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SUPPLY CHAIN MANAGEMENT IN RESIDENTIAL REAL ESTATE CONSTRUCTION

ABSTRACT

The problem of providing the population with housing is important and relevant for Ukraine and all countries of the world. The housing provision of the population is an important indicator of socioeconomic stability and quality of life. The article assesses the current state of housing provision for the population of Ukraine and analyzes the level of economic affordability of housing in the context of similar comparisons with EU countries. It was found that the income of Ukrainian households is insufficient to solve the housing problem. We see a solution to this important problem in the improvement of supply chain management in the construction of residential real estate. The article identifies and analyzes the functional features of supply chains in residential construction. According to the research results, the specific features of management and the main problems of supply chain management of Ukrainian companies have been specified. Digitization has been identified as one of the most promising tools for supply chain management in Ukraine for the future.

Keywords: cost of housing, construction, affordability, income, management, construction companies

JEL Classification: L74

INTRODUCTION

Housing policy is an important element of socioeconomic development programs of any country, for which the level of quality of life among the population as well as their social well-being are key strategic values. The right of citizens to housing is one of the fundamental rights of the population, it must be protected by the state and provided with appropriate social and economic guarantees. The problem of providing the population with high-quality and affordable housing has been one of the most acute ones in Ukraine for many years that requires appropriate solutions, which primarily concern financial support and regulation of the residential real estate industry. Providing residential real estate has always been one of the most complex and important socio-economic issues in Ukraine. Today, 24.2 m² of living space per person is calculated, which is much less than in foreign countries (France provides 37.5 m², Germany – 40 m², the USA – 65 m², Norway – 74 m² [1]. In recent years, this indicator has risen which demonstrates certain improvement in solving the housing problem of Ukrainians. Nevertheless, to achieve average indicators of housing equal to the population of Europe at the current pace of housing construction, Ukraine needs 90-170 years [2]. The lack of housing forms negative prerequisites for a person's self-realization has a significant impact on the quality of life, and opportunities to start a family, creates inclusive social gaps in society and increases the risks of growing poverty rates in the country. These consequences aggravate socioeconomic and demographic problems in the development of the country and society. In recent years, several studies have appeared, the results of which show a close relation with the availability of resources, in particular, housing and the socio-economic status of people, their health and well-being [3]. The housing provision is an important indicator of the socioeconomic structure of society and the hierarchy of personal status.

LITERATURE REVIEW

Research conducted by Feijten, P., & Mulder, C. H. (2002) showed that unsatisfactory housing conditions are one of the main problems, which outlines the socio-economic disadvantage of a person from childhood to the average working age [4]. Marie Huchzermeyer and Philipp Misselwitz consider the task of providing the population with housing as one of the highest priorities in the context of ensuring the sustainable development of the country [5]. Such tasks are consistent with the goals set forth in the UN Declaration "Transforming our world: the 2030 Agenda for Sustainable Development", which defines the goal of ensuring universal access to safe and affordable housing by 2030 [6].

In recent years, many scientific works devoted to the logistical issues of solving the problem of providing housing to the population have appeared. The global financial crisis of 2008 caused the need to find effective tools and levers to ensure the stability of the real estate market under the conditions of ensuring transparency, reducing the level of investment risk, and protecting the interests of investors. Scientists are researching the issue of choosing optimal supply chains actively, they try to find a balance between the level of flexibility of the chains and their cost [7]. The importance of ensuring the economy of resources in the supply chains management in construction today is considered as one of the key criteria of modern business [8]. Efficient and cost-effective supply chains are seen as short-term goals for construction companies and to achieve strategic benefits for the construction business [9].

Deshmukh P. S., More A. B., and Chavan S. A. (2014) consider logistics supply chains as the basis of effective management in housing construction, which can achieve the maximum speed of sharing information, materials, and distribution of the finished product [10]. Childerhouse, P., Hong-Minh, S., and Naim, M.M. (2000) emphasize that supply chains in the housing construction sector should be determined by a higher level of coordination of resource flows and management effectiveness, as they solve the most important task for society providing the population with quality and affordable housing [11]. The importance of these issues today and from the strategic perspective is decisive for housing construction management in Ukraine, in particular, considering the destruction, the decrease in the rate of construction and the standard of living of the country's population, which were caused by external political and economic factors.

Scientists have made a significant contribution to the development of the theory and practice of supply chains in the residential construction sector. At the stage of formation, the theory of supply chains was based on options for finding effective methods of managing reconstruction projects [11], optimal procurement systems of material and technical resources and services [12], as well as the search for compromises for transportation, supplies and costs based on strengthening the integration obligations of construction project participants [13].

Isatto and Formoso (2006) proposed a three-vector model for evaluating the effectiveness of management in construction based on a study of the interaction system of supply chain participants [14]. A similar management model based on the creation of an inter-organizational system was proposed by Roehrich, J., Lewis, M.A. (2010) [15]

In the research of Vrijhoef and Koskela (2000), four functional blocks of economic relations with participants of the supply chain were separated. The basis of their interaction within the construction system is the integration and satisfaction of common interests [16]. London, K., Kenley, R. (2000) propose their own methodology of supply chain evaluation based on a horizontal and vertical (competitive) analysis of the participants in the chain [17].

Albaloushi, H. and Skitmore M. (2008) define SCM from the standpoint of finding optimal options for distributing materials and finished construction products among customers [18]. Lee Hau L. and Corey Billington (1995) examine the issue of logistics chains in the construction sector from the perspective of integration of raw material producers, construction companies and intermediaries in the sale of ready-made real estate [19]. Green and May, (2005) identify the main elements that can be used to improve supply chains' long-term contracts with suppliers; balance of goals and interests within the chain; strengthening integration bonds; design by stages; continuous training of personnel; strengthening teamwork within the chain [20].

In the studies of Per Erik Eriksson (2010), the partnership is defined as the main tool for improving the management of logistics chains in the construction of residential real estate objects [21].

Recently, there has been an increasing number of studies aimed at finding innovative and cost-effective models and forms of supply chains. Considerable attention is paid to saving materials, reducing, and reusing construction waste [22]. With the development of digital technologies, more and more attention is paid to IT tools, with the help of which it is possible to ensure cost reduction and reuse resources [23]. Focusing on the final consumer, achieving the social goals of society's development, and creating long-term socio-economic values are central elements in modern developments [24]. Suhi et al., (2019) claim that the organization of sustainable supply chains in construction reduces the negative impact on the environment and creates prerequisites for gaining competitive advantages for construction companies [25].

In modern minds and the conditions of the near future, the management of supply chains in residential real estate is moving to the principles of digitalization and takes place in the digital plane.

In scientific works, there are different approaches to the definition of "digitalization". Here are examples of some of them:

- the process of digitization, converting analogue data into digital form [26];
- creating a digital version of analogue things. That is the process of converting something non-digital into a digital format, which can be used later in a computing system to achieve various goals. Digitization is the use of digital technologies and data for the purpose of making a profit [27];
- the process of creating a new product that exists initially in digital form and cannot be transferred to a physical medium without reducing its quality significantly [28];
- a way to optimize business with the help of software and information technology, which will help make it simpler, more economical and of higher quality in the context of providing services to clients and meeting their needs [29];
- the convergence of computer and communication technologies on the Internet, resulting in a flow of information and technologies that stimulate the development of electronic commerce and large-scale changes in the organizational structure [30];
- the integration of digital technologies into everyday life by transferring everything that can be digitized into a digital format [31];
- the process of introducing digital technologies to change the business model in order to benefit from the use of new advanced technologies that process a gigantic digital flow of information within a dynamic digital network [32];
- a combination of technologies of general application and several types of economic and social activities carried out by Internet users with the help of appropriate technologies. Thus, digitalization includes the physical infrastructure used by digital technologies (broadband networks, routers), access devices (computers, smartphones), information systems and the functionality provided by them ("Internet of Things", big data analysis, cloud computing) [33];
- part of the total volume of production, created by various digital resources. These resources include digital skills, digital equipment (components, software, and communications) and intermediate digital goods and services used in production [34].

The scientific approaches presented above to understanding the essence of digitization can be divided into four groups: digitization as a set of information resources (informational approach), digitization as a method of using the latest technologies in business processes (process approach), digitization as a method of transformations in the economy (structural approach), digitization as a prerequisite for the formation of new business models (business-oriented approach).

Analyzing the research of T. Linn, P. Rosati and L. Margherio [35; 36], we focus on areas of digitization that are crucial for the construction industry:

1. Digital products and services. This component includes products delivered using digital technologies, as well as types of services that are mostly digital in nature (online information services, software sales, e-education, etc.). We will give examples of the use of digital products for the management of the supply chain of construction materials [37]:
 - GoFor, part of the investment portfolio of CEMEX Ventures, is a North American leader in the supply of construction materials. Their platform helps create a better customer service algorithm, allowing users to track their orders and their costs, integrate it with their tools and provide contactless delivery of materials to ensure security for both parties;
 - LINKX is a cloud-based logistics software for shipping goods in Mexico. The platform allows to optimize operations by managing downloads and deliveries in real-time and integrating all sides of the transaction. The startup allows freight operators to assign delivery to their own carriers or third parties, offers advance delivery notification, digitizes delivery confirmation, allows partial delivery confirmation to avoid invoicing errors for incomplete orders, and provides fully digital real-time reporting with findings on the basis of data about its client's operations;
 - Soil Connect. Recognized as one of Contech's 50 Best Startups of 2020, this startup has created a digital marketplace that connects professionals who need to dispose of soil with those who need it, introducing a better and more efficient way to get materials into the construction sector;
 - Voyage Control, helps construction companies, developers and owners manage logistics and supply chain; this ranges from delivery to the construction site, inventory control and payment application support, end-to-end supply chain management and compliance;

- CEMEX Go. It is also worth emphasizing that CEMEX has its own solution and digital platform that optimizes the workflow, CEMEX Go is a platform that allows its customers to buy goods, track deliveries and manage orders.
- 2. IT-dependent services or production of goods. This group includes services, the provision of which is critically dependent on information technologies (for example, accounting services or complex technical projects), and the production of real goods, in the process of which the application of information technologies is of decisive importance.
- 3. A segment of the IT industry that serves all the above-mentioned areas of the digital economy (manufacturers of network equipment and personal computers, as well as IT consulting firms) [20; 38].

AIMS AND OBJECTIVES

The purpose of the article is to substantiate the practical toolkit of supply chain management in the field of residential real estate construction. Following the defined goal, the following tasks were set in the study:

1. Determination of the specifics of supply chains in the housing construction sector.
2. We are assessing the current level of security and economic affordability of housing for the population of Ukraine.
3. Substantiation of the conceptual principles of supply chain management in residential real estate construction.

METHODS

The substantiation of the purpose of scientific research determined the stages and directions of its implementation. The object of the study is supply chains in the housing construction sector.

The first part of the study includes a review of scientific works considering the problem of identifying the role of supply chains in the management of the activities of construction companies. The importance of supply chains for socio-economic development and solving the current problems of providing the population with housing was investigated. Based on the systematized scientific works and the substantiation of the author's vision of the realities of housing construction management, the functional features of supply chains in housing construction were determined.

In the second part of the work, the analysis of the current state of providing housing for the population of Ukraine was carried out. The task was to test the hypothesis, of whether housing is affordable for the population of Ukraine, considering the actual annual income of an average family. Monitoring was focused on the value and dynamics of changes in such main indicators as number of housings, cost, housing, indicators of the income level of the country's population, price and income indices. Based on statistical and economic data, a comparison of access to housing among the population of Ukraine and EU countries was made. Data from the State Statistical Service of Ukraine, data from Eurostat, data from monitoring of prices on the residential real estate market by regions of Ukraine, and state socio-economic standards of quality of life were used as sources for the analysis. In this part, the following trends are analyzed: the income level of the population of the countries, the cost of housing, and the level of provision of the population with their own and rented housing. Based on the UN-Habitat methodology, the hypothesis about the level of economic affordability of housing for the population of Ukraine was tested. The calculation was based on the formula, where is the coefficient of economic affordability of housing; $C1qm$ is the market price of 1 square meter of residential real estate; Sh is the total area of the required housing; If is the annual nominal income of the family; Nf is the number of family members who need housing. The hypothesis was confirmed that the level of economic affordability of housing for the population of Ukraine is excessively high and does not contribute to solving the housing problem. The results of the study gave rise to a new hypothesis: what impact of supply chain management in construction have on the cost and economic affordability of housing for the population?

In the third part, a study of modern supply chain management tools in housing construction was conducted. Based on the results of our own research and systematized scientific sources, the main characteristics of the concept of forming integration structures in the construction business were determined. The results of the study showed that under the current conditions of supply chain management of construction companies, digitization, digital products, and services are promising tools. Such research results were obtained based on the analysis of the stages of digitization in the construction industry and the analysis of information modelling (CAD, BIM, IFC, GIS, ERP models).

The materials for the study were primary data obtained by generalizations of domestic and foreign scientific works on the issues of supply chain management, the results of scientific developments, highlighted in professional publications included in the Scopus and WoS scientometric databases, became an important element of the research information base. Statistical

information collected by the authors from construction companies, real estate agencies and the Internet about the development of the residential real estate market was used as the basis of the analytical calculations. Data from the government portals of the European Commission, government portals of Ukraine, annual statistical reports, and strategic programs of international organizations (UN) became secondary sources of information.

When writing this paper, a set of general scientific and specific methods of economic research was used, in particular, the monographic method (when identifying the functional features of supply chain management in housing construction), synthesis, analysis method (used in calculating the level of economic affordability of housing), method of scientific and abstract systematization of the results of scientific research (used in determining the characteristics of the concept of forming integration structures in supply chains). The combination of methods of scientific abstraction, analysis, and specification made it possible to single out digitization as one of the most promising tools for managing supply chains in housing construction in Ukraine.

RESULTS

1. Functional features of supply chains in housing constructions.

Construction logistics is a branch type of logistics which is aimed at managing the material and technical support of construction production by managing material, information, and financial flows in order to implement the project with minimal costs in the real estate market.

Supply chain management (SCM) is a concept that focuses on aspects of production and logistics. Today, although it represents an autonomous management concept, logistics dominates mainly. The relationship between logistics and SCM currently has four interpretive approaches:

- logistics as part of supply chain management;
- management of supply chains as part of logistics;
- management of supply chains instead of logistics;
- logistics and supply chain management as two independent concepts that have certain points of intersection.

The general analysis of the available scientific works allows concluding that SCM belongs to the sphere of integration logistics, as the theory and practice of the interaction of organizational units, as well as other enterprises of the supply chain to develop a joint strategy within the framework of all elements creating added value. Along with integration, operational logistics is distinguished as focused on local functions of processing the physical flow of materials transformation. Operational logistics gravitate to the level of physical implementation of material flows, while supply chain management does to the managerial level.

Examples of tasks solved in operational logistics can be the management of intra-warehouse operations, optimization of transport routes, calculation of the optimal order quantity (EOQ), optimization of material stocks, and design of lifting and transport systems and loading systems for intermodal transportation. Examples of tasks at the level of supply chain management are the formation of a distribution, production and supply network, demand and supply forecasting, integration and coordination of supplies, management of relations with suppliers and customers, inventory management in the supply chain, integration of product manufacturing processes, supplies and the overall cycle of order fulfilment, supply analysis and controlling.

Supply chains in residential construction combine contractors, construction companies, engineering specialists, buyers of residential real estate objects, and management companies [26]. One of the key components of supply chains, which largely determine the cost of the final object and the efficiency of management, are logistics and transport links within their participants [38].

The logistics supply chain includes all aspects of the production process, including activities at each stage of the project, information that is transferred to all participants, natural resources that are transformed into useful materials, human resources and other components that participate in the implementation of a construction project. SCM involves the exchange of information on demand, the development of joint supply, production and sales plans, and long-term cooperation. Thus, it necessitates the use of a system approach in management processes with specification in the tools of the mathematical apparatus, information systems of collection, processing, and exchange of information among process participants. It is important to outline that an enhanced strategic planning capability is needed to enable contractors to move from a procurement-focused approach to a bottom-line approach meaning the end-to-end supply chain.

Specific features of the construction industry determine special requirements for logistics processes. The construction industry is distinguished by:

- the uniqueness of each object. The building is a unique prototype developed by a team of directly impacted stakeholders who often have no experience working together. The heterogeneity of construction sites requires the use of a project approach, which involves the development of a detailed work plan with reference to clearly defined dates and resources, and a specific budget calculation. Project orientation involves the planning of logistics for a separate project, thus making it impossible to form sustainable relationships with suppliers. Supply chain management is the development of a strategy that aligns with the project program, and it begins at the design stage when work is broken down into packages. Mutual control of market supply and demand as an element of using feedback from elements of the supply chain has the potential to avoid the appearance of bottlenecks in the program and save costs;
- fragmentation of the industry, i.e. an increase in the number of specialized suppliers/contractors, product specification and design and control activities. As fragmentation is a constant problem in the construction industry, the issues of forming integrated supply chains are relevant, mainly due to the interdependence of each field, the lack of a proven or standardized SCM model for the industry and of course, the lack of integration and cooperation between all parties involved. In traditional construction projects, project organizations are the first-tier suppliers, and the general contractor forms a supply chain of subcontractors and specialized suppliers. In complex construction projects, which include the construction of residential real estate, responsibility is cascaded to numerous suppliers. Nevertheless, the final elements of the chain may be unknown in its upper part. As experts claim [39], one of the problems in the construction industry is that the first and second elements of the supply chain usually sign burdensome agreements, and with the descent, the contractual obligations are reduced;
- territorial binding of construction objects. Construction is taking place on the territory where it will be used in the future. This situation dictates the need for the mobility of the means of production (labour items, means of labour), which acquire relevance during the construction process depending on the stages of the technological cycle, this increases the requirements for the synchronized activities of the elements of the logistics supply chain.

The specifics of the construction industry require the inclusion of a significant number of personnel, as well as various organizations: development companies, investors, general contractors, builders, subcontractors, suppliers of goods and services, and project organizations. Their activities must be coordinated during the entire project implementation period.

Studies of supply chains in the construction of residential real estate have shown the following configurations:

- convergent supply chains. Usually, in construction projects, operational capacities, documents, and materials are delivered to the site by subcontractors and suppliers under the control of the general contractor. The final consumer is a single person or a limited number of people;
- fragmented supply chain. Construction contractors, suppliers, and other project participants are active at different stages, and the distribution of responsibilities and authorities changes throughout the project;
- temporary supply chain. Construction projects are characterized by short-term partnerships while supply chain participants complete their roles and responsibilities at the end of the project;
- customer-initiated supply chains. Clients manage the creation of construction projects and are involved in the entire production process.

SCM in residential real estate construction consists of the human resources supply chain (responsible for the supply of supervisory personnel and labour), the support chain (providing expertise and equipment that facilitate the construction process), and the core chain (provides the supply of materials, assemblies, components, raw materials, electrical and mechanical equipment).

Design changes, imprecise calculations, and lack of trust among stakeholders can be obstacles to effective SCM implementation. Low-quality materials and equipment, inadequate training of subcontractors and workers, and a constant turnover of labour from one project to another are just some of the problems. In addition, there are no tools to measure the performance of all parties involved in the project effectively. An in-depth understanding of the problems of managing supply chains in construction is presented in the work [40], where they are segmented into three groups: demand, supply, and integrative problems. Demand problems include:

- non-compliance of selection criteria. The practice of concluding a contract based on the criterion of the lowest price without considering other important components is widespread. As a result, the probability of providing inadequate quality of services, resistance to project changes, and claims for additional remuneration increases;
- problems of intermittent and low demand in periods of economic recession and financial crisis;

- unbalanced distribution of risks in the project between the general contractor and the customer;
- frequent changes in specifications at the request of the client, which leads to adjustments of plans, cost, etc.

The problems of the supply are specified in the following aspects:

- negative public image. The construction industry is characterized by dangerous, uncertain working conditions, which makes it difficult to attract highly qualified personnel;
- inefficient construction method, which is a consequence of the lack of design process integration with the construction method;
- low construction quality.

Integrative problems include fragmented industry structure, competitive culture, insufficient investment in training, and inefficient management.

2. The current state of housing affordability: assessment of Ukrainian and European realities.

The development of the domestic market of residential real estate at the current stage is accompanied by a number of institutional and financial problems associated with ineffective principles of housing distribution, a low level of economic availability of residential real estate objects and the solvency of a large part of the country's population, the absence of a systematic state policy to provide the population with housing, low effectiveness of existing social housing programs and projects. Finding sources of financing for the construction of residential facilities remains a significant problem, which is characterized by a low level of practical involvement of institutional participants in the residential real estate market that does not exceed 33%. Furthermore, as statistical observations show, the total amount of investments in housing construction in Ukraine in recent years is determined by an unstable trend and in 2021 amounted to UAH 51,502.4 million [1].

The volume of housing construction and the possibilities of organizing supply chains are determined by the size of investment flows, the ratio of supply and demand in the market of residential real estate objects, and the level of income of the population as the final consumers of the construction industry product. Analysis of the dynamics of the housing provision level among Ukraine's population showed that in recent years the number of apartments per 100 people has increased (Figure 1).

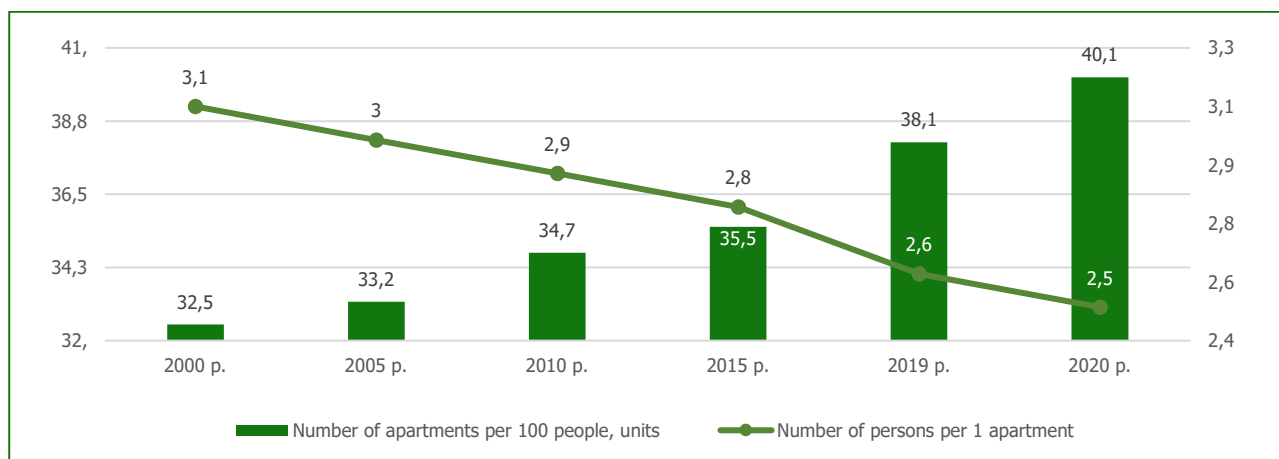


Figure 1. Analysis of the dynamics of the housing provision level among Ukraine's population. (Source: created by the authors based on the data of the State Statistics Service of Ukraine [1])

Under modern conditions in Ukraine, the question of the economic availability of housing for the population is crucial. The economic affordability of housing (purchase and rent) is largely determined by the level of income and solvency of the population. The assessment of the income level of households in Ukraine showed that the average monthly income per household in 2021 amounted to UAH 14,247 (463 euros) and, despite a steady upward trend in recent years, remains extremely low for the purchase of housing for most households in the country. With the average cost of a new home on the Ukrainian real estate market of 25,000/m² (625 euros), most of Ukraine's population can purchase a home only with credit funds. Monitoring of price fluctuations in the residential real estate market showed that prices for new housing for the period 2010-2021 increased by 32%, and the household income index was 116.3% [1] (Figure 2).

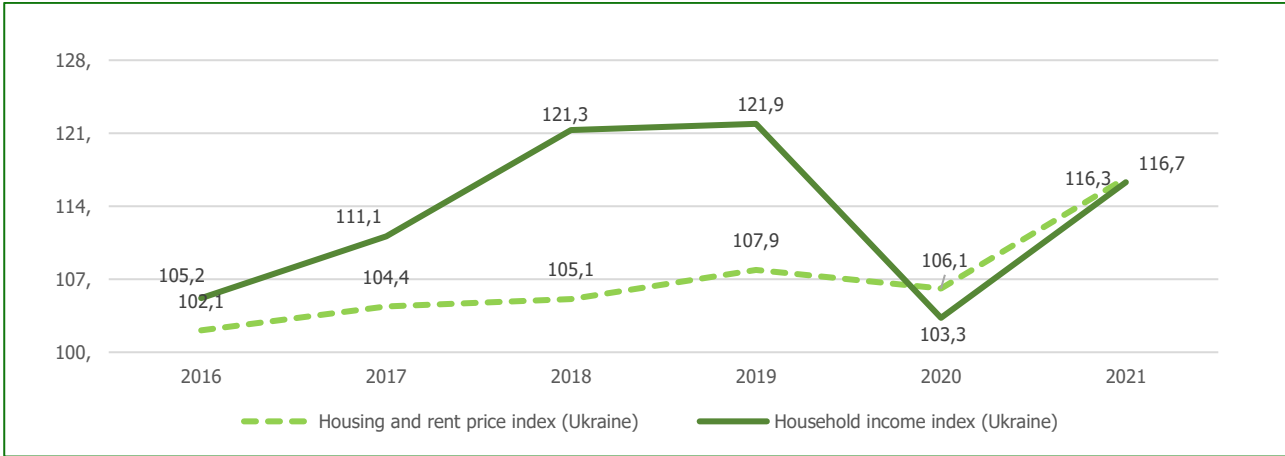


Figure 2. Housing price indices and population incomes, Ukraine. (Source: created by the authors based on the data of the State Statistics Service of Ukraine [1])

In general, as the results of the studies show, the problem of price gaps between the level of income and the cost of housing is relevant for all European countries. According to Eurostat data, for the period from 2010 to 2022 housing prices in the EU zone increased by 49.2%, while housing rental prices increased by 18.5%. The highest growth rates were recorded in Estonia (233%) and Lithuania (151%) [1]. Meanwhile, the average amount of income in the countries of the European Union amounted to 18,019 euros in 2021.

The complicated issue for the population of Ukraine and EU countries remains the acquisition of housing. In Ukraine, 54% of the population lives in overcrowded housing [2]. In the EU, about 70% of the population owns their own housing, and 30% live in a rented one (Figure 3).

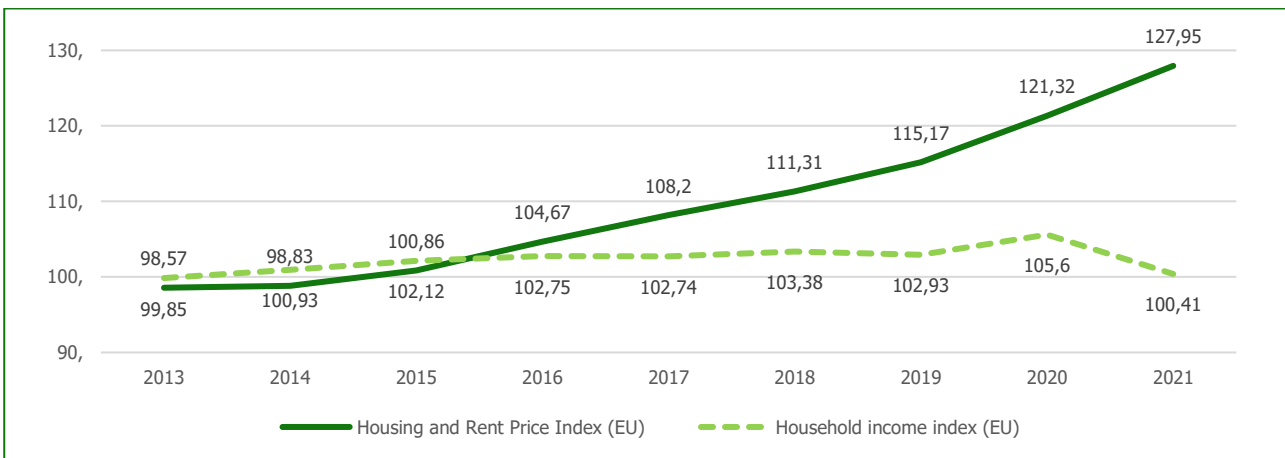


Figure 3. Housing price indices and population incomes, EU countries. (Source: created by the authors based on the data of the State Statistics Service of Ukraine [1])

About 71% of the population lives in apartments, and 28% live in houses [41]. The highest level of rented housing is observed in Germany, Austria, Denmark, France, and Sweden. The population of Romania, Hungary, and Greece has the highest level of housing provision (Figure 4).

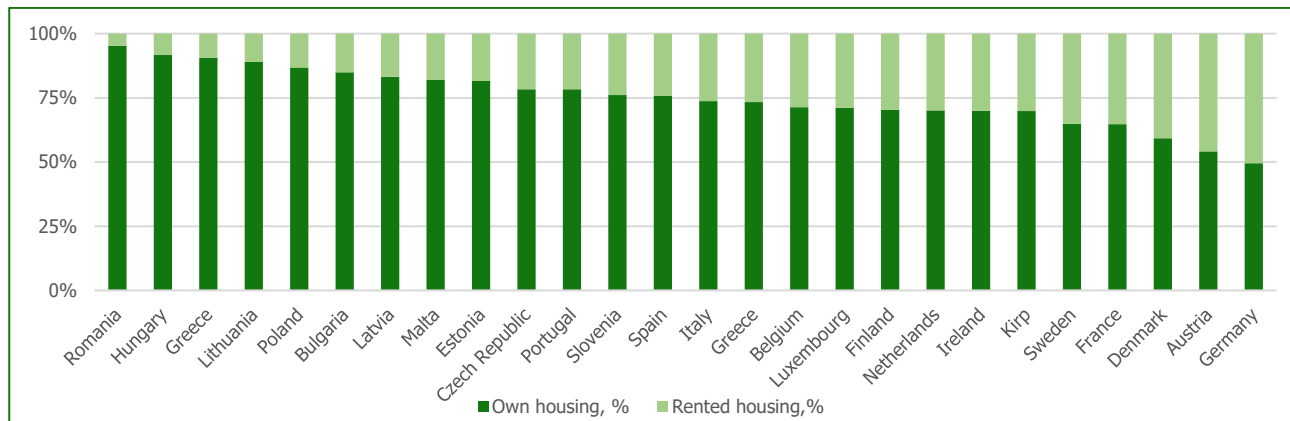


Figure 4. Distribution of the population of EU countries by own and rented housing, %. (Source: created by the authors according to [41])

Increasing demand for residential real estate is one of the key factors in revitalizing the housing construction market in Ukraine, attracting investments, and increasing its volumes. The growth of solvent demand among customers (population) is economically based on the level of household income, which affects the value of the housing affordability ratio. Based on the methodology provided by the UN-Habitat program (1978), the housing affordability ratio for the population of Ukraine was calculated. The calculation was made considering the cost of 1 square meter of residential real estate in Kyiv and the current average indicators of the housing provision level of the country's population at the level of 24.2 square meters per person. The calculation was made for a family of 3 people, of which 1 is a child (Table 1).

Table 1. Calculation of the housing affordability ratio in Ukraine, 2022.

Indicators	Value
The price of the apartment, UAH	72.6 x 30460 = 2211396 UAH
Average income per person, UAH/month	14678
Subsistence minimum (general indicator), UAH/month	2589
Family expenses at the level of subsistence minimum per person, UAH/month	7767
Coefficient of economic affordability of housing	6.3
Cost-based housing affordability ratio	7.9

The obtained results showed that under conditions of preservation of prices on the residential real estate market and at the average statistical level of household incomes in Ukraine, a family needs to save all its income for 6.3 years to buy a house. As the family's expenses will be equal to the subsistence minimum (about 65 euros), the potential period of purchasing a home will increase to 8 years.

The low level of economic affordability of housing based on one's own income causes the population to search for other sources and means of purchasing residential real estate objects. Mortgage lending, housing subsidy programs, and state and regional social housing construction programs are the main tools under modern realities. However, one of the most effective ways to increase the level of housing affordability is to optimize its cost based on the construction of efficient and economical supply chains by construction companies and other participants in the chain system.

3. Modern supply chain management tools in the construction of residential real estate objects.

The management of logistics supply chains in construction includes three stages: the investment stage of the project, the stages of implementation and control. Logistics activity at the first stage is characterized by relatively small costs with a significant impact on the overall success of the project because of the analysis and consideration of its features and potential risks. The interdependence of project participants, when the activities of some are the basis for realizing the potential of others at later stages, can cause inconsistency. This can be levelled by expanding the number of project development participants at the investment stage. There is a growing demand for startups that offer solutions that help solve this problem, reduce misunderstandings between stakeholders, limit procurement difficulties and provide enough flexibility so as not to limit the project to the initial conditions, all within time and budget. In the study [31], the emphasis is on this issue. Several analytical materials contain conclusions on obligatory negotiations and reaching agreements regarding future supplies at the investment stage, that is, it is possible to assert the appropriateness of applying the concept

of supply chain management in construction, which involves the formation of long-term relations, joint planning and supply control [42; 43].

Thus, supply chain management tasks at the investment stage (early planning) include:

- development of detailed supply plans;
- selection of suppliers that offer the best conditions for combining price and quality;
- signing of long-term contracts.

Management of logistics activities at the stage of project implementation involves the adjustment of the general plan in accordance with unforeseen, force majeure circumstances. One of the promising modern methods of project management is the concept of "lean construction", the main theorist of which is Lauri Koskela. The proposed approach involves continuous planning throughout the project. According to the concept of "lean construction", general long-term as well as more detailed short-term plans should be formed, while their implementation should be constantly monitored, and the reasons for unsuccessful implementation should be analyzed for the impact on the progress of the entire project and to prevent repeated failures. Based on this concept in the study [44], a model of supply in construction was proposed, which allows to optimize purchasing activities and reduce inventories. It should be outlined that planning at the implementation stage requires accurate and complete accounting, as well as consistency with the plan. It is better to automate these operations using digital technologies. MRP, ERP, and CSRP systems can be used:

- MRP (Material Requirement Planning) – planning which materials and resources are needed;
- MRP II (Manufacturing Resource Planning) – planning of production resources;
- ERP (Enterprise Resource Planning) – the organization's resource planning system;
- CSRP (Customer Synchronized Resource Planning) – resource planning of the organization, synchronized to the consumer;
- ERP II (Enterprise Resource and Relationship Processing) – management of the organization's internal resources and external relations.

Applying digital technologies to improve supply chain planning is essential to drive innovation in the sector. Network collaboration and integrated planning process for project implementation can provide better optimization in managing contractors to procure the necessary resources, construction, commission and deliver the project on time and on cost, thus meeting the client's requirements.

Management of supply chains at the stage of implementation includes solving the following tasks:

- ensuring high efficiency and productivity. After purchasing materials and resources, construction professionals must monitor their delivery and transfer to ensure that no delays or missing materials are encountered in the future. To provide productivity gains through supply chain management, a major shift in the way the construction industry is organized, must take place. The transformation process is critical and must visualize supply chains and decision-making based on timely and accurate data, and improve inventory, and on-site processing to prevent abuse;
- minimizing delays and reducing the need to store materials. This is complicated by space limitations, the risk of spoilage, material theft, as well as storage and transportation costs.

Control of logistics operations as a necessary element of the implementation of the concept of supply chain management is determined by the high intensity of consumption of construction materials, which determines the frequency of deliveries and the need for strict consideration of the condition of the delivered materials and their placement. This necessitates the standardization of delivery, unloading and warehousing operations.

The supply chain in the construction of residential real estate has a focal company in its structure, as well as suppliers of construction materials and services (contracting organizations) which are previous types of activities, consumers and various types of intermediaries that are subsequent types of activities. The latter are the companies that sell finished products (residential real estate objects) – real estate agencies and management organizations that act most often. As a rule, the focal company is a construction company, a developer, or a general contractor, which deals with the configurations of the supply chain and the organization of the interaction of the participants among themselves. The peculiarity of supply chains in the construction of residential real estate is, as already mentioned above, that for each new project, it is necessary to configure the supply chain again, based on the needs for materials, services, location of the construction site, etc. Depending on the number of elements, it is customary to distinguish a direct, extended, and maximum supply chain. All of them have a place in construction, however, according to experts, the optimal one for practical application is the extended supply chain, which can take the form presented in Figure 5.

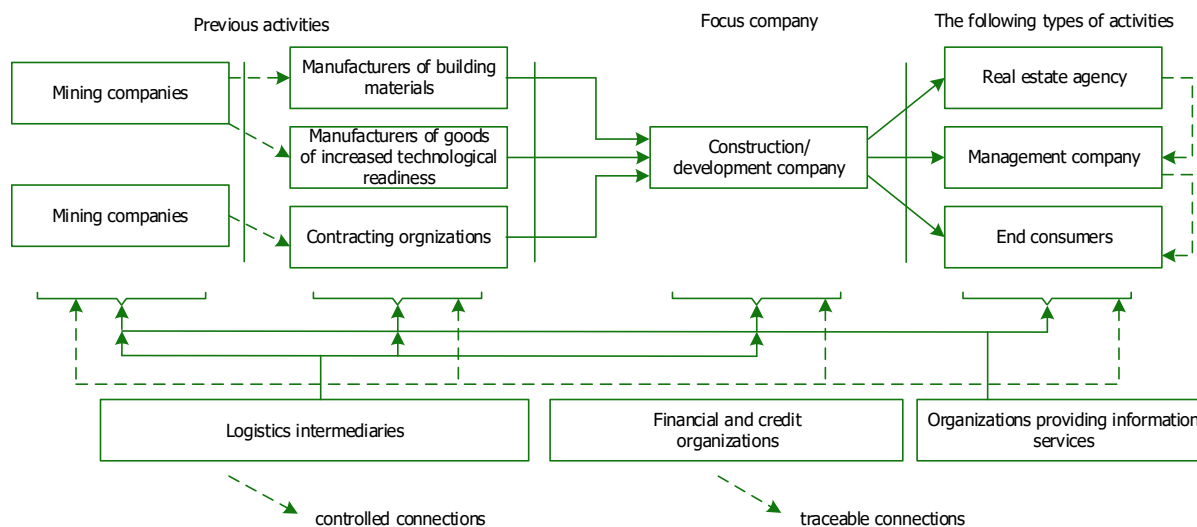


Figure 5. The extended supply chain of a construction company.

It is demonstrated that construction supply chains are usually quite short, involving only a few tiers of suppliers. Most large construction and development companies prefer to purchase materials directly from the manufacturer which reduces costs significantly and shortens delivery time. In a similar way, the purchase of products of increased technological readiness, such as reinforced concrete products, window, and door blocks, etc., is carried out. Separate links of the supply chain are subcontractors of various levels.

As for the following types of activities in the supply chain, it can be outlined that the sale of finished construction products (residential real estate objects) is carried out either directly to the final consumer or through one intermediary (real estate agency or management organization). Construction and development companies conclude long-term contracts with key contractors. Moreover, the focal company seeks to control part of the business relations directly (managed relations), and part of the relations is subject to indirect control (monitored relations). The distinctive feature of extended supply chains in the construction process is the virtual absence of unmanaged business relations. The choice of a suitable supplier, contractor, rental of special equipment, including the transportation of materials inside the construction site, and the warehousing process often accounts for most of the costs of a construction project.

Many companies are currently joining together in a group for a more efficient organization of the main logistics processes. The processes of forming integration structures based on the logistic approach in comparison with the traditional one was thoroughly analyzed by Chorna N.Yu., and the main conclusions of the mentioned study are presented in Table 2.

Table 2. The main characteristics of the concept of forming integration structures. (Source: 45)]

Nº	Traditional approach	Logistical approach
1.	Creation of integration structures as a "reaction to events"	Creation of integration structures based on "prediction of events"
2.	Catalysts for the development of integration processes are the desire for maximum productivity of the enterprise participant of the integrated structure	Catalysts of the process of development of integration interaction are the desire to increase flexibility and adapt production (integration structures) to market conditions
3.	Optimization of individual functions of business processes	Optimization of all flow processes in integration structures
4.	The creation of integration structures is accompanied by consolidation and complication of management structures, which occurs both at hierarchical levels (technological, operational-tactical, strategic) and in the organization of internal and external relationships formed in integration structures	Integration of all management subsystems into a whole, consideration of the management system of the integrated structure as a holistic phenomenon
5.	Preservation of infrastructural competition	Replacing competitive relations with various forms of cooperation
6.	Ensuring maintenance of a high utilization rate of production facilities by any means	Focus on increasing the throughput of production facilities
7.	Provision of necessary stocks in the form of material resources and finished products to ensure production (integration structures) and customer service	Orientation on the uninterrupted supply of internal needs of integration structures with the necessary resources in combination with the rejection of excess material and commodity stocks
8.	Passivity in the optimization of infrastructural transfers and redistributions	Elimination of irrational infrastructural transfers and redistributions

Therefore, integration based on the construction of logistics supply chains compared to the traditional approach has the advantage of focusing attention on the mechanism of combining individual links of integration structures into a single economic flow, which allows obtaining a synergistic effect from the integration process based on the performance of a predictive function as opposed to the formation of tactical responses to changes in the parameters of the external environment; to ensure the general optimization of all elements of the integration structure, as well as the adaptability of the system in external challenges.

Digitization has become an objective process of modern society development in the conditions of neo-economics. It was a response to requests for simplification and acceleration of work with large volumes of data, provision of automation of all types of business activities (operational, investment, financial), and improvement of communication with customers, suppliers, partners, and institutions of the external environment. Digital technologies are designed to form new principles of interaction within the enterprise as well as between divisions, employees, and management. The prerequisite for digitalization was the rapid spread of Internet technologies, which became a kind of technological mainstream at the end of the 20th century.

The construction industry occupies the lowest place in the implementation of information technologies. Such a conclusion appeared as part of the study of the digital orientation of MIT. The construction industry scored 34.9 index points, when the average value was 43.9, and the real estate sector was also named as a laggard with a figure of 38.6 index points [46].

Considering the certain inertia of the field of residential real estate construction, in our opinion, a model of three-stage digitalization of processes covering the investment stage of the project, implementation and control stages is appropriate (Table 3).

Stage	Goal	Content
Investment stage	Digital modelling	Development of 3D - project models for obtaining a schedule of construction and installation works and determining the cost of the project
Implementation stage	Digital support of internal processes	Representation of the internal environment of the construction company based on the integration of design processes, financial analysis, construction and assembly works, building operation
Control stage	Digital supply chain support	Unification of all participants of the supply chain in a common information environment, which allows to control the entire set of flows within the framework of the implementation of construction projects

The implementation of complex digitization of the construction industry is possible based on the systematic implementation of BIM technologies. Such understanding reached a qualitatively new level of institutionalization in Ukraine, so, from July 1, 2020, the National Standard DSTU 19650-1:2020 "Organization and digitization of information on buildings and structures, including building information modelling (BIM) came into force. Information management using building information modelling. Part 1. Concepts and principles". This document is identical to the international standard ISO 19650-2:2018. Building Information Modelling is a digital representation of the physical and functional characteristics of an object that creates a shared information resource of a given object and forms a reliable basis for decision-making throughout its life cycle: from early concepts to disposal [47].

BIM makes it possible to digitize the construction process, i.e. to create a calculation model of the object, floor plans and sketches of the main building elements, to establish the sequence of installation and start of work with the control of all involved participants. In other words, with the help of BIM tools, you can create a digital construction model within a single system of reports for production, installation, and ongoing daily control [50], which has the effect of reducing the cost of construction materials and saving financial resources, shortening the construction period, reducing the cost of developing CM and CMD projects, minimizing the availability of warehouse stocks directly at the construction site, etc.

Construction industry researchers, namely Mark Bew and Mervyn Richards [47], offer a definition of maturity levels of information models of the specified industry:

- **level 0.** ("unmanaged CAD"). Users apply traditional CAD in 2D format. In the drawings, building elements are depicted by lines, arcs that define the geometry of the structure. Data exchange between project participants takes place on paper or electronic media;

- **level 1.** Users apply CAD in 2D or 3D format. The first-level models contain mostly basic information. Electronic files are used to exchange information. At this level, the interaction between participants is organized through the Common Data Environment. However, there is no full-fledged interaction between participants belonging to different disciplines;
- **level 2.** The BIM project of this level is a complex model on which specialists of different specialities work in different programs in parallel. Assembly of the general model, analysis and detection of collisions are carried out in special "composite" software applications. This level involves adding the following measurements: 4D (time) and 5D (cost). For this level, the formation of object data in COBie format is expected;
- **level 3.** The construction project relies on a single integrated model, which is created and used by all participants in the process, such as project customers, designers, engineering services, contractors and subcontractors, and facility owners. It is a fully integrated data and integrated process that uses web services and is compatible with the new Industry Foundation Classes (IFC) standards.

Today, companies in the construction industry are at different levels of maturity and, as a rule, use BIM to solve narrow-profile tasks. It will take time for the industry to accumulate enough knowledge and experience to move gradually from the first and second levels of maturity, where most of them are now, to the third level using fully integrated BIM.

For the purposes of accounting for logistics operations, many authors have developed systems based on geographic information technologies (GIS) and technologies of radio frequency identification of goods (RFID). In particular, the information system is proposed that combines the advantages of BIM and GIS technologies. With the help of BIM, there is a detailed display of the necessary materials and GIS-tracking of their location. In this way, accurate accounting, and control of the use of materials are ensured. Disadvantages of this system include the lack of payment accounting and lack of integration with planning systems.

Several authors suggest using ERP to solve the tasks of control and accounting of logistics operations, as well as for general planning tasks. In a study [48], its own ERP system is offered based on web technologies. This system was used by a construction company in real conditions, while a 10-20% reduction in project implementation time was achieved. Although the use of ERP looks attractive, it is related to the specifics of the construction industry and therefore hides several pitfalls. The use of ERP systems in construction looks promising, however, the methodology for implementing ERP in construction has not been developed so far. It should also be notified that ERP is a comprehensive solution that affects the entire construction process, not just supply. At the stage of implementation, logistics faces the task of complete and accurate accounting of materials, which can be achieved using the power of information technologies.

DISCUSSION

Solving the strategic task of increasing the level of sustainability and the population's quality of life is inextricably linked to solving the problem of improving its housing provision. Solving this task involves the search for effective supply chains, the options for organizing which are somewhat debatable today. In own scientific work Vrijhoef, R., Koskela, L. (2002). "Roles of supply chain management in construction". In Proceedings IGLC-10, Gramado, Brazil. pp. 133-146 suggest the use of a project-oriented approach. Still, along with this, among the distinguishing features of such an approach, they only consider the differences between the construction and manufacturing industries. The specificity of the construction sector in the field of housing construction is more critical and determines the specifics of the organization of supply chains with enterprises of many types of economic activity. According to the authors, this requires a more detailed approach to analyzing the factors that determine the special conditions of managing the logistics process in the industry.

We share the scientific position of Dubois, A. and Gadde, L.-E. (2000), "Supply strategy and network effects - purchasing behaviour in the construction industry", *European Journal of Purchasing & Supply Management*, Vol. 6 Nos. 3-4, pp. 207-15., we consider insufficient criteria of efficiency and economy of supply chains as the only critical factors for ensuring strategic advantages of the construction business. Under the conditions of the spread of the concept of sustainability in all spheres of society and business, we consider it appropriate to supplement these criteria with the criterion of inclusiveness, which we see, first, as a manifestation of the physical and economic availability of housing for the population of Ukraine.

Over the past few years, scientists have proposed several primary digital tools for supply chain management: GoFor, LINKX, Soil Connect, CEMEX Go, and others. At the same time, having studied the specifics of the activity and the current state of development of the residential real estate construction sector in Ukraine, we consider Building Information Modeling to be the most optimal among all proposals, which, according to the authors, is one of the most systematic options that allows building the most complete and perfect model. We also consider the author's method of determining the

economic affordability of housing based on costs, which were used in the study, to be temporary and in need of constant adjustment. The controversial nature of the methodology lies in the continuous change in the value of the residential real estate object, which is characterized by significant price fluctuations under the influence of the continuation of martial law in Ukraine. However, in modern scientific literature, there are practically no methods that make it possible to accurately estimate the cost of housing under the conditions of an active military conflict.

CONCLUSIONS

The issue of increasing the level of housing provision of the population is one of the most important and urgent for Ukraine. The conducted analysis showed that, in comparison with the EU countries, Ukrainian households have significantly fewer opportunities to solve the housing problem, and family incomes are insufficient to purchase housing. In recent years, the share of rented housing in the EU has been increasing in such countries as Germany, Austria, Denmark, Sweden, and France. Ukraine has much lower indicators of housing area per inhabitant than the population of European countries. Solving the problem of increasing the affordability of housing is possible due to the optimization of supply chain management in housing construction.

The concept of supply chain management (SCM) as a type of integrated logistics represents the theory and practice of interaction within the internal environment of the organization, as well as the formation of a joint strategy with enterprises of the external environment, which are elements of the supply chain in the process of creating added value. The implementation of the strategic goal of SCM, which is to expand the ability of strategic planning, is achieved by forming a network of distribution, production and supply, forecasting of demand and supply, integration and coordination of supply, management of relations with suppliers and customers, management of inventory in the supply chain, integration of manufacturing processes up to the final product, deliveries and the overall cycle of order fulfilment, analysis of deliveries and controlling.

The peculiarities of supply chain management in the construction industry are determined by the specifics of the latter, which is defined by the uniqueness of each object and the fragmentation of the industry, the territorial binding of construction objects. The heterogeneity of construction sites complicates the formation of sustainable relations with suppliers significantly. The increase in the number of specialized suppliers/contractors, product specification and design and control activities rise the issue of forming integrated supply chains due to the interdependence of their individual elements, the lack of a proven or standardized SCM model for the industry, as well as integration and cooperation of all involved parties. The complex mechanism of construction projects implementation leads to the deconcentrating of responsibility, which has the effect of reducing production efficiency indicators in case the coordination system of activities of direct influence stakeholders is absent. The lack of opportunity for the construction objects mobility increases the requirements for synchronizing the activity of the logistics supply chain elements at each stage of the technological cycle.

The configuration of the extended supply chain in the field of residential real estate construction is structurally represented by the focal (construction) company, previous activities (companies supplying construction materials and services), and subsequent activities (intermediaries and consumers). Construction is characterized by short supply chains formed based on managed relations. The latter is the result of concluding long-term contracts and ensures the predictability of the situation in the long term. Traceable connections, which involve indirect control by the focal company, are preserved in the field of financial and credit relations, the activities of intermediaries in the real estate market, as well as relations with suppliers of the first and second levels.

Low indicators of information technologies implementation in the field of residential real estate construction, which are caused by the inertia of the industry, raise the issue of developing an adaptive model of digitization. According to the author's concept, it is implemented in the conditions of an integrated approach covering three stages: the investment stage of the project, project implementation and control. Thus, a systematic solution to interrelated problems, which are decomposed into such elements as digital modelling, digital support of internal processes, and digital support of the supply chain, is provided. Each previous stage is the basis for the effective implementation of tasks of a higher hierarchical level. The goal of the digitalization process is to create a single information environment for all participants in the supply chain in the construction of residential real estate based on creating a digital model of the project and integrating the processes of design, financial analysis, planning of construction and installation works, and operation of buildings.

ADDITIONAL INFORMATION

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УПРАВЛІННЯ ЛАНЦЮГАМИ ПОСТАЧАННЯ В БУДІВНИЦТВІ ЖИТЛОВОЇ НЕРУХОМОСТІ

Проблема забезпечення населення житлом є важливою й актуальною для України та всіх країн світу. Забезпечення населення житлом є важливим індикатором соціально-економічної сталості та якості життя. У статті проведено оцінку сучасного стану забезпечення населення України житлом та проаналізовано рівень економічної доступності житла в контексті аналогічних порівнянь із країнами ЄС. Було виявлено, що розмір доходів домогосподарств України є недостатнім для вирішення житлової проблеми. Розв'язання цієї важливої проблеми ми бачимо в удосконаленні управління ланцюгами постачання в будівництві житлової нерухомості. У дослідженні виявлено та проаналізовано функціональні особливості ланцюгів постачання в житловому будівництві. За результатами досліджень конкретизовано специфічні риси управління та основні проблеми управління ланцюгами постачання українських компаній. Визначено диджиталізацію як один із найбільш перспективних інструментів управління ланцюгами постачання в Україні на майбутнє.

Ключові слова: вартість житла, будівництво, доступність, дохід, менеджмент, будівельні компанії

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