southern, eastern, and central regions (South Kazakhstan, Almaty, East-Kazakhstan, and Karaganda regions), and the central and northern regions (Karaganda, Kostanay and Pavlodar regions) in terms of the share in the number of single-industry towns (Turgel and Linshi, 2016). Figures 1 and 2 show the abandoned panel houses of Kurchatov and Saran City of Kazakhstan.

Figure 1: Abandoned panel houses, Kurchatov City

Figure 2: Abandoned panel houses, RTI micro-district, Saran (Turar Kazangapov)

According to Turgel and Linshi (2016), The Ministry of Regional Development of the Republic of Kazakhstan allocates single-industry towns as per the following criteria: the volume of industrial production of city-forming enterprises, mainly in the extractive sector, is more than 20 % of the citywide production, city-forming enterprises employ more than 20 % of the total employed population, cities where the city-forming enterprises partially operate or have suspended their activities, and only cities with a population of 10 k to 200 k people are included. The city of Saran was formed in 1954 as an industrial satellite of Karaganda, where it was planned to place several service industries in addition to the main city–forming enterprises, a factory of rubber products, and mines. In the mid-1970s, about 40 industrial enterprises, transport, and construction organizations worked in Sarani: 7 mines, 3 processing plants, 4 construction organizations, 2 precast concrete plants, 2 brick factories, a bakery, and a dock (Akimzhanov and Kh.R., 2014). The RTI plant in the village was put into operation on December 30, 1974, and for the next 20 years, the company was the first in the country to produce rubber products.

Figure 3: Abandoned panel houses, RTI micro-district, Saran (Turar Kazangapov)

Figure 4: Restored panel houses, RTI micro-district, Saran

In those years, a work settlement was built at the plant as part of 3 micro districts, where 25 k people lived. Then RTI micro district was built up, developed, and flourished. But after the collapse of the USSR in 1994, the company was declared bankrupt, and water and power outages began in the micro-district. Gradually, residents, having lost all hope for the best, were forced to leave their homes. Currently, there are 106 empty high-rise buildings in Saran RTI, 23 of them are not subject to restoration. Figure 3 above show the abandoned panel houses, while Figure 4 portrayed the retrofitting's of the abandoned house in RTI micro-district, Saran (Turar Kazangapov).

At present, the rate of housing construction in Sarani has increased by 260 %. This made it possible to begin the revival of the entire RTI micro district, which was also in a state of "stagnation" for decades. An industrial zone is being expanded in Sarani. Due to the creation of enterprises, new jobs are created that can employ more than 6 thousand people. Due to the creation of new jobs, the RTI micro district has been actively restoring abandoned houses for several years (Turar Kazangapov). Many other dilapidated buildings in Kazakhstan need to be renovated to improve energy efficiency.

3. Analysis of the Experience of Foreign Countries

Reconstruction of buildings in foreign countries is a common practice aimed at improving the condition, functionality, and aesthetics of existing structures. This includes carrying out necessary repairs, upgrading outdated systems, improving energy efficiency, and upgrading the building by current standards and regulations. In Gagliano et al. (2013), during an in-depth study of energy problems related to social housing units in Italy, an analysis of the building's enclosing structures was carried out and a scheme of energy behavior was developed throughout the building, which allowed to change various factors to assess which technological components need to be changed to improve energy behavior. The energy redevelopment presented in the study results in multiple benefits, including (i) reductions in municipal water usage, (ii) decreased primary energy consumption for indoor heating, (iii) lower primary energy consumption for DHW; and (iv) the generation of approximately 20.0 MWh of electricity annually from renewable energy sources. The accuracy of these findings was verified by comparing the energy demand projected by the software with the actual energy bills. This validated energy model can be applied to propose large-scale actions aimed at lowering energy consumption and enhancing residents' comfort. The authors argue that prioritizing building modernization in design is crucial to meet the necessary standards for safety, indoor comfort, and energy efficiency.

In studied by El-Darwish and Gomaa (2017), propose a modernization strategy in an attempt to increase energy efficiency in a sample of higher education buildings located in a hot, arid climate (Egypt). Upgrading some elements of the building's enclosing structures can provide comfort without compromising on functional needs. Comfort needs that include thermal, visual, and acoustic needs can reduce energy consumption. In this study, much attention was paid to thermal comfort in terms of energy efficiency. Some of the important measures used in the building envelope modernization process include insulation of exterior walls, type of window glazing, tightness (infiltration), and sun protection. The results of the study show that simple modernization strategies, such as sun protection, window glazing, air tightness, and then insulation, can reduce energy consumption by an average of 33 %. Based on the possible shell characteristics used in this study, the study provides a proposal for design standards that support thermal comfort, suggests a feasible modernization strategy, and inputs specifically designed for local energy efficiency.

Many systems and tools have been developed around the world to support decision-making when choosing the preferred upgrade scenario or alternative. These existing systems often do not take into account social aspects and do not analyze the emotions of building residents. To address this gap, Stanevich et al. (2022) proposed an innovative system for making decisions on sustainable reconstruction based on emotion recognition. To achieve this goal the MCDA (Multiple Criteria Decision Analysis) approach was analyzed in Criteria Decision Analysis. In Zemitis and Terekh (2018), methods for evaluating the economic efficiency of additional thermal insulation of building enclosing structures and determining the optimal thermal resistance are considered, and the disadvantages of these methods are noted. A model for determining the optimal level of thermal protection in the new economic conditions is proposed. As a result of the review of the optimal thermal protection model, it was concluded that it is advisable to search for new effective and inexpensive domestic thermal insulation materials, effective thermal insulation technologies, fastening elements and protective elements, and methods of mechanization of work. The study by Ongpeng et al. (2020) employed MCDA technique by combining Analytical Hierarchy Process (AHP) and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) methods to evaluate retrofit strategies based on environmental, economic and technical criteria. A case study involving an old university building in Philippines demonstrates the practical application of these methods. Notably, stakeholders prioritise initial investment costs over technical performance, favoring cost-optimal and eco-friendly scenarios.

4. Proposal of Renovation Framework

Based upon the present condition of dilapidated buildings across Kazakhstan, the relevant past studies, and the Analysis of Renovation of Buildings of Foreign countries, a New Renovation Framework is proposed as per Figure 5, demonstrating the need for localized strategies that address the economic, climatic and social conditions of the country. While foreign countries offer valuable insights into energy saving and building modernization, it is important to consider Kazakhstan's climate, financial constraints, and the historical significance of its aging building. This gap calls for tailored solutions that not only enhance energy performance but also preserve cultural heritage, improve resident satisfaction, and ensure financial feasibility in Kazakhstan's unique context. This framework consists of ten steps to renovate a building which are discussed as under:

Figure 5: A Renovation Framework

1. Building: Identify the building which needs to be renovated.
2. Stability Analysis: Perform the stability Analysis of the building, if it meets the requirement then further program should be determined.
3. Analysis of Engineering System: In this step the verification of ensuring the conditions of the Operating Facilities of the building.
4. Analysis of the Enclosing Structures: The building Envelope should be analysed.
5. Data Collection and Analysis: The data relating to the materials, stakeholders, environmental conditions, financial conditions of the end users, and problems of the building must be collected and analysed.
6. Selection of Best Renovation Program: Based upon the data collected and analysed in step (e) the suitable renovation program must be selected.
7. Budget Definition: The Budget for the renovation of the building must be properly defined.
8. Reconstruction of the Building: After defining the Budget required for the renovation of the building, the reconstruction of the building should be started.
9. Creation of Affordable Housing for the Population: After renovating the dilapidated buildings, Affordable Housing for the Local people should be created.
10. Preservation of Architecture and History: By renovating the existing buildings, the Architecture and History of the old age buildings must be saved or protected.

This proposed Renovation Framework has to be complimented with the following requirements:

- Preference for environmentally friendly and safer for the health of occupants in utilising the building materials;
- Ensuring that the renovation project is managed in compliance with all deadlines and budgets;
- Appointing qualified specialists to monitor all stages of work;
- Regular quality control of the performed works and their compliance with the project documentation;
- Streamline permitting and approval processes for renovation work; and
- Compliance with all safety standards and regulations during construction work and minimise disruption to local communities.

5. Case Study: Renovation proposal of thermal insulation retrofitting

This paper conducted a case study for the research methodology.
Step 1: Problem Formulation
An analysis of the thermal insulation properties of enclosing structures was carried out on the example of a residential building in the city.
Step 2: Analysis of Case Study
The data obtained gave a clear picture of the problems of heat loss of the exterior walls. Based on these results, a methodology was developed with a specific action plan, such as renovation or reconstruction of the building itself. The renovation was chosen since the identified problems that have arisen do not require huge costs.
Step 3: Literature Review & Comparison to Existing Models
During the development of the study, a review of the literature of foreign countries with more experience in the renovation of buildings and structures was carried out.
Step 4: Propose Renovation Framework

- A new composition of foam polystyrene concrete has been developed as tabulated in Table 1.
- Investigated the properties of Polystyrene concrete panels that differ in composition as shown in Figure 6.

Table 1: Composition of expanded polystyrene concrete per 1 m^3

No.	Name of materials	Unit	Material consumption per 1 m^3 polystyrene concrete		
1	Polystyrene foam granules (PFG)	m^3/kg (mm)	1.0/9 (0-2.5)	1.0/6 (2.5-5.0)	1.0/3 (5.0-10.0)
2	Cement	kg	330	330	330
3	Foaming agent PB 2000	l	1.0	1.0	1.0
4	Setting accelerator, CaCl	kg	6.6	6.6	6.6
5	Saponified wood resin (SDO)	kg	1.0	1.0	1.0
6	Polypropylene fibers	kg	0.6	0.6	0.6
7	Water	l	168	150	130

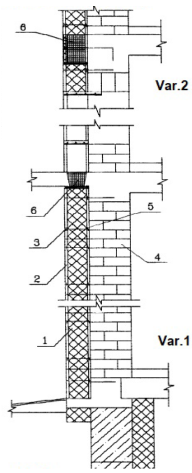

Figure 6: Cladding plate for insulation and decoration of buildings (1-expanded polystyrene, 2-cement, 3-hinges, 4-load-bearing wall of the building, 5-holes for hinges, 6-fire protection.)

The proposal is via comparison of two types of materials enclosing wall structures. The results of comparing two types of enclosing insulation material to wall structures are presented in Table 2 below.

Table 2: Comparison of two types of enclosing structures

Material properties	New composition of expanded polystyrene concrete and polystyrene concrete panel	Ordinary composition and ordinary panel
Thermal conductivity coefficient, W/mK	0.12-0.15	1.69
Frost resistance, cycle	200-300	200
Compressive strength, MPa	B40-60	B30
Water absorption, % by weight	5.5	No more than 6
Crack resistance	0.246	0.57

The new composition of expanded polystyrene concrete and polystyrene concrete panels has resulted in better thermal conductivity in the range of 0.12 – 0.15, which is 90 % improving thermal performance. The proposed insulation retrofitting still has additional requirements of finishing materials such as facing bricks, decorative plaster, siding, etc.

6. Conclusions

Sustainable reconstruction plays a key role in improving energy efficiency, achieving the broader benefits of sustainable living, and improving a city's neighbourhood well-being. This study concluded that it is necessary to renovate the existing old-age buildings of Kazakhstan to provide affordable and comfortable housing for the people of Kazakhstan by taking several steps of consideration for suitability of renovation, while at the same time preserving its architecture and history. It is important to note that renovation projects require an understanding and compliance with local regulations, cultural characteristics, and specific building codes. Engaging with local experts, architects, contractors, and stakeholders is critical to a successful and culturally appropriate renovation, as mentioned in the paper by the example of a residential building renovation in Saran, a dilapidated building that was successfully renovated with new materials and technologies. The paper also proposed a case study of thermal insulation retrofitting that is expected to reduce energy consumption by the behaviour of the building envelope after the renovation of dilapidated buildings. The proposed new composition of expanded polystyrene concrete and polystyrene concrete panels offers significant improvement in the thermal conductivity of the building block and in the overall thermal efficiency of the building.

References

Akimzhanov Kh.R., Safronov S.G., 2014, Socio-economic transformation of the territorial structure of the Karaganda agglomeration, Regional Studies, 2(44), 86–96.

Amangeldikyzy R., Amandykova D., Tokayuk A., 2023, Architectural renewal of industrial buildings on the example of large cities in Kazakhstan, Cities of the future and the environment, 9(1), 6.

Cherenkova E.O., Cherenkova A.O., Gulyaeva L.V., 2016, Energoreconstruction of buildings and structures by installing external thermal insulation, Russian Science Citation Index, 115-2, 241–243.

Dosaliev K.S., Nurgali T.A., Maratov A., 2018, Analysis of the state of external enclosing structures of large-panel buildings, Nauchnye Trudy SKSU im., 4(48), 70–74.

El-Darwish I., Gomaa M., 2017, Retrofitting strategy for building envelopes to achieve energy efficiency, Alexandria Engineering Journal, 56(4), 579–589.

Gade A.N., Larsen T.S., Nissen S.B., Jensen R.L., 2018, REDIS: A value-based decision support tool for renovation of building portfolios, Building and Environment, 142, 107–118.

Gagliano A., Nocera F., Patania F., Capizzi G., 2013, A case study of energy efficiency retrofit in social housing units, Energy Procedia, 42, 289–298.

Ivanova S., 2016, Generalized criteria of energy performance evaluation in early design stages of nearly zero-energy buildings, World Science, 2(6), 22–28.

Ongpeng J.M.C., Rabe B.I.B., Razon L.F., Aviso K.B., Tan R.R., 2020, Multi-criteria decision analysis for energy retrofit in buildings, Chemical Engineering Transactions, 81, 79–84.

Saduakas A.T., Adilova D.A., 2021, Typology of residential buildings in the Republic of Kazakhstan: Advantages and disadvantages, StudNet, 4(3), 18.

Stanevich, V.T., Bulyga, L.L., Vyshar, O.V., Girnis, S.R., Rakhimova, G.M., 2022, Analysis of energy efficiency of building envelopes of JSC "Station EGRES-2", AIP Conference Proceedings, 2559, 050006.

Turar Kazangapov, <kazangapov.com/> accessed 17.01.2024.

Turgel I.D., Bozhko L.L, Linshui S., 2016, Government support of single-industry towns in Russia and Kazakhstan, Finance: Theory and Practice, 2(20), 22–32.

Zemitis J., Terekh M., 2018, Optimization of the level of thermal insulation of enclosing structures of civil buildings, MATEC Web of Conferences, 245, 06002.