PROBLEMS OF CONSTRUCTION AND OPERATION OF BUILDINGS AND STRUCTURES IN THE CONDITIONS OF RECONSTRUCTION AND RESTORATION USING UNIVERSAL MACHINES

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Abstract: The article considers modern landscape and development vectors in the field of reconstruction and restoration where universal machines are applied. As practical examples, two options are considered: the technology of superstructure of the attic floor - superstructure with enlarged metal block sections and superstructure of the attic floor from lightweight aerated concrete blocks. The possibilities of using BIM and robotics in reconstruction and restoration are analyzed.

Keywords: reconstruction; machines; BIM; robotics

1 Introduction

One of the features of the reconstruction should be the need to take into account the position of the facility in the urban environment, which significantly affects both the type of work performed and the general appearance of the territory on which the building is located. The reconstruction process includes not only changing the external appearance of the building, but also conducting additional studies of soils, hydrogeological and structural indicators of the object as a whole - this allows eliminating possible design errors during reconstruction [22].

Reconstruction begins with the development of a special task, which includes information regarding the goals, basic requirements, and operating conditions of the facility after completion of the reconstruction. Specialists examine the documentation of the object and then conduct a thorough inspection. The purpose of such an inspection is to identify emergency components of the building and carry out their modernization during the full construction period.

It should be noted that the reconstruction of buildings today acts as a main direction in the field of capital construction. Unlike the construction process, reconstruction has a number of features:

- The work performed during the reconstruction process is heterogeneous, dispersed, and small-scale;
- The work carried out during reconstruction differs from that carried out during the construction process (dismantling of structures, their strengthening, replacement of individual structural elements, etc.);
- There are cramped working conditions, and this significantly affects the overall scheme of organizing work on the reconstruction of building, especially industrial;
- It is necessary to implement an individual approach to restoring operation indicators and strengthening the load-bearing elements of buildings and structures.

The choice of building reconstruction method is significantly influenced by the level of cramped construction area, which determines the possibilities of organizing and technology of work using mechanization, advanced technologies, and building materials.

The development of new methods and technologies for the reconstruction of residential and other buildings, ensuring a significant extension of their life cycle, reducing and eliminating moral and physical wear and tear, increasing operational reliability and comfort, is acquiring great socio-economic importance and relevance.

In particular, one of the important tasks of residential buildings reconstruction is the elimination of moral and physical wear and tear of buildings. Very relevant in the reconstruction of the housing stock is the development and adaptation of industrial methods and technologies that reduce the overall cycle of reconstruction work, as well as ensure the work is carried out without evicting residents, the use of new composite materials and structures which reduce the weight of the built-on floors and have increased durability. Here one should also mention development of methods and new technologies to increase the operational reliability of buildings, reduce heat losses and energy consumption, increase the comfort of apartments, improve the architectural appearance of buildings while reducing costs.

The main methods for improving the reconstruction system include the following [13]:

1. Increasing the accuracy of diagnostics and checking the condition of an existing building, which would reduce errors and diminish the labor costs of preparatory work. The invention of high-precision instruments, means of analysis and processing of results becomes necessary. The creation of such an “instrumental” system would allow for complete control and analysis of the reconstruction process, identification of dangerous areas and installation moments, which will facilitate the work of analysis experts, the reliability of decisions made will increase, and the safety margins, stability and rigidity of structural elements will be identified.
2. Improving the computerization of the design process, which ensures optimization and high efficiency of constructive, space-planning solutions. Modern calculation methods more accurately take into account the laws of deformation of materials under appropriate application of loads, the characteristics of the operation of all elements of the building, both individually and in aggregate.
3. Completely new design solutions based on the use of traditional materials (brick, metal, reinforced concrete, etc.). It is also relevant during reconstruction to use lightweight concrete (expanded clay concrete, cellular concrete) for the construction of walls and floors, to reduce the weight of the part being built on, as well as to reduce the cost of materials (by about 15%) and their installation (by 30%). The scope of application of corrugated sheets should also be increased. In large cities, it is promising to use beamless floors in a reinforced concrete frame, represented by a frame-braced system of columns and flat prefabricated floor slabs (above-column, inter-column, span). As a result of creating rigid cells, a frame-braced system is obtained. This solution would seem universal for civil and industrial construction.
4. The use of new materials (fiberglass, nanoconcrete, fiber cement, basalt-plastic reinforcement, ecowool, etc.). For example, glass-plastic (fiberglass with a synthetic binder) can be used in large commercial buildings and a number of office complexes. Its use is justified by its low weight and the ability to transmit sunlight. It can also be used as a coating for defective reinforced concrete slabs to transfer snow loads directly to beams and trusses. The number of polymer materials has grown significantly in recent years, but this is not the limit.
5. Innovative methods for restoring the performance qualities of structures: the use of prestressing in reinforced concrete structures, the use of expanding cements (self-stressing), shotcrete and much more. Particular attention should be paid to strengthening the base (gas silicization, electrothermal fastening, vibration compaction, etc.). Structures with cracks can be restored to their original appearance by applying polymers to epoxy binders, which will harden at low temperatures. Fiberglass reinforcement of cracks in combination with polymer solutions is a particularly effective set of restoration measures. The widespread use of this method is most acceptable in large-panel buildings [16]. Fiberglass reinforcement is indispensable in the reconstruction of buildings exposed to

aggressive environments, performing a protective function. Columns can be wrapped with fiberglass impregnated with a binder; several layers can increase the load-bearing capacity of a given structure by more than 2 times [17].

6. Application of new construction machines and mechanisms, expansion of the range of machines. Development of effective technologies and use of automation tools in limited, cramped conditions.

This last point is extremely important, especially with regard to the use of universal machines in reconstruction and restoration, since the effective use of such machines can optimize the process.

Moreover, at the present stage of the technological race and, as a consequence, in the conditions of increasing need for the reconstruction of old industrial buildings, the most pressing issue is the development of a scientifically based approach to the architectural reconstruction of industrial buildings. There are a number of ‘textbook’ reconstruction methods:

- Strengthening structures to restore lost load-bearing capacity or increase load-bearing capacity (in construction science and practice, methods for strengthening the structures of industrial buildings have been sufficiently developed and tested; as a rule, strengthening structures does not change the architecture of the internal space and the external appearance of the building);
- Partial replacement of structural elements to increase their load-bearing capacity or change the architectural and construction parameters of the building (depending on the requirements of engineering and technology, crane beams, columns are replaced, roof elevations are raised, additional spans are added, the number of floors is increased; partial replacement of structural elements and architectural changes construction parameters of a building can lead to changes in its internal space and external appearance);
- Reconstruction with complete or partial replacement of building structures and even the shape of the building - sliding new ones of higher productivity onto old foundations at metallurgical plants, installing new chemical equipment on old foundations and shelves, adding additional floors at light industry enterprises.

In the practice of developed countries, old industrial buildings are often renovated, in other words, they lose their original function. In particular, in the UK this approach is most developed and, moreover, it is strongly supported both at the level of local government and at the state level. The main task of the architect-renovator of an old industrial facility is to develop a design solution that is attractive for investment and at the same time not implying losing the aesthetic and functional potential of the building or complex of buildings, with one “concern” - functionally they will change towards public or residential purposes, depending on individual characteristics of specific object. Since the second half of the last century, or more precisely, since the 1970s, in Europe and the United States, under the influence of postmodern ideology, a rather rapidly spreading idea arose about a global environmental catastrophe, which is inevitably approaching as a result of industrial activity that has a detrimental effect on the lives of creatures and processes occurring on the planet. Most authors suggest that industrial buildings should no longer be used for their original purpose; however, there are a number of practical approaches related to the reconstruction and modernization of industrial facilities.

In addition, one should not forget that the choice of space-planning, design solutions, technology and organization of work, materials, including composite and nano, during the reconstruction of buildings and structures must be justified not only from an economic, but also from an environmental point of view, based on carefully developed regulatory documents. In today's world, the consumption of energy and resources is becoming increasingly serious, and energy and environmental issues are receiving attention. Statistics show that energy consumption in the construction industry is 50%, and this has a huge impact on resource consumption and environmental pollution [1]. Reconstruction of old buildings allows saving resources, which corresponds to the concept of sustainable development.

2 Materials and Methods

The research is based on the proven paradigm implying that the level of reconstruction work can be increased only by using industrial methods of work, new materials and designs with a high level of manufacturability, as well as implementing modern principles of organizational and technological reliability of construction with a high degree of mechanization of construction processes. Methods and technologies for carrying out work to increase and restore the load-bearing and operational capacity of structural elements of buildings by strengthening them and replacing them have been studied.

The research methodology included system analysis and synthesis, theoretical study of the technological parameters of the attic floor superstructure and the corresponding requirements for universal machines on the construction site. Recent achievements and prospects of BIM application and on-site robotization in the restoration and reconstruction projects were analyzed based on the method of content-analysis.

3 Results and Discussion

With the development of new housing construction in large cities, there are fewer and fewer free areas for development. The inevitable factors for expanding the boundaries of cities are: development of suburban lands, engineering development of remote territories, large costs for the creation of infrastructure facilities, which leads to the high cost of housing under construction and high operating costs for its maintenance.

Meanwhile, studies show that it is more rational to use densely built-up and developed areas within the city limits. Moreover, it is important to consider the reconstruction of the housing stock and the construction of new housing as a single process that ensures an increase in space, extending the life cycle of buildings, and increasing of their comfort and energy efficiency [21].

The main structural and technological techniques for the reconstruction of residential buildings of old standard series are: the addition of attic floors, the addition of small architectural volumes, rigging with the expansion of buildings and the addition of several floors. The decision to reconstruct the facility is evidently made based on the technical and economic requirements for the building subject to reconstruction, based on compliance with the principle of self-sufficiency during the billing period, realistically available sources of covering costs, and high-quality conditions for financing the work [22].

Based on the existing facts, a process such as the reconstruction of a building and carrying out major repairs is an appropriate and rational method in the development of a residential urban environment. The most effective and comprehensive method of achieving the set goals is to reconstruct the building with the addition of an attic floor, since, as a rule, it does not require additional investment in creating or expanding the infrastructure of the area, performing construction and installation work on laying utility networks, transport support and cultural and social amenities service. This makes it possible to use the existing reserves of the load-bearing capacities of the main building structures and load-bearing elements of buildings, including bases and foundations.

Reconstruction of large-block mass buildings is a strategic direction in solving urban planning problems of dilapidated housing stock, which will improve the living comfort of buildings residents and their energy efficiency, improve the architectural and aesthetic appearance, extend the life cycle of buildings, and also increase the area for people to live. Reconstruction can be carried out by adding attic floors, which will increase the total living area of the house with different layouts and configurations of rooms/premises. The reconstruction method using a combined load-bearing frame of the attic floor from rolled steel structures and light thin-walled structures, according to technical and economic calculations, is the most effective and expedient, as it allows, due to the standard construction of these objects, as well as the existing reserve of load-bearing capacity of structures and building elements, including bases and foundations, implement this technology for the reconstruction of buildings, while significantly reducing capital investments, the labor intensity of the work performed, and construction time.

A technical and economic comparison has established that the most rational option is the technology of using a combined load-bearing frame of the attic floor made of rolled steel structures and lightweight thin-walled structures [11]. The rationality of the choice is justified, in particular, by the reduction in costs for the use of powerful lifting machines and mechanisms, which makes it possible to carry out work on the superstructure without creating inconvenience for the residents of the house and allows reducing the use of the local area for the purpose of the construction site (it is possible to use small-sized stationary cranes or winches on the roof of the building). This technology does not require the resettlement of residents and raises the increase in area.

One of the modern trends in the renovation of city neighborhoods is the complete demolition of existing buildings with the further construction of a completely new, modern residential area. But the problems of the practical implementation of the demolition of residential buildings concern quite a few aspects: social and domestic, technical and technological, economically justified, environmental requirements and disposal of dismantled structures, etc. In these conditions, a way out of this situation may be constructive and technological techniques for the reconstruction of secondary residential buildings, such as: superstructure, extension of small architectural volumes, construction with the expansion of buildings and the addition of one or more attic floors. Technical and economic requirements for the reconstructed building are based on compliance with the principle of self-sufficiency in the required billing period, real sources of covering costs, and favorable financing conditions for the work. Technological solutions for reconstruction are quite diverse. They are based, first of all, on existing conditions: type of buildings, level of reconstruction work, use of appropriate technical equipment, and other factors [11].

The most important criterion when choosing options for constructive and technological solutions is the duration of the work and the conditions for intensifying the main construction processes. In this aspect, the construction of attic floors from volumetric blocks of partial or complete factory readiness, as well as technologies in which modern lightweight materials are used, deserve attention [17].

Analysis of the experience of various countries allows noticing a trend in the use of technologies and methods for the reconstruction of standard residential buildings in countries such as France, Finland, Germany, Poland, Sweden, etc. [10]. From the experience of existing technologies introduced in these countries, one can see various options for the reconstruction of buildings of these types. A number of cities in Germany and Finland are using the experience of de-densification of buildings. Thus, individual houses are dismantled, freeing up the area for landscaping and planting of greenery (Figure 1, 2). The experience of dismantling several blocks of sections of the house is also used, allowing the apartments to be converted into two levels. Due to the release of territories and changes in the architectural appearance of the building, the configuration of the building is added and developed, with according modernization by adding balconies and loggias (Figure 2) [10].

Figure 1. Germany. Reconstructed large-block residential buildings [10]

Figure 2. Finland. Residential area of reconstructed large-panel buildings [10]

The technology for adding an attic floor during reconstruction is clearly illustrated using the example of Figure 3. The proposed technology provides for the location of construction and installation zone III in the local area, to which half-spans of metal block sections of the attic floor II are brought. These blocks are mounted on a stationary platform using temporary fixing load-handling mechanisms 4 and scaffolding auxiliary means 3. The fixation of the halves of the block sections 2 is most often performed using a bolted connection. The block section of the attic floor is assembled over the entire width without intermediate supports, and is carried out in assembling taking into account the selected span spacing of the enlarged assembly [2]. At the roof level, work is being carried out to dismantle the floor slabs located above the flight of stairs. Then a flight of stairs for the future floor to be built on is built. Ventilation pipes are built on, communications are provided above the floor. A monolithic reinforced concrete strapping belt is installed along the building's contour with the installation of embedded metal parts, on which the mounted metal block sections are subsequently supported. Elements of block sections are mounted from the ground in separate parts or assembly units 6. At the level of the floor being built on, they are aligned in the design position. The supporting structure of the spans is welded to embedded parts installed in a monolithic reinforced concrete belt. Further, during the installation of the block of sections, work is carried out on installing an insulated roof and interior finishing work on the arrangement of living spaces. In addition, when using this installation method, a reduction in reconstruction time is achieved due to the enlarged assembly and installation of fully prefabricated openings of factory-ready block sections, the installation of assembly units is simplified, the negative impact of installation and dismantling work on the residents of the building is minimized, one longitudinal side of the building facade is used.

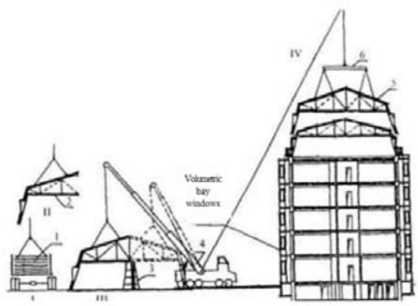


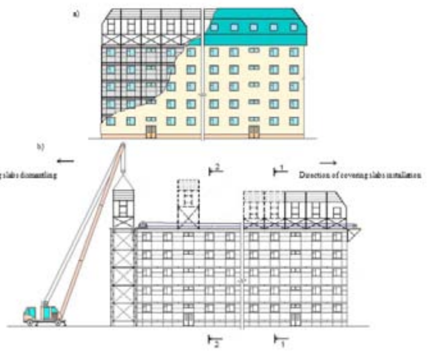
Figure 3. Schematic diagram of the technology for superstructure of an attic floor with enlarged metal block sections without widening the body (first option): I – unloading of half-spans of block sections; 1 – truck with spans; II –

unloading of metal spans with delivery to the assembly zone in enlarged block sections; 2 – half the span of the block section; III – zone of enlarged assembly of metal block sections; 3 – additional means of scaffolding; 4 – pneumatic wheel jib crane; IV – installation of a fully prefabricated enlarged metal block section of the built-on floor; 5 – enlarged block section; 6 – traverse

Reconstruction of buildings and structures may well act as part of the overall reconstruction of the entire complex of buildings. It also implies some change in the external architectural style. Such an operation must first of all be comprehensive; many factors must be taken into account when carrying out the appropriate measures. Thus, buildings can be of industrial and residential type, as well as administrative and commercial. Depending on this, the work carried out differs significantly from each other.

However, as it was mentioned above, in general, the reconstruction of buildings today acts as a main direction in the field of capital construction. In contrast to the construction process, reconstruction has a number of features: the work performed during the reconstruction process is heterogeneous, dispersed and small-scale; the work carried out during reconstruction differs from that carried out during the construction process (dismantling of structures, strengthening them, replacing individual structural elements, etc.); there are cramped working conditions, which significantly affects the overall organization of work on the reconstruction of an industrial building; it is necessary to implement an individual approach to restoring operational indicators and strengthening the load-bearing elements of buildings and structures.

This technology has a number of technical, economic, design and planning positive characteristics, which affects the profitability of its use in the reconstruction of narrow-frame buildings of standard construction with an attic floor superstructure. Construction and installation work is carried out in the most cramped conditions at all stages: the stages of preparatory work, organizing the construction site for the enlarged assembly of block sections, the main cycle of installing volumetric block sections in the design position, dismantling roofing structural elements, as well as when performing a complex of internal and external work on the installation of end walls, execution of work on the installation of sanitary and ventilation units. In the case of multiple repetition of this option, its further development could be the method of conveyor-block installation (Figure 4).



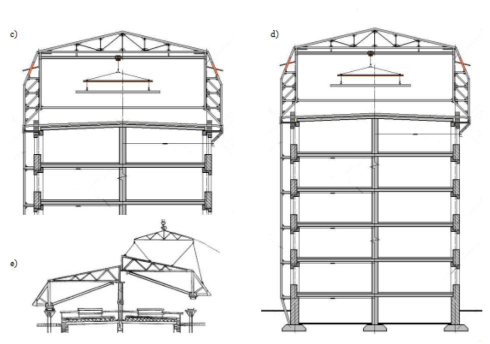


Figure 4. Organizational and technological schemes for carrying out reconstruction work with a superstructure using the conveyor-block method: a – house after modernization; b – work execution (general technological scheme); c – carrying out dismantling work under the protection of a spatial block with lifting and transport equipment; d – mounted spatial block of the attic floor; d – assembly of a spatial attic block from two symmetrical parts

Another option for the possible reconstruction of a standard residential building is the addition of an attic floor from lightweight aerated concrete blocks. This technology for constructing an attic floor differs significantly from previous options for on-building a floor and is based on the use of lightweight structural materials that meet all modern requirements for thermal performance, reliability of use, and durability of materials. The decision to apply the method of superstructure from modern lightweight small building materials with a monolithic reinforced concrete reinforcing belt resting on the load-bearing walls of an existing building is also a progressive and technologically sound technology. This technology also involves the dismantling of floor slabs located above the flight of stairs, with the installation of flights of stairs with access to the attic floor. A monolithic reinforced concrete strapping belt is installed along the contour of the load-bearing walls. A guide metal profile is fixed to this belt. Lifting of building material is carried out by truck cranes from the side of a truck in pallets.

In the first of these considered options, a jib wheel-mounted crane is used, and in the second case, a modular spider crane and a stationary roof crane are used. In both cases, the operation of the building during construction work is safe. Both options are characterized by a reduction in the cost of using powerful lifting machines and mechanisms, which makes it possible to carry out work on the superstructure without creating inconvenience for building users and reduces the use of the local area for the purpose of the construction site (it is possible to use small-sized stationary cranes or winches on the roof of the building).

Both in new construction and in restoration and reconstruction, the most important task in preparing construction production is the selection of an effective system of construction machines [8,19]. In any case, it is obvious that the equipment must meet both technical characteristics and operational qualities to perform tasks of any complexity and under any external conditions, as well as economic indicators. High efficiency of complex mechanization can be achieved with a rational combination of these components[7].

The demand for construction machinery is calculated in the following order: identifying the quantity of work to be done; determining the structure of mechanization methods; The operational hourly productivity of machines is determined; the necessary number of machines to do the specified quantities of work is computed [16]. Calculating the number (need) of construction machines N using the formula:

$$N = \frac{Q}{b_{ech} * T_t} \qquad (1)$$

where Q - amount of a specific sort of work in kind; b_{ech} - the machine's operational productivity when executing the specified sort of task; T_t - duration of work of the machine on the given type of work, mach.-h.

The following formula determines the machine's work time for the specified type of work. (2):

$$T_t = \frac{(T_{dv} - d_{nB}}{\frac{1}{t_{sm*}k_{sm} + DT_p}} \qquad (2)$$

where T_{dv} - specified period of machine operation as indicated by the timetable, days; t_{sm} - average duration of shifts, h, k_{sm} - average shift factor of the machine; d_{nB} - average time to transfer the machine, in days; DT_p - duration of machine staying in maintenance and repair (TM and R), days/mach - hour.

The following formula determines the machine's specified duration as per the timetable.:

$$Tdv = (T_d - D_v) * \left(1 - \frac{D_1}{T_d}\right) \qquad (3)$$

where T_d-planned schedule of construction of the site (calendar), days; D_v - number of days off; D_1 - number of days characterized with unfavorable weather conditions.

When estimating the demand for universal machines of one size that execute two or more types of work, the calculation is carried out according to the formula:

$$N_0 = \sum_{i=1} N_i = \sum \frac{Q_i}{b_{echi}} * T_{vi} \qquad (4)$$

where N_i — the need for machines on the i-th type of work; Q_i - the amount of work i-th type in kind; T_{vi} - duration of operation of the machine at the i-th type of work; b_{echi} - hourly operational performance of the machine when conducting i-th type of work.

Using formulae (1) and (4), one may compute the requirement for leading machines. The demand for non-leading machines functioning in the technological complex is determined based on the performance of the leading machine. [16].

Figure 5 demonstrates the flow of the performance evaluation of the intelligent lubrication system for construction machinery.

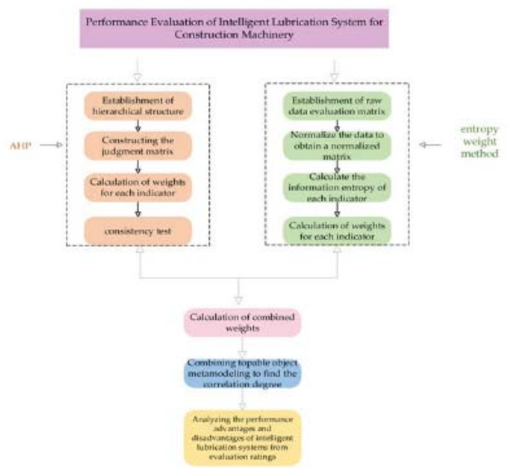


Figure 5. Performance evaluation of the intelligent lubrication system for construction machinery [15]

*AHP - analytic hierarchy process, AHP)–entropy weight method

The determining factors in the choice of mechanization means are the methods of work: construction of a built-in frame from prefabricated or prefabricated monolithic structures, extension or superstructure of a building from piece, enlarged flat, or volumetric elements, etc. [24]. The selection of lifting mechanisms is carried out based on the geometric dimensions of the building in plan and height, as a result of which the parameters of the installation cranes are determined: the height of the hook, the reach of the boom, the length of the crane runway. Depending on the mass of the load being moved and the required reach of the boom, its carrying capacity is determined.

The choice of crane type and lifting capacity is determined by the technology of work and, first of all, by the maximum mass of mounted elements. When performing reconstruction work using monolithic reinforced concrete, the determining factors are the mass of formwork panels and tubs with concrete mixture, when building floors from volumetric blocks - their weight and dimensions, when constructing floors - the geometric dimensions and weight of reinforced concrete panels, etc. [17; 18].

The choice of an economically feasible option for integrated mechanization is carried out in two stages. At the first stage, machine systems are identified that, in terms of technical characteristics and performance qualities, can perform work in the conditions of a given facility. At the second stage, from the identified machine systems, an economically feasible option for integrated mechanization is selected and its effectiveness is assessed. It is recommended to choose this option not for individual types of work and reconstructed objects, but for their entire complex, including all types of mechanized work at all objects for the planned period. This approach is determined by the specifics of construction and installation work in the context of building reconstruction, when the most effective system is one that includes universal machines capable of performing several mechanized processes. Depending on the characteristics of the machines, the system may be for certain units or areas of the facility that are most suitable for the conditions of conducting work.

Appropriate ones for reconstruction conditions are such options for integrated mechanization that are based on small-sized, universal and mobile machines [13]. These machine systems operate in cramped conditions at optimal modes, have a multi-purpose intention, and can be quickly relocated to any site of the object being reconstructed. These qualities, along with low cost, increased reliability and efficiency, characterize these kits as the most effective for reconstruction.

Regarding the design of reconstruction or restoration, BIM has proven itself well in the reconstruction projects. When designing a BIM-based renovation of an old building, each process is managed by the appropriate designers. They make proposals for architectural designers based on their professional knowledge.

BIM can convert the current serial connection into a parallel connection during the design process. All participants can make decisions together, which reduces design changes and saves money and time. During the reconstruction design process, all employees involved in the reconstruction design had to record relevant design standards in the BIM platform, understand their responsibilities, ensure construction quality and processing depth, and check their own permits.

As the red line in the graph on Figure 6 shows, by dynamically connecting design, analysis, and documentation in a BIM workflow, the majority of the effort in a design project is shifted back into the detailed design phase, where the ability to impact project performance is high and the cost of making design changes is low. This allows engineers to spend more time considering what-if situations to improve the design and less time creating construction paperwork.

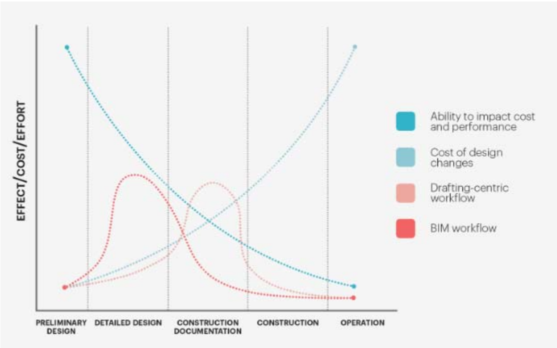


Figure 6. Advantages of BIM for projects [5]

When designing the renovation of old buildings, several characteristics can be identified, such as low safety, low durability, and low comfort levels. But in the process of reconstruction, spatial reconstruction of old buildings is advisable [24].

BIM can involve all staff in design and encourage them to actively engage in renovation, which promotes the development of a consciousness of democratization of design and socialization of the building. User requirements can be taken into account during design, which can enhance the sense of identity when achieving the design.

In addition, BIM brings together different groups of specialists involved in the renovation of old buildings for construction. A design decision support platform that brings together different professions significantly improves the efficiency and quality of renovation plans for old buildings [23].

After applying BIM-based performance modeling analysis, reconstruction and input of original information are not required, which can shorten the analysis cycle. The introduction of BIM into performance modeling analysis software can facilitate the simulation of the internal and external structure of old buildings, directly carry out the performance analysis and assessment of the internal and external environment in the renovation project of old buildings, and adjust the layout according to the simulation conditions. BIM allows adjusting and analyzing the design at any design stage and timely reflecting the situation when evaluating the simulation.

Creating a BIM model allows speeding up the development and design process, optimizing the timing of work, and also carrying out all types of control directly on the construction site. Moreover, the model lives with the building throughout its entire life cycle, including the stages of operation and demolition. The advantage of the information model is its integrated approach: it combines the architectural, structural, technological, and cost estimates of the project with the issues of providing engineering equipment, transport infrastructure, logistics, and other sections necessary for a specific project [24].

It is critical to stress the availability of BIM approaches for work facilities and the proper location of tower cranes on building sites with repeated activities. In this scenario, the transition from a passive to an active BIM methodology is evident [9]. The proper location of tower cranes with the goal of lowering the cranes' overall operating time cycles is an important scientific issue. The significance of the work arises from the well-known facts that tower cranes are big power users on building sites, and that electricity prices are steadily rising in most nations. Over the last few decades, numerous optimization models have been developed and tested to handle such challenges, and in the last decade, BIM has arisen as a viable combination with optimization approaches. Theoretically, this combination might generate a synergy between those techniques. On the one hand, BIM may dynamically obtain validated (i.e., optimal) information, while on the other hand, the outcomes of the optimization can be simulated with other project information, allowing enjoying all of the benefits of reconstruction over new construction.

Marzouk and Abubakr published a study presenting a BIM-based optimization model for tower crane selection, number, and arrangement [12]. The authors employed the analytical hierarchy process (AHP) to pick the kind of tower crane, and a genetic algorithm (GA) to determine the ideal crane number and configuration. The model was applied to a case study situation and produced satisfactory results.

Leading companies associated with robotics are already producing a variety of construction devices that are successfully used in the construction and reconstruction of large objects. Such devices have shown their high efficiency at all stages - from design to finishing. In particular, a popular device is the Geko PV lift. This is a self-propelled device in the form of a crank-elbow mechanism with special vacuum-type grippers of increased power. With their help, the equipment captures and holds large objects weighing up to 175 kg. The load can be rotated and fixed in the horizontal and vertical plane. Robotic cranes are also universal machines. They are designed for the assembly of building structures in high-rise buildings and are part of the automated RCA system, which combines the following subsystems: preparation and assembly of material, assembly of beams and trusses, construction system of the entire facility, control and management. Among the best devices, the MCC 804 on caterpillar tracks stands out. The equipment is equipped with a telescopic 4-section boom, capable of lifting a load weighing up to 8 tons to a height of almost 14 m [4].

The use of construction robots has a number of undeniable advantages for the reconstruction and restoration of buildings [3]:

1. Accuracy of installation, elimination of errors during design and construction. The possibility of spatial modeling is created.
2. Construction time is significantly reduced. Strict implementation of the agreed schedule is ensured, regardless of weather conditions.
3. Optimal consumption of materials. The amount of waste is significantly reduced.
4. Ensuring reconstruction in hard-to-reach places and in extreme conditions.
5. Creation of complex, unusual forms that cannot be built manually.

During the construction process, difficulties often arise due to inaccurate calculations when designing a construction project, imperfect communication with contractors, the notorious human factor, etc. Robotization helps to avoid all these problems and speed up the design process, bringing it to a new qualitative level, with the use of the above-mentioned BIM technology.

As it is known, this approach to the construction, equipment, maintenance and repair of a building (to the management of the life cycle of an object) involves the collection and comprehensive processing during the design process of all architectural, design, technological, economic, and other information about the building with all its interrelations and dependencies, when the building and everything related to it are considered as a single object. That is, a three-dimensional model of the building is being developed, linked to an information database, in which additional attributes can be assigned to each element of the model. The peculiarity of this approach is that the construction project is designed virtually as a single whole. And a change in any one of its parameters entails an automatic change in the remaining parameters and objects associated with it, up to drawings, visualizations, specifications, and a calendar schedule.

However, as practice shows, a precise BIM model will not be built accurately [6]. The reason for this is the reliance on manual operations, including when operating universal machines. No matter how professional the workers are, mistakes will occur. These are technical errors - regardless of the simplicity of the design, for example, if the column was planted a few centimeters from the intended position, the coordinates of the beams and other structural elements should be reconsidered and moved.

The problem is the lack of integration between BIM and contractors. Prefabricated structural elements may not be installed correctly if older construction methods were used. Therefore, technology must be effectively deployed to accurately transfer technical data of models using robots.

The use of BIM technology in AEC (Architecture, Engineering, and Construction) firms is quickly expanding. According to a recent report, 49% of surveyed builders said they use BIM in their firms for visualizations. Figure 7 indicates the same [20].

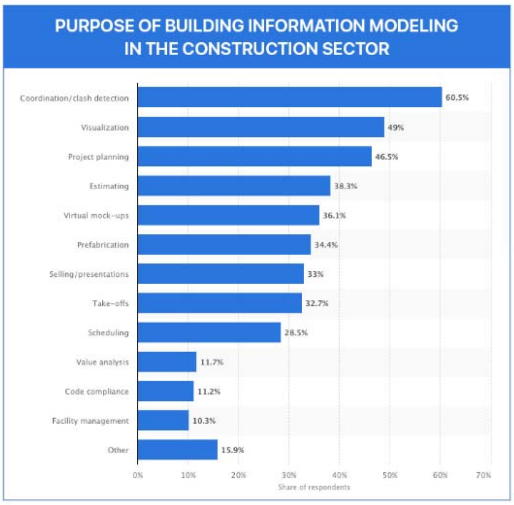


Figure 7. Purpose of BIM in construction [20].

Thus, these statistical data support the statement on high importance of robot technology and BIM combination in the projects of reconstruction and restoration.

Swinerton Builder is the first firm to use Tekla Structures/LM80 software and integrate it with portable software. Trimble LM80 software can accurately transfer data from Tekla Structure Layout Manager to Trimble Robotic Stations, establishing the coordinates of structural elements on the site. Thanks to this connection, specialists receive accurate and coordinated information on the ground. Through its virtual design and construction initiative, Swinerton has become a national leader in the application of building information modeling (BIM) and 3D modeling, estimating, simulation and planning techniques.

Of interest are human-controlled robots designed to lift and install large glass panels, sandwich panels, metal sheets and other building elements - especially those that are of considerable value and size. Such devices are used where it is inconvenient to use traditional cranes or lifts.

A new technique for automatically erecting steel structures in high-rise buildings is called the RCA (Robotics and Cranes Automated Construction System) system. The RCA system can be divided into four main systems:

- Monitoring and management system
- Material assembly system
- Beam assembly system
- Facility Construction System (CF).

The MCC 804 mini crawler robotic crane has the powerful lifting capacity of a crane and can reach the height of a mini spider crane. This 8 ton capacity crawler crane can be lifted to a maximum working height of 13.7 meters using a four-section telescopic boom that can be precisely adjusted with a joystick [3].

Thus, the problems and opportunities for the construction and operation of buildings and structures in the context of reconstruction and restoration using universal machines should be considered in conjunction with the development of BIM and robotics [14].

In the construction industry, the reconstruction of buildings and structures still does not lose its relevance, despite the general growth of buildings from year to year throughout the world. Along with the growth of construction, prices for land (and there is a shortage of land), materials are also rising and, in general, the oversaturation of the market with new buildings and structures sets certain limits for the construction of new ones and activates projects related to the reconstruction or restoration of objects. In addition, the legacy of the construction of the last century, where buildings were often erected without taking into account energy efficiency and high requirements for housing comfort, plus the problem of efficient use of space - all this determines the demand for reconstruction in construction industry no less than the construction itself.

The main problem is that reconstruction itself is a complex process, which is important to organize wisely, carry out accurate preparatory design work and conduct accurate calculations taking into account the characteristics of a particular building, correlate, check and carry out all design documentation, as well as take into account nearby infrastructure and structures in order reconstruction had no effect on them. If it is about the reconstruction of industrial operating facilities, then it is important not to stop production (at least for a long time and in all units), but to find a solution for working in cramped conditions and prepare impeccable design work. Reconstruction of residential buildings or commercial real estate also has its own nuances, which are not always easy to implement without the use of advanced technologies in materials, as well as without effective digital technologies, in particular when determining the need for the use of universal machines and optimizing this use.

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Primary Paper Section: J

Secondary Paper Section: JM, JN