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Implementation of Machine Learning Models in the Construction Site Organization Process

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Abstract

Introduction. Strategic planning is important for effectiveness of investment and construction projects. Complexity of solving problems increases with growth of variables in calculations and constraints. For effective planning of construction sites, many factors need to be taken into account, such as spatial constraints and distances between objects. To solve such problems, it is possible to use a mathematical machine learning model – a genetic algorithm (GA) to optimize the placement of objects on a construction site. The aim of this study is to improve the accuracy and flexibility of solutions in the organization of the construction site, reduce complexity of calculations and minimize the amount of data.

Materials and Methods. The realization of this goal is possible by introducing the Systematic layout planning (SLP) method into the planning process to optimize space on construction sites. To confirm the effectiveness of optimizing the location of objects, the SLP method was applied in the organization of planning the construction site of an administrative building. The planning took into account the stages of work, the required economic facilities, data on safety and environmental safety of the construction site. The use of the Dynamo plugin for analysis made it possible to adjust the location of objects taking into account the utilization factor of the territory.

Research Results. As a result of the modeling of the construction site plan, it was found that using the SLP method, the process is adapted, taking into account the location of objects according to the established values of the relationship matrix using automation and color coding to simplify analysis. Flexibility in making informed decisions is important for designers, given the safety and intensity of the workflow. The SLP method reduces distances through optimization of logistics, optimizes the location of objects on the construction site, taking into account restrictions. This hybrid approach increases the efficiency of implementing machine learning models in the design process of building master plans of facilities. The integration of the genetic algorithm and BIM technologies into the construction site organization process helps to optimize solutions based on optimal distances, improves the visualization of decisions and problem correction.

Discussion and Conclusions. The results of the study contribute to decision-making efficiently and quickly, minimizing the time required for analysis compared to some other approaches. The result of the research is the creation of a system that is not only flexible and adaptable, but also overcomes the limitations typical of previous methods. The use of machine learning technologies to predict optimal design decisions and automate the establishment of key relationships can significantly reduce the need for manual data entry, thereby simplifying and speeding up development processes. Adding new examples of diverse plans and spatial constraints will strengthen the foundations of the concept and enrich its application in a variety of investment and construction projects.

Keywords: construction organization, construction site, machine learning algorithms, artificial intelligence, end-to-end technologies

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Оригинальное эмпирическое исследование

Применение моделей машинного обучения в процесс организации строительной площадки

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Аннотация
Введение. Стратегическое планирование важно для эффективности инвестиционно-строительных проектов. Сложность решения задач увеличивается с ростом переменных в расчетах и ограничений. Для эффективного планирования строительных площадок нужно учитывать множество факторов, таких как пространственные ограничения и расстояния между объектами. Для решения таких задач возможно применение математической модели машинного обучения — генетического алгоритма (GA) для оптимизации размещения объектов на строительном участке. Цель данного исследования — улучшение точности и гибкости решений в организации строительной площадки, уменьшение сложности вычислений и минимизация объема данных.
Материалы и методы. Реализация цели исследования возможна с помощью внедрения в процесс планирования метода Systematic layout planning (SLP) для оптимизации пространства на строительных площадках. Для подтверждения эффективности оптимизации расположения объектов метод SLP был применен в организации планирования строительной площадки административного здания. В планировании учитывали этапы производства работ, требуемые хозяйственные объекты, данные о технике безопасности и экологической безопасности территории строительства. Применение плагина Dynamo для анализа позволило скорректировать расположение объектов с учетом коэффициента использования территории.
Результаты исследования. В результате проведенного моделирования плана строительной площадки установлено, что с помощью метода SLP процесс происходит адаптировано, учитывая расположение объектов согласно установленным значениям матрицы взаимосвязей с помощью автоматизации и цветовой кодировки для упрощения анализа. Гибкость в принятии обоснованных решений важна для проектировщиков, учитывая безопасность и интенсивность рабочего процесса. Метод SLP сокращает расстояния через оптимизацию логистики, оптимизирует расположение объектов на строительной площадке с учетом ограничений. Этот гибридный подход повышает эффективность внедрения моделей машинного обучения в процесс проектирования строительных генеральных планов объектов. Интеграция генетического алгоритма и BIM-технологий в процесс организации строительной площадки помогает оптимизировать решения на основе оптимальных расстояний, совершенствует визуализацию принимаемых решений и корректировку проблем.
Обсуждение и заключение. Результаты проведенной работы способствуют эффективному и быстрому принятию решений при организации строительной площадки, минимизируя время, необходимое для анализа, по сравнению с другими подходами. В результате исследования создана система, которая не только гибка и поддается регулировке, но и преодолевает ограничения, характерные для предыдущих методов. Применение алгоритмов машинного обучения для прогнозирования оптимальных проектных решений и автоматизации установления ключевых связей может значительно уменьшить необходимость ввода данных вручную, тем самым упрощая и ускоряя процессы разработки. Добавление новых примеров разнообразных планов и пространственных ограничений укрепит основы концепции и обогатит ее применение в разнообразных инвестиционно-строительных проектах.

Ключевые слова: организация строительства, строительная площадка, алгоритмы машинного обучения, искусственный интеллект, сквозные технологии

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Introduction. Strategic planning transforms a construction site into a highly organized mechanism where each element yields to the logic of optimal use of space, time and material resources. Innovative design methods enable the design of the most adaptive and efficient working environments [1].

The logistical efficiency of construction sites depends not only on the technical parameters, but also on the quality of the preliminary planning. There might be economic losses due to improper organization of the workspace creating delays and reducing the employees' overall productivity.

Construction site facilities are complex systems where every element — from access roads to internal infrastructure — has a key role to play in the overall concept of sustainable development. The major aspect is not just the physical location of the facilities, but their integration into the overall resource optimization strategy in order to minimize unforeseen costs [2]. It is essential to realize that the initial planning of a construction site might have a dramatic impact on the final effectiveness of an investment and construction project, transforming investments into either considerable savings or additional unplanned costs.

The efficiency of the project enhances due to the competent planning of the location of economic facilities. This approach does not only serve to optimize working processes, but also creates a safe environment conducive to higher productivity levels. Unhindered movement around the facility and uninterrupted operation become possible if the space is thoroughly organized, which ultimately leads to a higher overall performance and maneuverability on the site.

According to the theory of algorithms, organization of space on a construction site belongs to the category of NP-complete problems involving high computational complexity [3]. As the number of variables and constraints goes up, complexity of solving such problems rises, making it more daunting to identify the optimal location due to the rapid increase in the number of possible options. In particular, the development of effective plans for construction sites calls for a whole host of factors to be accounted for, including spatial constraints and the need to maintain certain distances between objects [4]. A variety of approaches can be employed in order to address such complex problems, including mathematical modeling, computer algorithms, and approaches based on rules and knowledge, each offering unique advantages for organizing space on a construction site [5].

While methods yielding the best results call for a great deal of computational effort and time, particularly while expanding tasks, heuristic approaches stand out for their ability to perform quick calculations and adaptability to new conditions and problems [6]. In spite of this, the major problem with heuristic methods is their inconsistency in delivering the best result, which might force one to have to strike a balance between speed and accuracy. In conditions where time is a crucial factor, particularly while working with large and complex tasks, it is customary to compromise choosing between the speed of calculations and the accuracy of the results [7].

As part of improving the efficiency of developing a construction site plan and optimal placement of facilities on it, it is recommended thatadvanced mathematical optimization techniques, particularly the "genetic algorithm" (GA), are used [8]. This optimization method is considered most suitable for planning the location of facilities on construction sites [9]. The genetic algorithm, inspired by the Darwinian theory of evolution, effectively deals with problems similar to the processes of natural selection and genetic changes making it possible to find the best options for space allocation [10].

What sets Algorithms based on genetics apart are their global search capability and efficiency in solving nonlinear problems of high complexity. However, their implementation can be confusing, and they typically perform slower in the search process [11]. This, in turn, increases the likelihood of algorithms reaching imperfect solutions even before a truly optimal answer has been identified.

While developing construction master plans, time-tested approaches are commonly used and based on past experience, as well as guided by specialized standards and regulations such as NOSTROI 2.33.52-20111 and SP 48.13330.20192 which contain construction sites standards instead of relying on mathematical methods. The implementation of innovative planning strategies in construction typically faces obstacles due to a range of factors. Existing mathematical approaches to planning offer only partial solutions that cannot adequately adapt to the changeable and unstable conditions typical of construction projects.

One of the major problems is the need for significant time for data processing by algorithms in their quest to identify ideal solutions, which becomes particularly pronounced as projects start growing in size and complexity. A tool for developing a construction site plan should be easy to use, capable of working with a limited amount of source data, and readily adaptable to a variety of construction projects and land plots. It should help to obtain results as soon as possible, while accounting for the key aspects such as the duration of transportation, safety of work and financial costs, minimizing the need for in-depth analysis for a better outcome.

In order to optimize the planning of the construction site, it is necessary to apply a hybrid approach combining professional experience, standards and strategies for optimizing space. Its aim is to improve the accuracy and flexibility of solutions, reduce computational complexity, and minimize the need for large amounts of data to be entered. In the context of streamlining work on construction sites, the hybrid mathematical optimization method Systematic layout planning (SLP), which is widely used in the organization of space in manufacturing enterprises and in the field of services (Fig. 1), acts as a logical optimization strategy [12].

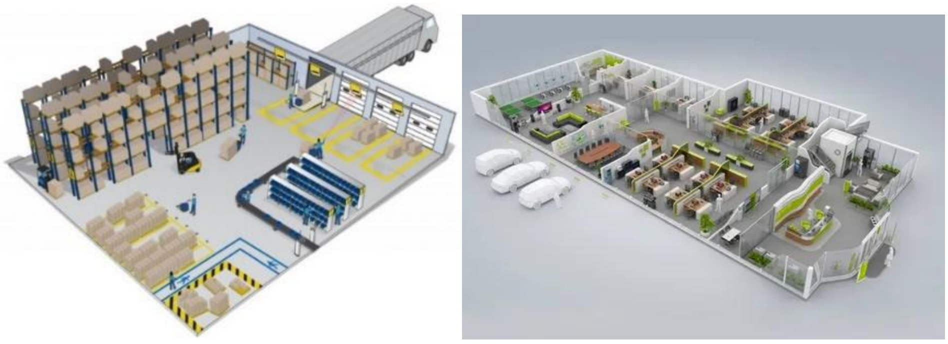


Fig. 1. Space optimization using the SLP method

The SLP method is unique as it allows the application of norms developed based on an in-depth analysis of the relationships between layout elements and their location. In turn, BIM technologies provide an opportunity to efficiently organize the construction process. The SLP principles focus on an integrated approach to the development of construction site plans, accounting for interactions of construction processes and optimal use of space. Using the Dynamo visual programming environment and Python automates processes and improves planning quality. The use of the Dynamo plugin in Revit enabled us to optimize layouts in a BIM environment providing real-time analysis.

Studies designed to analyze the effectiveness of SLP and GA methods demonstrate that hybrid approaches lead to successful results, despite being faced with some problems [13, 14].

In all of the analyses a specially developed method of arranging space was employed where the objects were arranged in an automated mode. The spatial volume rigidly corresponded to the needs for placing the simulated objects which were identical in size and shape. These analytical works enrich the practice with new information on the synthesis of different strategies for space organization, however, they indicate the need to increase the flexibility of planning processes.

The aim of this study is to improve the accuracy and flexibility of solutions in the organization of the construction site, reduce the complexity of calculations and minimize the amount of data.

Research Results. The use of technology to optimize the location of objects on a construction site through SLP (construction site layout optimization — CSLP) is key to effective expansion of available space by means of integrating elements into unused areas while observing a set of unique and interrelated tasks and co+nstraints. This approach to planning does not only increase the overall efficiency of land use, but also causes a reduction in design costs, reduces the need for transportation of building materials and provides a higher level of accessibility and safety for the employees on the site.

For a more in-depth understanding of CSLP, it is necessary to become familiar with some key terms including h the concepts of space, time and aspects of structuring occupy a special place. In the context of spatial analysis, special attention is paid to the three major methods of representing the work area. One involves the use of fixed locations, which greatly simplifies the CSLP process transforming it into a process of distributing objects to predefined positions. Another approach divides the territory into sections using a grid where each cell is equipped with a control point for effective use of every square meter for placing the objects.

In a method that recognizes space as continuous, objects can be placed anywhere in a specific area representing a continuous zone. However, this raises the complexity of the process, as it is necessary to make use of more complex algorithms in order to avoid conflicts between objects, and calls for more time for data processing.

Shapes such as cylinders and rectangles are employed to display objects on a construction site, which allows one to accurately determine the location and dimensions. This provides a clear idea of the available resources and facilities on the site. During the construction process, as the building is ready, the need for certain objects and the space they occupy changes, which directly affects how long they are used on the construction site.

In the context of temporary changes that might take place during construction, there are three modeling methods. One is static, which provides for the constant presence of all the facilities throughout the entire duration of the project ignoring any time fluctuations [15].

The use of a method that divides the construction production process into different periods and provides for the development of separate options at each stage serves to assist in overcoming some limitations. In contrast, the method that adapts to the actual time frame of each stage of construction and adjusts plans in accordance with current changes on the construction site differs from the sequential approach, where certain elements of the project remain unchanged over a few stages.

Parameter improvement strategies for CSLP modeling can be classified as accurate, experience-based (heuristic), and mixed methods.

Various approaches are used for the best results to be delivered. In the case of using methods based on precise calculations, objective functions are employed in order to identify ideal answers, but these are costly in terms of computing resources, which reduces their effectiveness in large-scale investment and construction projects. On the other hand, heuristic approaches are able to offer solutions that are close to ideal ones with no need to devote significant resources to identifying the absolute optimum. Combining these two approaches, hybrid methods use mathematical modeling and algorithmic strategies to improving the effectiveness of solutions. Optimization problems are formulated based on mathematical models includinge various quantitative analysis methods such as linear programming, integer programming, and mixed programming [16].

As the complexity of the task rises due to the increasing number of goals and constraints, the solution becomes significantly more time-consuming due to the exponential increase in complexity. Instead of focusing only on specific optimization goals, applying rules based on personal experience enables one to form guiding principles making the task easier for designers to deal with. Algorithms, in turn, are focused on identifying the best or near-best solutions for those optimization problems that are inherently highly complex, particularly in the context of computational complexity theory [17].

The SLP principles establish an approach to developing spatial plans through an integrated approach, starting with data analysis and ending with the selection of the optimal layout option. The methodology relies on the importance of understanding the interactions between different activities, as well as the need to identify the volume, shape and type of each allocated space. The effective combination of these facilities within the framework of the project allows achieving better planning results. Fig. 2 shows the sequence of SLP procedures with the results achieved at each stage.

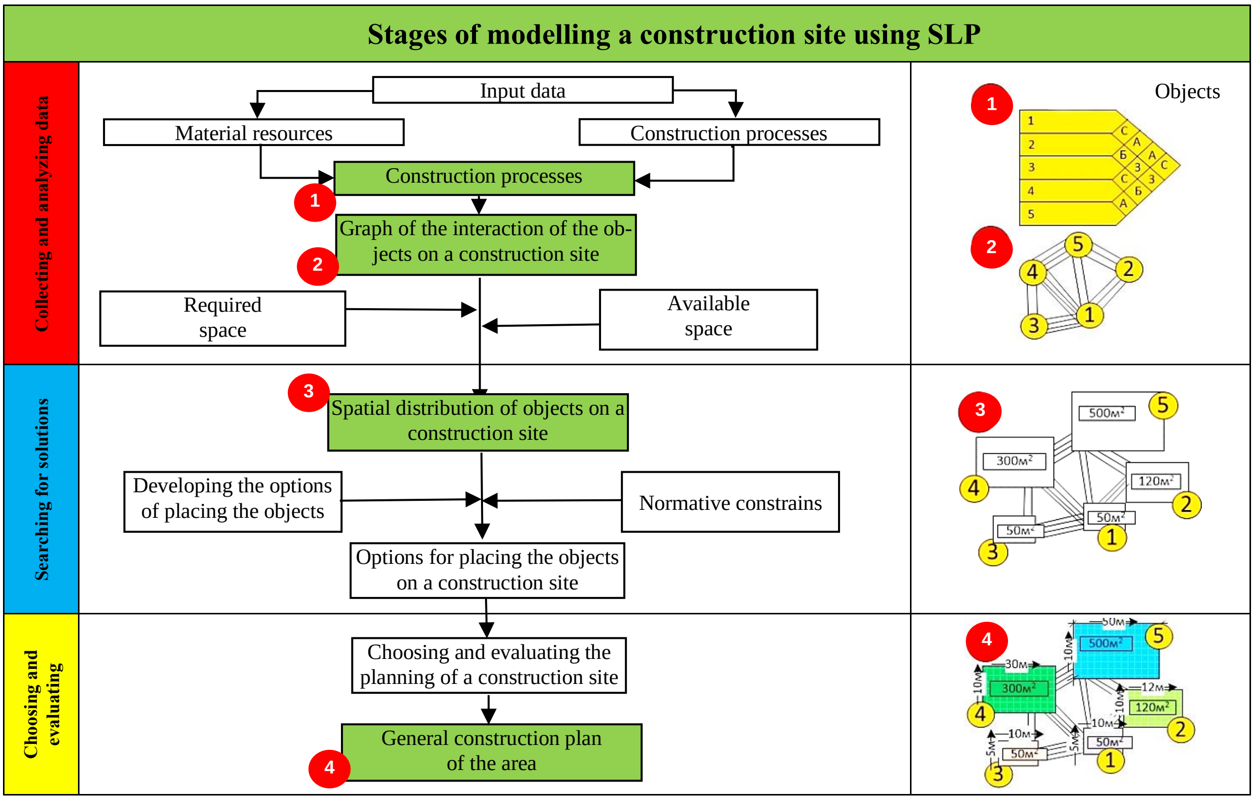


Fig. 2. Stages of construction site modeling using SLP

The SLP method is designed to optimize the building site space, which is not only functionally, but also rationally organized — from the initial stage of data analysis to the final layout. The multi-step process enables the designer to create balanced and thoughtful spatial concepts, building bridges between key objects to achieve the best results. At the very initial stage, the interaction of resource flows in different areas and their impact on areas of activity is assessed using preferred ways to visualize these relationships.

This method makes it easier to understand the connections between different objects by making it possible to design diagrams visualizing these connections via activity. In the graphs (Fig. 2), each diamond-like element shows the level of interconnection in numerical terms.

For SLP, certain designations of the levels of interrelation of objects were introduced: "A" — absolute, "S" — significant, "S" — standard, "A" — acceptable, "O" — optional and "U" — unacceptable. The number of lines between two elements reflects the degree of significance of their relationship.

What the designer does first is collect and analyze the data to develop a diagram that shows how the objects will interact with each other. This is followed by the second phase, where identifying the requirements for the area occupied by the object, the necessary equipment, mechanisms and the availability of free space to ensure optimal location is key. The analysis then proceeds to a stage where potential design changes are evaluated to identify the level of their feasibility and optimality, while taking into account costs, technical limitations and safety issues. The final stage of the design process is to analyze alternative locations and select the most appropriate one looking at both their advantages and disadvantages.

This study employs a design approach known as Design Science Research (DSR) whose results are called artifacts [18]. Design starts with a series of steps performed by a specialist designer with the aim of developing an artifact product. Creating an artifact provides the researcher with a more nuanced understanding of the problem, which helps to improve the design process by rethinking it. This evaluation and development process is commonly repeated multiple times until the final design artifact is completed. These artifacts are also important for developing theoretical approaches. As part of this project, a BIM technology-based platform was developed to optimize the planning of construction sites using SLP.

Fig. 3 shows the outline of the research project. The project is implemented in several stages: first, the issues are identified followed by the stage of proposals as well as development, an assessment is then carried out with the outcome at the final one. During each stage, specific steps were taken leading to the completion of the study, which ensures that the idea is successfully implemented.

Stages	Activity	Results
1 Identifying the problem	Identifying the research problem ↓ Familiarization with the normative guidelines for planning a construction site ↓ Studying, comparing and training in programming languages ↓	Systematize the knowledge on planning of a land plot as a construction production using the SLP
2 Decision-making	Organizing the macrostages based on the genetic algorithms of SLP procedures and algorithms ↓	Structuring a computational tool
3 Conducting research	Obtaining information from the normative documentation ↓ Preliminary development of the algorithm model ↓ Use of a mathematical model in the study ↓ Identifying the issues and constrains ↓	Developing a model based on the SLP method
4 Evaluating the research results	Correcting the solutions ↓ Testing the efficiency of a mathematical model ↓	Optimization of the project solutions
5 Conclusions of the research results	Research Results	Identfying the theoretical and practical importance of the study

Fig. 3. Plan of the study implementation

The Dynamo visual programming environment, the Python programming language and the Revit 2023 software package were used for data processing providing automation of CSLP processes. The Dynamo environment served as a platform for visual programming making it possible to create an information model for computing, thereby providing convenient and flexible management of software processes using a node system.

Python scripts were actively used in the processes of visual programming using the Dynamo environment for wider modeling capabilities. They were also used for complex tasks, e.g., optimizing layouts using a genetic algorithm. This approach in modeling allowed us to create lots of layout options, adjusting various parameters and selecting the most effective solutions. Interaction with the Revit software package through the Dynamo plugin provided a visual representation of optimized layouts in the BIM environment allowing for a thorough analysis and optimization of the planning process in real time.

The information model for the analysis was refined step by step as the results were adjusted, which contributed to its improvement and allowed for higher performance in the accuracy and efficiency. The meticulous study of the feedback contributed to the improvement of the functionality of the model, including the ability to adapt to difficult construction site conditions and develop optimal types of layouts. All of this resulted in a new, more reliable and flexible decision-making model that integrated SLP approaches and provided handy tools for assessing the degree of interconnection and importance of various elements and objects on the site.

First and foremost, a strategy was developed for plans for the territory of the building site based on design experience and regulatory documentation. Next, the connections were assessed between the various objects necessary for the location on the construction site, noting the importance of their mutual location, which generally made it possible to develop an optimal model for the location of objects on the construction site. Using the Dynamo software, an estimation tool was implemented that calculated the total length of paths between objects, accounting for the optimal distances and relative positions of these objects. Using genetic algorithms, the optimal location of the objects was selected after the program had automatically generated a reference plan. The progress was assessed using the DSR (Design Science Research) method. The differences between the initial and optimized plan were revealed due to the territory utilization coefficient, which indicated the degree of progress achieved by applying a reduced list of object interconnection levels in the SLP to four to assess the degree of significance of the connections where the model were encoded under the symbols "H" — high level, "M" — medium importance, "L" — low level of importance, and "U" is an undesirable interaction. The assessment of facility interactions took into account factors such as operational activities, safety, and management preferences, which may include, for example, management's desire to place temporary buildings near the entrance to the construction site to facilitate access. In the procedure for assessing the level of interrelation between objects, each degree of significance of the relationship was assessed on a scale with four levels: 0 — absent, 1 — minimal, 2 — medium and 3 — high. Combining these estimates resulted in a proximity index ranging from 0 (no need for interaction) to 3 (high need for interaction). The matrix of interrelations of objects is shown in Fig. 4.

Levels of the organization of the objects on a construction site	Entry	Storage of bulk materials	Semi-closed cement storage	Concrete mixing node	Closed storage	Storage for the fencing materials	Formwork storage	Area of large assembly of elements and structures	Temporary buildings	Construction quarter	Waste accumulation spot
Entry											
Storage of bulk materials	HHM1										
Semi-closed cement storage	HHH0	HHH0									
Concrete mixing node	HHH0	BHB3	BHB3								
Closed storage	HHH0	HHH0	HHH0	HHH0							
Storage for the fencing materials	CHC2	HHH0	MHB3	HHH0	HHH0						
Formwork storage	HHH0	HHH0	HHH0	HHH0	HHC1	HHC1					
Area of large assembly of elements and structures	HHH0	BHB3	HHH0	HHH0	BHB3	HHH0	HHH0				
Temporary buildings	HBB2	HHH0	HHH0	HHH0	HBB2	HHH0	HBB2	HHX0			
Construction quarter	BBB3	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0		
Waste accumulation spot	HHC1	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	BBH1	HHH0	

Designation	Object consistency level
B	High
C	Medium
H	Low
X	Undesirable

Designation	Level of significance of the relationship
3	High
2	Medium
1	Minimal
0	Absent

Fig. 4. Matrix of interrelationships of objects on the construction site

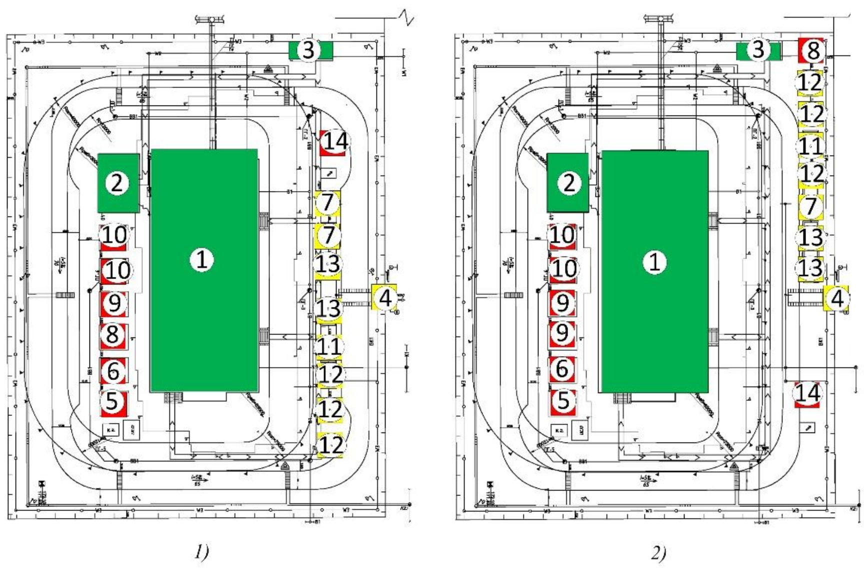
Through the course of the study, the CSLP method was tested during the planning of the construction site. The site was modeled in order to compare the initial and optimized site plan, as a result of which the optimization efficiency was evaluated. The object of the study was a plot of 300 m^2 with a building area of 158 m^2 designed for construction of an administrative building.

At the initial stage of the development of the plan, special attention was paid to the consideration of structures under construction. Basic elements such as the workers' entry points and transportation of materials, as well as the distribution of the road network influenced the initial setup of the platform. In addition, an important and unchanging part of the planning was the mounting crane whose location required significant computing resources exceeding the capabilities of the algorithm used. In order to form a single space on the building site, 14 new facilities were added to the existing ones. These have a variety of dimensions limited by the minimum dimensions established by the design documentation. The compactness of the organization was prioritized making it possible to create a tightly connected matrix of relationships as seen in Fig. 5.

Levels of the organization of the objects on a construction site	Entry	Storage of bulk materials	Semi-closed cement storage	Cloakroom	Closed storage	Storage for the fencing materials	Formwork storage	Dining room	Temporary buildings	Construction quarter	Waste accumulation spot
Entry											
Storage of bulk materials	HHH0										
Semi-closed cement storage	HHH0	HHH0									
Cloakroom	BHB3	HHH0	HHH0								
Closed storage	CHC2	HHH0	HHH0								
Storage for the fencing materials	CHC2	HHH0	MHB3	HHH0	HHH0						
Formwork storage	HHH0	HHH0	HHH0	HHH0	HHC1	HHC1					
Dining room	BHB3	HHH0	HHH0	BHB3	HHH0	HHH0	HHH0				
Temporary buildings	HBB2	HHX0	HHX0	BHB3	HBB2	HHH0	HHX0	BHB3			
Construction quarter	BBB3	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0		
Waste accumulation spot	HHC1	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	HHH0	BBH1	HHH0	

Fig. 5. Matrix of the interrelationships of objects on the construction site of an administrative building

Fig. 6 shows the initially designed plan of the construction site and the plan optimized by means of the CSLP method where various functional areas are highlighted in different colors: green — stationary facilities, red — production and warehouse facilities, yellow — temporary buildings.



1. Object under construction
2. Assembly mechanism
3. Temporary electric power station
4. Entry
5. Storage of bulk materials
6. Semi-closed cement storage
7. Cloakroom
8. Closed storage
9. Storage for the fencing materials
10. Formwork storage
11. Dining room
12. Temporary building (shower, toilet)
13. Construction quarter
14. Waste accumulation spot

Fig. 6. Construction site layout: 1 — initial plan; 2 — optimized plan

The use of built-in Dynamo functions for analysis enabled the evaluation and adjustment of the location of the objects accounting for the territory utilization rate. Table 1 shows the calculation results and a comparison of the final values of the building coefficient for the two variants.

Table 1

Indicators of the construction site layout

Construction site planning	Coefficient of the area use
Initial	1.04
Optimized using the SLP method	1.2

Research Results. It was important for the CSLP process to adapt SLP procedures to better match the dynamics in the planning of construction sites that differ from static layouts. During the manufacturing process, SLP combines both stationary and mobile facilities, while temporary facilities in construction are moved during the course of work. CLP allows one to improve the SLP relationship matrix, making it more convenient and intuitive by automating and using colors to simplify relationship analysis. CSLP also accounts for the intensity of the workflow and safety aspects while determining the interconnection of facilities, which contributes to more efficient layouts accounting for the progress of the construction production.

Flexibility in making informed decisions is key for designers, as this enables them to consider the key factors such as safety and workflow intensity. The main goal of the SLP method is to reduce unnecessary distances through logistics optimization achieved by means of decision-making processes.

What makes the CSLP method different is that it allows optimization of the location of the objects on the construction site for any area in compliance with the restrictions. This hybrid approach reflects the designer's choice during planning and increases confidence in the tool, unlike the strict criteria of pre-established standards.

The integration of the genetic algorithm into the layout process makes it possible to implement a variety of solutions and optimizes them based on optimal distances significantly expanding the possibilities of layout. BIM technologies have a key role to play by providing visualization that improves the identification of problems and their subsequent correction. The combination of SLP with BIM technologies and genetic algorithms enables one to maintain the optimization logic adapting it to the layout of the construction site. Although real-time layout changes at various stages of construction production are not yet accounted for in the design standards, this approach significantly increases work efficiency and minimizes unnecessary movements.

Discussion and Conclusion. This paper presents an innovative approach to designing a collaborative computing environment that combines elements of strategic logistics planning (SLP) with the functionality of a BIM platform forming a unique hybrid system. The key advantage of the system is the visualization of the design process, focusing on the optimal organization of space for temporary facilities, accounting for such important aspects as workflow efficiency, safety and consideration of management preferences. The innovation of this approach is integration of decision-making mechanisms into the process of territorial distribution of administrative and economic facilities at the construction site, which ensures improved labor productivity through the competent organization of logistics at the facility. This hybrid model is able to combine machine learning algorithms with the involvement of expert experience, making it possible to efficiently generate various layout options with minimal requirements for source data, thereby speeding up the development process.

This platform makes use of modeling techniques that allow objects to occupy space with no reference to rigid coordinates or predefined grids. This enables the optimization of the use of each square meter by automatically calculating the optimal size of objects and their placement so that unnecessary occupied space is avoided. Effective adaptation and optimization of space directly affects the increase in labor productivity on the construction site, minimizing the occupied space on the building site and thereby financial costs.

The results of the work contribute to efficient and rapid decision-making, minimizing the time required for analysis unlike some other approaches. The result of the work is a system that is not only flexible and adaptable, but also overcomes the limitations found in previous methods. Unlike standard approaches that relied on standards or predefined templates, the suggested system operates within the framework of a model of unlimited space, which makes it possible to freely place elements. This approach provides designers with an unusually high level of control over setting constraints, selecting available space, and identifying access points.

The analysis conducted using CSLP to improve the layout of the land for the construction of an administrative building revealed that the possibilities for reducing inefficiently used space with no increasing costs vary depending on the size of the project and its complexity.

Depending on the complexity of the conditions for planning a construction site, a range of factors such as area restrictions, the variety and characteristics of facilities, the need for a specific location, fixed locations of some facilities, multi-level placement and non-standard shapes of sites might affect the ability of the platform to reduce unnecessary distances. Despite these challenges, the CSLP method can significantly improve performance in both simple and more complex environments. However, the effectiveness of this tool is limited by the quality of the source data and designer's active involvement in the process of identifying the relationships.

For successful design, it is necessary for developers to gain experience to help prevent possible miscalculations from occurring. However, it should be remembered that their personal views might unconsciously influence the final product, particularly in aspects related to establishing connections and interactions in the system.

In the future, the introduction of machine learning models into the design process can be significantly transformed by introducing optimization algorithms. They are designed to achieve a rational balance between speed and accuracy of data processing, which is critical for complex tasks. Using machine learning algorithms in order to predict optimal design decisions and automate the establishment of the key relationships can considerably reduce the need for manual data entry, thereby simplifying and speeding up development processes. Adding new examples of diverse plans and spatial constraints will strengthen the foundations of the concept and enrich its application in a whole range of investment and construction projects.

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