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THE IMPACT OF MODULAR RESIDENTIAL CONSTRUCTION AND HYBRIDIZATION PROCESSES ON THE SOCIAL ASPECTS OF URBANIZATION AND SUSTAINABLE URBAN DEVELOPMENT

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ABSTRACT

The expansion and considerable densification of cities entail an increased demand for micro-housing. The popularity of micro-housing is shaped by the high cost of urban land, a shortage of area for construction, and high real estate prices. The study aims to assess the effects of modular residential construction and hybridization processes on the social aspects of urbanization and the advancement of sustainable urban development. The study employs a qualitative-quantitative approach, which establishes three directions of application of the term "hybrid residential houses" in contemporary architecture. The first one is associated with the hybrid engineering strategy, the second – with remote work from home, and the third – with the development of functional hybrids. Based on the identified current trends in modular housing design, the authors establish that modular residential construction is connected with hybridization processes in construction and architecture. It is concluded that we are witnessing the development of a hybrid approach to modular housing design, which has emerged in response to the challenges and problems of urbanization for orderly and sustainable urban development. The practical significance of the study is provided by the fact that the presented conclusions may be applied in the design of modular residential buildings.

Keywords: Modular residential houses; Modular construction; Hybrid living house; Hybridization; Engineering hybrid; Functional hybrid.

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RESUMO

A expansão e o considerável adensamento das cidades acarretam um aumento na demanda por micro-habitações. A popularidade das micro-habitações é moldada pelo alto custo da terra urbana, pela escassez de área para construção e pelos altos preços dos imóveis. O estudo tem como objetivo avaliar os efeitos da construção residencial modular e dos processos de hibridização nos aspectos sociais da urbanização e no avanço do desenvolvimento urbano sustentável. O estudo emprega uma abordagem qualitativa-quantitativa, que estabelece três direções de aplicação do termo "casas residenciais híbridas" na arquitetura contemporânea. A primeira está associada à estratégia de engenharia híbrida, a segunda, ao trabalho remoto a partir de casa, e a terceira, ao desenvolvimento de híbridos funcionais. Com base nas tendências atuais identificadas no projeto de moradias modulares, os autores estabelecem que a construção residencial modular está ligada a processos de hibridização na construção e na arquitetura. Conclui-se que estamos testemunhando o desenvolvimento de uma abordagem híbrida para o projeto de moradias modulares, que surgiu em resposta aos desafios e problemas da urbanização para um desenvolvimento urbano ordenado e sustentável. A importância prática do estudo se dá pelo fato de que as conclusões apresentadas podem ser aplicadas no projeto de edifícios residenciais modulares.

Palavras-chave: Casas residenciais modulares; Construção modular; Casa híbrida; Hibridização; Híbrido de engenharia; Híbrido funcional.

1 INTRODUCTION

Housing construction never loses its topicality from the standpoint of increasing population demand (Rybak et al., 2023; Stepanova et al., 2023). Today, in the face of rising prices for urban land plots for construction (Anokhina et al., 2020), increasing transport and labor costs, and demographic changes (Petrov, Churilova, & Nikiforova, 2022), architects and developers are offering new forms of housing (Gladilina et al., 2023).

National programs lie in the framework of sustainable development (Ydyrys et al., 2023), considering their principles and requirements regarding the architectural formation of the residential environment (Bondarenko et al., 2023). This involves, first, functional design solutions, second, universal design (Xiong, Zheng, & Nazarov, 2023), meaning that the environment is shaped based on inclusivity, and, third, the environment formed following the principles of harmony, environmental friendliness, and integrity (Asadulagi et al., 2024; Zhukovsky et al., 2017).

All these approaches are fundamental, but today their application needs to focus on the speed and universality of construction and the diversity of building types. These requirements can all be fulfilled by hybrid residential housing, which is now actively

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introduced in global practice (Belabid et al., 2022).

Of great interest for the implementation of national housing programs in modular construction as a variety of engineering hybrids (Salama et al., 2017), since it can provide the high speed and universality of construction (Generalova et al., 2016).

The relevance of the present study is determined by several factors: 1) the search for new methods of design and construction based on the modular method, which provides fast-building flexible structures, is becoming a scientific issue; 2) the need to utilize progressive experience in modular housing.

2 LITERATURE REVIEW

By the definition offered by S. Isaac et al. (2016), modular architecture is a process under which all components of a building are manufactured away from the construction site in controlled conditions and then transported to the project site and assembled. Thus, a high-quality building is erected in a shorter time, has more predictable costs, and lower environmental losses – for example, through reduced volumes of the consumed materials and produced waste (Kuderina et al., 2021; Lacey et al., 2018). For these reasons, architects have long been using and realizing modular construction (Lawson & Ogden, 2008).

In addition, the class of modular technologies extends to block-modular buildings as a type of fast-building structure. These houses are assembled from ready-made modules produced entirely at factories and shipped to the construction site as a ready-to-use package (Lawson et al., 2011).

As described by P. Sharafi et al. (2018), modular residential houses are buildings constructed from pre-made, prefabricated structures (modules) prepared in advance, the design of which allows quickly connecting anywhere from several units to several dozen modules. These connections may be both horizontal and vertical, forming multistory structures.

The term "modular construction" has two common uses. The first relates to the volumetric planning solution of the building in which the house's layout, certain planning modules consisting of a set of rooms are repeated to form the residential building (Satasivam & Bai, 2016). The second context refers to the construction solution in which the building is comprised of cells – block-modules. In the second case, the construction module also assumes the presence of a planning module in the building (Li et al., 2001).

The theoretical aspects of modular construction are explored by M.A. Hana et al. (Economist Impact, 2022), K. Adeyeye et al. (2010), and E. Mussinelli et al. (2017), who

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outline the typological signs of hybrid buildings and consider hybrids from the point of view of the evolution of multifunctional structures.

The term "hybrid residential house" in architecture and construction has been in active use since the last quarter of the 20th century (Bouchlaghem et al., 2004). Initially, the term was used by architects to negatively refer to an anarchic mixing of architectural styles that does not create a harmonic form and to buildings that contradict the environment or the culture and identity of residents (Abrams, 2001). Researchers believe that hybrid design is a search in its nature, so the result is not always a success (Haddadi, 2020).

Nevertheless, several researchers see hybrid buildings as catalysts for new and experimental types of architecture, emphasizing the obtained new qualities of hybrid buildings. These buildings are not merely a mix of different functions but provide an integration of these functions, and sometimes their unexpected combinations (Gyurkovich, 2022). Some examples are the Rotterdam Market Hall (Rotterdam, Netherlands), which comprises residential housing and a city market, as well as a hybrid residential project with a tramway depot on Laajäsalo Island (Helsinki, Finland) (Franta, 2019).

In recent years, the search for typological features of hybrid residential buildings has intensified in architectural theory. Researchers identify three distinctive features of hybrid buildings: three or more profitable functions; significant functional and physical integration of components of the object; and development following an integrated design (Innella et al., 2019).

K. Adeyeye et al. (2010) have attempted to establish a model of a hybrid residential building, which includes the following parameters: 1) large scale; 2) positioning on densely developed urban territories; 3) functional diversity; 4) diversity on the range from large scale functions to small "micro-urbanisms"; 5) integration of functions; 6) flexibility as the ability and capability to change over time (i.e., the hybrid is designed as an "open form"); 7) the presence of vertical connection ensuring the integration of functions; 8) the presence of interior public spaces for gatherings and communication, which are integrated into exterior urban public spaces.

However, following M. Halfawy and T. Froese (2005), we have to admit that not every single realized architectural hybrid corresponds to these criteria, and based on the predominant objective, architects identify their own characteristics of hybrids. However, this model can be considered an ideal model for the new type of residential environment that research in modern architecture seeks. Hybrid design, in turn, is exploratory, absorbing, and integrating progressive modern architectural concepts and theories.

Considering the preceding discussion, this research aims to investigate the implications

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of modular residential construction and hybridization processes on urbanization patterns and the facilitation of sustainable urban development.

3 METHODS

To reach the set research goal, the study utilized a qualitative-quantitative approach.

In the first stage of the study, we analyzed scientific sources dealing with the problem of the design and construction of hybrid residential houses as a contemporary trend in urban development and architecture. The analysis showed three primary directions in the use of the term.

In the second stage, based on the analysis of contemporary experience in the design of modular residential buildings, the main advantages and current trends in the construction of modular residential buildings were identified.

In the third stage, respondents for an expert survey were selected from among construction project officers and invited to participate in the study via email.

The survey included a total of 82 respondents, who were informed of the goal and program of our research in an email. The survey was carried out from July 15 to September 15, 2023 and consisted of the following question: In your opinion, what are the current trends in modular construction?

After the experts' responses were collected, they were sent a follow-up letter asking them to rate the identified trends in modular construction by importance, placing them on an ordinal scale by assigning points. Next, we identified the rank and weight of each trend according to the experts, which determines the significance of the respective trend.

4 RESULTS

An analysis of the scientific literature on the use of the term "hybrid residential houses" showed that the term is currently used in three main directions (Table 1).

Table 1. Uses of the term "hybrid residential houses" in scientific literature

No.	Direction	Source
1	Hybrid engineering strategies	D.P. Abrams (2001), D. Bouchlaghem et al. (2004), S. Haddadi (2020), M. Halfawy and T. Froese (2005), G.Q. Li et al. (2001), E. Mussinelli et al. (2017)
2	Opportunity to work from home	Economist Impact (2022), E.E.-S. Etman (2011), M. Gyurkovich (2022), T. Salama et al. (2017)
3	Development of functional hybrids	K. Adeyeye et al. (2010), A. Belabid et al. (2022), A. Franta (2019), E.M. Generalova et al. (2016), E. Mussinelli et al. (2017)

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Based on the results of the expert survey, we identified the following current trends in modular construction (Table 2).

Table 2. Contemporary trends in modular construction

Contemporary trends	Rank	Weight
Automation of mass production and unification of elements	1	0.33
Striving for maximum diversity of modules, apartments, and types of housing	2	0.24
Transition to lightweight wood and metal structural modules	3	0.19
Striving to maximize the size of building and construction modules	4	0.15
Introduction of energy-efficient and smart technologies and materials and the use of secondary resources	5	0.09

Note: compiled from the expert survey.

5 DISCUSSION

As demonstrated by our review of scientific sources (Table 1), the first direction in which the term "hybrid residential houses" is applied relates to hybrid engineering strategies. Herein, a hybrid residential house implies a house with a non-standard construction solution, using a range of various construction materials, construction methods, or construction elements and systems. This term is actively used in civil engineering to describe the mixing of various materials and processes to improve certain aspects of the building (Bouchlaghem et al., 2004). Indeed, the combination of materials (wood/clay – wood/steel – wood/concrete – reinforced concrete/steel) allows using the advantages of one material while also overcoming their limitations and drawbacks (Li et al., 2001).

Mixing materials to improve certain aspects of construction is a long-standing practice. This approach became popular with the Industrial Revolution and the development of science. At one time, the mixing of concrete with steel reinforcement became a revolution in construction, and now reinforced concrete is the most popular building material on the planet. The most commonly used hybridization in the 20th century was the integration of reinforced concrete with monolithic elements, the purpose of which was to combine speedy production and finishing works and the best performance of prefabricated reinforced concrete with the flexibility and cost-effectiveness of monolithic concrete "on-site". However, it was only in the 21st century, with the establishment of the environmental paradigm in architecture, that these houses, methods, and materials began to be referred to with the term "hybrid".

A trend of the 21st century is the search for environmentally friendly construction materials and methods (Bekezhanov et al., 2023) to minimize the environmental impact of construction, the emissions of greenhouse gasses, solid and liquid wastes during the building's life cycle (Muzalev et al., 2023), and the consumption of energy and water.

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Therefore, researchers see a direction for prospective further research in the production of hybrid construction materials by mixing to develop sustainable materials (Zakharov, 2023) that meet low-carbon requirements, as well as in the integration of modern construction processes with traditional approaches to increase the competitiveness and sustainability of buildings (Salama et al., 2017; Sergeeva et al., 2023).

The second direction in which the term is used is defined by the problems of remote work from home (Bayazitova et al., 2023). In this context, a hybrid living house is a residential structure that contains both accommodation and business or industrial spaces, enabling residents to work from home (Kenzhin et al., 2021). In this case, the inhabitants of this structure occupy both types of spaces, and this structure is built specifically to combine the functions of housing and workplace. The rising relevance of such buildings owes to changes in the traditional working environment, which were further accelerated during the COVID-19 pandemic and forced remote work (Vinichenko et al., 2022).

The requirements, limitations, and norms of the organization of workplaces in a residential environment depend on the type of production activity. Thus, the design of the building needs to account for the functions, equipment, and operational requirements for a particular job. This shapes the diversity of techniques and means of organizing hybrid housing, which boil down to the differentiation of spaces (placing workplaces in separate premises), integration of living and working spaces (combining living and working places by forming a hybrid space), and intensification of the use of spaces (densification of functions and organization of workplaces with convertible furniture) (Economist Impact, 2022).

There are also three ways to set up workspaces in apartment buildings: the creation of workplaces inside an apartment (interior level), the creation of shared working spaces for the residents of one house (house level), and a combination of the two methods. Importantly, projects of new residential buildings need to offer the residents the opportunity to work from home without sacrificing the confidentiality, comfort, security (Avdeev, et al., 2023), and environmental friendliness of the residential environment.

The third use of the term is related to the development of functional hybrids. Here, a hybrid residential building is a housing structure with mixed functional use, serving to fulfill several functions simultaneously. So far, this understanding of the term is the most prevalent. This hybrid in architecture has its roots in the postmodernist rejection of the rigid functional division of buildings that defined the modernist model of the city. Being a product of modern culture, the architectural urban hybrid is founded on a mixture of structures, spatial arrangement, and functions at different scales. There are no rules or conditions for the combination of functions. This category of houses includes, for example: homes for the

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elderly, which combine accommodation and care for the residents; mixed-use residential buildings with hotels, commercial premises, bars, and restaurants; residential apartment buildings with urban farms, etc. (Bantserova & Ivanova, 2023).

Researchers have uncovered another trend in the hybrid design of residential environments – the blending of established housing typologies into a single structure, i.e., the emergence of intra-type typological hybrids. Access balconies, lamellar houses, townhouses, and dormitories, as well as elite and social housing, are combined into a single mega-structure to ensure the social diversity of the inhabitants of such a hybrid. This provides communication and interaction of people from different strata, which is the key to a sustainable territorial society (Castañeda-Pérez & Cortés Acuña, 2023).

A hybrid living house becomes a means to achieve socio-economic stability of the city and the urban area, as well as social activity and unity of citizens. For the same purpose, urban public spaces (Sarvut & Tkachev, 2022), common premises for residents, winter gardens, and roof gardens are introduced into the typological hybrid (Trofimova, 2023). For example, a competition for the construction of hybrid housing in Hamburg, Germany set the objective of combining different types of housing in the building and accommodating public spaces (Mussinelli et al., 2017).

Ultimately, a functional residential hybrid should be defined as a mega-structure (Adeyeye et al., 2010), since it possesses its key characteristics (large scale; multifunctionality; extreme difficulty of construction). The concept of a functional hybrid also develops one of the defining characteristics of a mega-structure – multifunctionality. Hybrid residential buildings play a prominent role in the integration of the urban environment. This architectural intervention into the urban environment essentially becomes an urban planning intervention. From this point of view, we have to admit that we are dealing with interdisciplinary hybrid design because a mega-structure combines both architecture and urban planning. Thus, there appears an additional strategy for solving the problems of a modern city – the hybrid approach.

Tracing the relationship between modular housing and hybrid housing, let us refer to the results of our expert survey. Our findings indicate that proceeding from current trends in modular construction (Table 2), the leading feature of contemporary modular construction across the world is the proliferation of a new hybrid concept that seeks to combine the automation of mass production and the unification of elements with mass individualization – variability and diversity of modular elements, apartments, and types of housing.

Thus, modern modular housing includes several types and aspects of hybridization:

modular construction itself is a hybrid method (combining traditional "on-site" construction

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with the production of modules in factory conditions);

the use of hybrid materials and enclosing and supporting structures;

implementation of the hybrid concept of mass individualization;

functional and typological hybridization – mixed functional use and mixing of established housing typology in one housing structure (combination of luxury and social housing, apartments for the elderly and students, access balcony and lamellar houses, etc.).

The above provisions agree with previously conducted studies (Lawson & Ogden, 2008; Salama et al., 2017).

However, the variety of building modules, the variability of apartments, and the expressiveness of architectural solutions are only possible in the presence of a large number of construction firms and market competition. Regrettably, Russia has already had an unfortunate experience of large-panel and modular mass construction of housing, which came down to total unification at the country-wide level and created an aggressive environment of residential neighborhoods.

6 CONCLUSIONS

At the start of the 20th century, modular residential construction received a strong impetus for development because of a variety of its advantages, the key ones being reduced time of construction and minimization of costs, as well as construction in difficult natural conditions. It is found that the term "hybrid living house" is currently in a stage of active development, while its interpretations in architecture are diverse and cover different aspects of a building as a system. Our study has established three directions of use of the term "hybrid living house".

The first direction is connected with the hybrid construction strategy. Here a hybrid residential building is defined by the application of hybrid construction methods, materials, and construction schemes, which allows to reinforce the desired characteristics of various materials, objects, and processes and overcome their drawbacks. With a building viewed as a system, hybrid construction focuses on improving its engineering and construction subsystems, the subsystems of enclosing elements and their materials, as well as the search for new methods of construction.

The second direction is associated with the combination of the resident's accommodation, work, and business in a single residential structure and is defined by the need to address the need for home-based work. From a systemic point of view, the key objectives here are solved by means of coordinating the functional, circulation (communications), and spatial

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subsystems of the building.

The third direction of the use of the term relates to the development of functional hybrids, in which public services and other functions previously considered incompatible with housing are integrated into the residential environment. This refers to mega-structures with a great degree of integration of different functions ("a city within a city") and high integration with the environment. The architectural image of the structure becomes an important factor.

The relationship between modular residential construction and hybrid residential houses has been established. Contemporary modular residential houses demonstrate several types and aspects of hybridization: a combination of traditional "on-site" construction with the production of modules in factory conditions; the use of hybrid materials and enclosing and load-bearing structures; the implementation of the hybrid concept of mass individualization; a combination of luxury and social housing, apartments for the elderly and students, access balcony and lamellar houses, etc. Thus, we are witnessing the development of a hybrid approach to the design of modular residential houses, which emerged in response to the problems and challenges of urbanization for orderly and sustainable urban development.

Among the limitations of our study, we can note the limited set of scientific sources. Given current trends in modular construction, prospects for further research can be found in a more thorough investigation of particular directions in hybridization in the construction of modular residential houses.

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