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MODELING THE DIVERSIFICATION OF A HIGH-TECH ENTERPRISE THROUGH RELOCATION AND SUPPLIER RECOVERY

This study addresses the urgent challenge of enterprise diversification to restore high-tech production (aviation technology, UAVs, rocket engineering, etc.) through relocation and modification of component suppliers. The research is particularly relevant for high-tech enterprise recovery during national emergencies and post war reconstruction. Therefore, the topic of the proposed publication, which examines the activities necessary for planning projects related to the diversification of enterprises under threats, is relevant. ***This study proposes*** *a comprehensive set of mathematical, simulation and agent-based models to facilitate planning for diversification and supply recovery under emergency conditions. This study analyzes existing challenges in enterprise diversification, focusing on relocation due to various threats, including military threats. A systematic analysis of the diversification logistics of high-tech enterprises is conducted. A set of diversification strategies is developed with a special focus on enterprise relocation and supplier recovery. Potential new locations for enterprise relocation are analyzed based on qualitative assessments of key logistical indicators (e.g., safety, infrastructure, and supplier proximity). A set of alternative relocation sites is established, and the most suitable location is selected using lexicographic ordering. The study also focuses on forming a network of component suppliers to consider enterprise relocation and emerging orders, including military applications. The supplier selection and supply routes are optimized using integer (Boolean) programming, accounting for key logistical factors such as component inventory levels, delivery time, costs, and supply risks. To analyze the dynamic process of transporting technological equipment and components, a simulation model was developed using the AnyLogic agent-based platform. A set of agents is formed that represents the main logistical events for planning the enterprise relocation. Based on the simulation results, key relocation indicators are assessed, including location selection, supplier network formation, supply route optimization, delivery time, and inventory levels.* ***The scientific novelty*** *of this research lies in the development of original models that determine a new location for high-tech enterprises, form a network of suppliers to meet production needs, establish supply routes and evaluate feasibility and risks in executing a diversification plan under special conditions.* ***These findings*** *are highly relevant for planning diversification processes in high-tech production, justifying enterprise relocation decisions, approving supplier networks and forming rational and secure supply routes under threat conditions. These efforts ensure the effective recovery of high-tech production during national emergencies and post war reconstruction.*

Keywords: *relocation; production diversification; component suppliers; supply chain optimization; simulation and agent-based modeling.*

1. Introduction

In the conditions of the country's special state, processes of relocation of high-tech enterprises (aerospace industry, mechanical engineering, etc.) arise by moving from the frontline zone to the rear [1, 2]. At the same time, suppliers of components, materials and raw materials change, which must ensure the fulfillment of current orders of the enterprise, including military ones (creation of new UAVs, aviation equipment, armored vehicles, etc.). There is a need to diversify production by relocating the enterprise and restoring supplies and suppliers of components, as well as forming new logistical supply chains [3, 4]. Therefore, there is a need to plan and implement projects for the diversification of high-tech enterprises and their relocation, due to changes in production conditions [5, 6]. The logistical process of supply, in the conditions of the current state of the country, is associated with the actions of possible threats that affect production plans for the release of current products [7, 8]. Therefore, diversification is needed not only of production, but also of supply logistics of high-tech enterprises. It can be argued that this is a difficult task, which is carried out in conditions of possible threats and requires the creation of relatively safe logistics supply chains [9, 10]. Keeping in mind the above, we can conclude that the research being conducted is relevant and is devoted to the analysis and

modeling of possible strategies for diversification of production and the search for rational logistics supply chains of high-tech enterprises.

1.1. Motivation

Diversification of production and search for suppliers and new, relatively safe routes of supply, in conditions of threats, is a complex task that must be solved in a short time to ensure the earliest possible restoration of the enterprise. When forming measures for diversification with the relocation of the enterprise and the change of suppliers, it is necessary to ensure the stability of supply, fulfillment of requirements for the required nomenclature and quantity of components, formation of necessary stocks of components for the successful fulfillment of current orders of a high-tech enterprise [11, 12]. When creating new logistics chains, it is necessary to take into account the heterogeneity of the transport environment that will be used for diversification of supply, possible transshipments from one transport network to another, temporary stops due to threats, etc. [13, 14].

Therefore, there is an actual solution to the problem of planning the process of diversification of production through the relocation of the enterprise and the change of suppliers in the conditions of the special and post-war state of the country.

1.2. State of the Art and problem statement

There are several problems associated with the diversification of high-tech production. These problems have been partially solved, but there are new problems that have arisen in the current state of the country, which require research to solve them:

1. Diversification of high-tech production by relocating the enterprise to a new location to restore its operation [15, 16].

2. Formation of a set of suppliers of components, considering possible import substitution [17, 18].

3. Use of a heterogeneous transport environment for supply in conditions of threats [19, 20].

4. Long logistical supply chains [21, 22].

5. Impact of threats on supply logistics, including military ones [23, 24].

6. Optimization of time and costs for relocation and restoration of production [25, 26].

7. Ensuring a stable, planned supply process for the formation of the necessary stocks of components in a changing political and economic environment [27, 28].

This is an incomplete list of problems that continue to be replenished in the conditions of the country's special state, which indicates the relevance of projects for the diversification and restoration of supply logistics of high-tech enterprises.

The analysis of publications, according to the above list of problems, showed the complexity of the tasks of diversification of production, which requires the use of different models for further research [29, 30].

This study presents possible solutions to some of the specified problems, namely:

- a set of strategies for diversification of production through relocation and change of suppliers of components is substantiated;
- a set of suppliers is analyzed, and ways of supplying components are optimized;
- a simulation model is created to study, in time, the dynamic process of moving technological equipment and supplying components of high-tech enterprises.

The work presents a systematic analysis of the diversification process of high-tech enterprises, which includes structural and dynamic aspects of the study.

Structural analysis includes the formation of a set of relevant options and their lexicographical ordering to justify a new location of production. To optimize the composition of suppliers and supply routes, the method of integer (Boolean) programming is used, in which the relocation time, transportation costs, logistical risks, etc. are used as indicators. This is a well-known method that has been successfully used in various subject areas where a set of alternative options is formed to select the best one [31].

For dynamic analysis, a modern method of simulation modeling in agent representation is used, which allows, by simulating, in time, the transportation process, at a given scale, to investigate the movement of trucks under the influence of threats [32].

1.3. Objectives and methodology

There is a contradiction between the need to carry out the diversification process for enterprises that are forced to move to new places of production and the imperfection, as well as the lack of methods and models that would allow, to the full extent, to plan and carry out effective measures for relocation and the formation of new suppliers and supply routes of components, in the conditions of the special state of the country.

The purpose of the study is to create a set of mathematical, simulation models, with the help of which it is possible to plan the process of diversification of production and restoration of supply of high-tech enterprises in the conditions of the special state of the country.

In accordance with the set goal of the study, it is necessary to solve the following tasks:

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1. Conduct a system analysis and form a set of strategies for diversification of the enterprise through its relocation.

2. Determine the new location of the enterprise for its relocation from the front-line zone.

3. Select and optimize the composition of suppliers and supply routes of components.

4. Create a simulation multi-agent model for analyzing and planning the relocation process and the supply of components of a high-tech enterprise.

The article is structured as follows.

Section 2 is devoted to a systematic analysis of the diversification strategy of high-tech enterprises through relocation and moving to a new location.

Section 3 is related to solving the problem of finding a new location for a high-tech enterprise.

Section 4 is devoted to the selection of suppliers and ways of supplying components under threats.

Section 5 is related to creating a simulation model for analyzing the dynamic process of diversification of a high-tech enterprise.

Section 6 contains a discussion of scientific results and their presentation in the form of a methodology, which allows emphasizing the significance of the research for practical application.

Section 7 concludes the article with a summary of the conclusions, gives prospects for further research and the creation of applied information technology.

2. System analysis and formation of a set of strategies for diversification of the enterprise through its relocation

The analysis of a set of diversification strategies for enterprises, due to relocation and change of suppliers, determined the dependence of the production restoration process on the following factors:

1. The peculiarity of new locations of enterprises for the relocation process (safety, social conditions, location, etc.).

2. The need and possibility of fulfilling new orders by the enterprise after its relocation.

3. The availability of supply routes for components at the new location of the enterprise.

4. The level of impact of threats and disruption of logistics chains of transportation.

5. Considering the cost of components with the possibility of their import substitution.

Let us form a set of strategies that can be used when planning the diversification of enterprises in a special state of the country:

1. Diversification strategy due to a change in the location of a high-tech enterprise.

This strategy is associated with the need to relocate the enterprise due to the emergence of threats.

2. Diversification strategy by changing suppliers of components of a high-tech enterprise.

This strategy is associated with the need to change suppliers in connection with the implementation of new urgent orders by the enterprise, including military ones.

3. Supply chain diversification strategy.

This strategy is associated with the need to change existing supply chains in connection with the change of suppliers and the emergence of threats.

4. Strategy for diversifying orders of a high-tech enterprise in the conditions of a special state of the country.

This strategy is associated with the emergence of new urgent orders, which leads to the resumption of production and supply of components.

5. Mixed strategy for diversifying a high-tech enterprise by using a combination of strategies 1-4.

The presented list of diversification strategies is not final and may be supplemented by new ones that arise in the conditions of a special and post-war state of the country.

The methods and models developed in the conducted study can be used in the planning and implementation of projects for the diversification and restoration of production of domestic enterprises.

Thus, this section provides a systematic analysis of the diversification process of high-tech production, identifies possible diversification strategies for use in the country's special situation, which are based on relocation and change of suppliers of components to restore the enterprise's operation.

3. Formation of a new location for the enterprise to relocate it from the frontline zone

In the special state of the country, there is a need for diversification, due to the relocation of an enterprise located in the frontline zone, by moving and restoring production to a new location. This is especially important for an enterprise that fulfills current orders to produce military equipment and weapons (aviation equipment, UAVs, electronic warfare, etc.). Relocation requires finding a new location for the enterprise that has the necessary conditions for the restoration of high-tech production. Therefore, the urgent task of relocation and restoration of high-tech production in a special period of the country.

Let's form a set of indicators that must be used when choosing a new location for the enterprise:

1. The level of safety of the new location of the enterprise – Q.

2. The presence of infrastructure that ensures the functioning of the enterprise – P.

3. Proximity to suppliers of components – V.

4. The presence of social conditions for the enterprise's employees – F.

5. The time required for relocation and restoration of the enterprise's work – T.

6. Relocation costs – W.

7. Relocation process risk – R.

The assessment of these indicators can be both quantitative and qualitative. At the initial stage of relocation planning, to justify the relatively safe location of the enterprise, we will use a simpler assessment in the form of qualitative assessments of experts (relocation specialists, enterprise management, logistics managers, etc.). For this, we propose to use the linguistic variable y_{ij}, where i will be related to the i-th indicator (Q, P, V, F, T, W, R), and the index j – to the qualitative value of the i-th indicator. The following values can be proposed y_{ij}:

$$y_{ij} = \begin{cases} A - \text{ very good value;} \\ B - \text{ good value;} \\ C - \text{ satisfactory value;} \\ D - \text{ acceptable value;} \\ E - \text{ very low value.} \end{cases} \quad (1)$$

For example, for the time indicator (T), the following values of the linguistic variable are possible y_{ij}:

$$y_{ij} = \begin{cases} A - \text{ minimal time of relocation and restoration enterprises's work;} \\ B - \text{ good time;} \\ C - \text{ satisfactory time;} \\ D - \text{ acceptable time;} \\ E - \text{ very long time.} \end{cases} \quad (2)$$

To compare possible options for a new location of an enterprise, it is necessary to form several indicators considering their importance. The importance of indicators depends on the following factors:

- the need for urgent evacuation of the enterprise;
- ensuring the earliest release of relevant products (for example, military equipment);
- diversification of the enterprise as soon as possible to fulfill new orders, etc.

To form several indicators, taking into account their importance, it is necessary to use the opinion of experts, who take into account the relevance of orders, instructions from the military administration and representatives of local communities, etc. Supposedly, after the assessment of experts, the following number of indicators for the relocation of the enterprise was formed, taking into account their importance: Q, P, T, V, R, F, W.

Each possible option for the relocation of the enterprise to a new location can be represented by a tuple (Q, P, T, V, R, F, W), which contains qualitative values for each indicator. For example, we have the following possible set of options for the relocation of the enterprise:

1. B, C, B, D, A, A, B
2. C, A, B, C, A, B, D
3. A, C, B, C, B, A, E
4. D, A, B, A, C, B, A
5. B, B, A, C, D, C, A
6. A, D, C, B, A, B, E
7. B, C, A, B, A, C, D
8. A, B, D, C, E, A, B
9. B, C, A, B, C, D, B
10. A, B, A, E, C, D, B.

(3)

We will reject the enterprise location options that have an evaluation of relocation indicators with a value of E, because they do not meet the experts' requirements for enterprise relocation (very low indicator values). We will obtain the following set of enterprise relocation options:

1. B, C, B, D, A, A, B
2. C, A, B, C, A, B, D
4. D, A, B, A, C, B, A
5. B, B, A, C, D, C, A
7. B, C, A, B, A, C, D
9. B, C, A, B, C, D, B.

(4)

To select the most suitable option, considering the importance of the indicators, we will use lexicographic ordering of options. In this case, such ordering corresponds to the ordering as in a dictionary. After lexicographic ordering of options, we will obtain:

5. B, B, A, C, D, C, A
7. B, C, A, B, A, C, D
9. B, C, A, B, C, D, B
1. B, C, B, D, A, A, B
2. C, A, B, C, A, B, D
4. D, A, B, A, C, B, A

(5)

Using the importance of ordered indicators (Q, P, T, V, R, F, W), as well as their qualitative values (A, B, C, D, E), it can be argued that the best option for choosing a new location for an enterprise, for its relocation, will be the fifth option (B, B, A, C, D, C, A), in which:

- the level of security of the new location is good (B);

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- the presence of infrastructure that ensures the normal functioning of the enterprise is good (B);
- the minimum time for the relocation of the enterprise (A);
- satisfactory proximity to suppliers of components (C);
- the acceptable risk of the relocation of the enterprise (D);
- satisfactory social conditions (C);
- the minimum cost of relocating the enterprise (A).

Thus, using qualitative assessments of the main indicators of relocation and lexicographic ordering of possible options for the location of the enterprise, the task of diversifying production by relocating it to a new location was solved.

4. Selection and optimization of suppliers and supply routes of components

Relocation of a high-tech enterprise, by moving to a new location, led to the need to search for new suppliers and ways to supply components. At the same time, it is necessary to consider the risks of threats in the special state of the country. To search for suppliers, we will use the following set of logistical indicators:

- stocks of components that the supplier enterprise can create in the allotted time (T) for forming the volume of supply of components – V;
- time required for supply of components to create stocks of components (V) that ensure the planned nature of production work – T;
- costs for supply of components – W;
- risks of supply of components – R.

Globalization in supply has led to the emergence of a set of alternative options for choosing the necessary suppliers and possible ways of supply. Therefore, to select the most suitable suppliers and supply routes for a high-tech enterprise, we will use the method of integer (Boolean) programming, which has shown its effectiveness in various subject areas, where there are many alternative options and it is necessary to choose a rational option, considering several indicators. Let's introduce a Boolean variable x_{ijk}:

$$x_{ijk} = \begin{cases} 1, \text{ if supply i-th item} \\ \quad \text{of the j-th supplier} \\ \quad \text{with k-th supply route;} \\ 0, \text{ otherwise.} \end{cases} \quad (6)$$

Let us present the logistic indices V, T, W, R considering the variable x_{ijk}:

$$V = \sum_{i=1}^{M} \sum_{j=1}^{m_i} \sum_{k=1}^{n_j} v_{ijk} x_{ijk}, \quad (7)$$

where v_{ijk} is the stock of components of the i-th item that can be created by the j-th possible supplier, considering the k-th supply route;

n_j is the number of possible supply routes from the j-th supplier to the new location of the enterprise;

m_i is the number of possible suppliers for the i-th item of components;

M is the volume of the nomenclature of components that is required to produce a high-tech product.

$$T = \sum_{i=1}^{M} \sum_{j=1}^{m_i} \sum_{k=1}^{n_j} t_{ijk} x_{ijk}, \quad (8)$$

where t_{ijk} is delivery time of components for the i-th item for the j-th possible supplier, considering the k-th supply route for creating a stock of components v_{ijk}.

$$W = \sum_{i=1}^{M} \sum_{j=1}^{m_i} \sum_{k=1}^{n_j} w_{ijk} x_{ijk}, \quad (9)$$

where w_{ijk} is supply costs associated with choosing the j-th possible supplier and k-th supply route for the i-th component item to create a component stock v_{ijk}

$$R = \sum_{i=1}^{M} \sum_{j=1}^{m_i} \sum_{k=1}^{n_j} r_{ijk} x_{ijk}, \quad (10)$$

where r_{ijk} is risk of supplying components to create inventories v_{ijk}.

Depending on the specific conditions of the country and the need for serial production of relevant products, including military equipment, the choice of the most important indicator that needs to be optimized leads to the following possible statements of integer (Boolean) programming problems.

1. Maximize the inventory of components to ensure planned, sustainable production of relevant high-tech products at the new location of the enterprise:

$$\max V, \; V = \sum_{i=1}^{M} \sum_{j=1}^{m_i} \sum_{k=1}^{n_j} v_{ijk} x_{ijk}, \quad (11)$$

considering the limitations:

$$T \le T', \; W \le W', \; R \le R', \quad (12)$$

where T′, W′, R′ are the acceptable values of time, cost and risks of component supply.

2. Minimize the time of component supply to create conditions for the earliest resumption of production at the new location of the enterprise:

$$\min T,\ T = \sum_{i=1}^{M}\sum_{j=1}^{m_i}\sum_{k=1}^{n_j} t_{ijk}x_{ijk}, \qquad (13)$$

subject to restrictions:

$$V \geq V', W \leq W', R \leq R', \qquad (14)$$

where V′ is necessary stocks of components to create conditions for planned serial production of high-tech products.

3. Minimize costs for the supply of components:

$$\min W,\ W = \sum_{i=1}^{M}\sum_{j=1}^{m_i}\sum_{k=1}^{n_j} w_{ijk}x_{ijk}, \qquad (15)$$

subject to restrictions:

$$V \geq V', T \leq T', R \leq R'. \qquad (16)$$

4. Minimize the risks of supplying components in the context of the country's special situation:

$$\min R,\ R = \sum_{i=1}^{M}\sum_{j=1}^{m_i}\sum_{k=1}^{n_j} r_{ijk}x_{ijk}, \qquad (17)$$

considering the limitations:

$$V \geq V', T \leq T', W \leq W'. \qquad (18)$$

To solve the integer Boolean programming problem, depending on the dimension of the problem, you can use:

1. The exhaustive search method (low dimension).

2. The modified branch and bounds method (high dimension).

3. The random search method, which does not guarantee finding an extremum, but allows you to improve the value of the indicator (very high dimension).

Thus, using the integer (Boolean) programming method, which works on a set of alternative options, the problem of finding the necessary suppliers and ways to supply components to resume planned serial production of current products at the new location of a high-tech enterprise was solved.

5. Simulation multi-agent model for analysis and planning of the relocation process and supply of components of a high-tech enterprise

The structural analysis of the process of diversification and restoration of production of the enterprise, in conditions of a special state, allows to determine the new location of the enterprise when it is relocated to the rear, to form a set of suppliers, to fulfill new orders, and supply routes, considering the increased risks of threats, including military ones. To analyze the dynamic process of relocation of the enterprise, transportation of technological equipment and components, a study was conducted using the created simulation model, using the Any Logic agent platform. A set of agents was formed, which allows, through interactive management, to form new locations of the enterprise, during their relocation, suppliers of components and to explore possible supply routes, under the influence of threats. Fig. 1 presents a structural diagram of the agent simulation model. The set of agents of the simulation model includes:

1. “Transport network structure” Agent. With the help of this agent, a heterogeneous transport environment is created for the formation of possible transportation routes.

2. “Location of the enterprise” Agent. A place is formed in the transport network where the enterprise is located before the relocation.

3. “New location of the enterprise” Agent. A new location of the enterprise is formed, which is indicated on the transport network.

4. “Formation of the relocation path” Agent. A path for moving the enterprise from the old to the new location is created in the transport network.

5. “Supplier Formation” Agent. The location of component suppliers in the transport network is formed.

6. “Supply Route Formation” Agent. The route for supplying components to a high-tech enterprise at a new location is created.

7. “Enterprise Relocation Simulation” Agent. The relocation of an enterprise is simulated, on a given time scale and along a given path for moving technological equipment.

8. “Supply Simulation” Agent. The movement of trucks with components from suppliers to a new location of the enterprise is simulated, on a given time scale.

9. “Threat Emergence” Agent. The emergence of threats is simulated due to a random generator, which leads to the destruction of the enterprise’s movement path or the supply of components.

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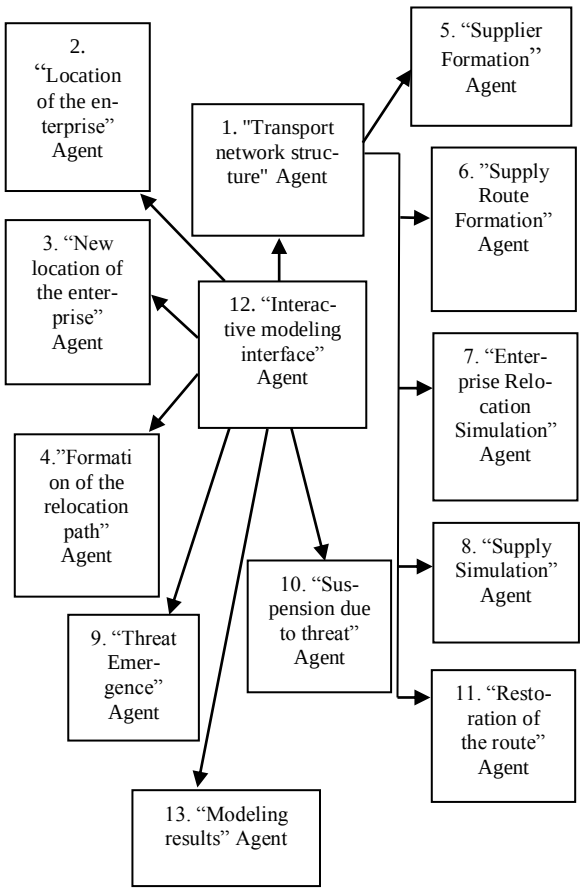

Fig. 1. Structural diagram
of the agent simulation model

10. "Suspension due to threat" Agent. Simulates a temporary delay in the movement of technological equipment or components for the period of restoration of the supply route.

11. "Restoration of the route" Agent. Simulates a delay in the restoration of the enterprise movement route or the supply of components.

12. "Interactive modeling interface" Agent. The agent allows you to control the simulation in interactive mode.

13. "Modeling results" Agent. Used at the end of the study to generate the results of the simulation of the relocation process. The modeling results include:

- the created structure of the transport network used for the relocation of the enterprise and the supply of components;
- the old and new locations of the enterprise;
- a set of suppliers and their locations;
- the actual time required for the relocation of the enterprise;
- the time required for the supply of components to create inventories for the production of a high-tech enterprise;
- the time associated with the termination of the process of moving the enterprise's technological equipment due to the manifestation of threats;
- the time associated with the termination of the supply of components due to the manifestation of threats;
- violation (in percent) of the enterprise relocation plan;
- violation (in percent) of the supply plan of components.

Thus, using modern agent-based simulation modeling of the production restoration process, by simulating the relocation of the enterprise to a new location and transportation of components to ensure planned work, the task of analyzing the dynamic process of production diversification in the conditions of the country's special state was solved.

6. Discussion

A systematic representation of the process of diversification and restoration of the work of a high-tech enterprise due to its relocation to a new location and changes in the set of suppliers and supply routes of components has been created. Possible diversification strategies for a high-tech enterprise in the conditions of a special state of the country have been analyzed. A conclusion has been made on the relevance of the process of relocation of the enterprise in conditions of military threats. A new location has been selected for the restoration of high-tech production, using lexicographic ordering of possible options for the location of the enterprise. Integer (Boolean) optimization of the composition of suppliers and supply routes of components has been carried out. The dynamic process of diversification of production has been studied by simulating, in time, the process of relocation and supply of components. An agent model has been created to study the transportation of technological equipment and components to a new location of the enterprise under the influence of threats.

The following research methodology has been proposed:

1. Conducting a systematic analysis of diversification of high-tech production in the conditions of a special state of the country.

2. Formation of a new location of the enterprise for its relocation.

3. Creation of a set of suppliers of components and supply routes for the fulfillment of new urgent orders of the enterprise.

4. Modeling, in time, the relocation of the enterprise and the supply of components.

The relevance of the proposed approach is associated with the need to diversify high-tech enterprises that are forced to move to a new location to restore produc-

tion in the conditions of the special and post-war state of the country.

A set of models has been developed aimed at planning projects for the diversification of high-tech production in the conditions of threats. This allows us to conclude about the timeliness and effectiveness of the proposed approach for the restoration of domestic production in the current state of the country.

Future research will focus on improving the applied information technology of modeling the logistics of diversification of high-tech production, due to the relocation of the enterprise and changing suppliers and supply routes of components.

7. Conclusions

The conducted research allows planning measures and actions for the diversification of the enterprise, due to its relocation to a new location, namely:

- choose the necessary strategy for the diversification of production, in the conditions of a special state;
- justify the new location of the enterprise for its relocation;
- approve the composition of suppliers of components for the fulfillment of new current orders;
- form new ways of supplying components to the new location of the enterprise;
- analyze the implementation of the relocation plan of the enterprise, by means of simulation modeling of the movement of technological equipment and the supply of components.

The scientific novelty of the research is associated with the creation of original and new models that allow determining the new location of a high-tech enterprise, a set of suppliers, for the fulfillment of current orders, ways of supplying components, assess the possibility and risks of implementing the diversification plan and restoring production in a special period of the country.

Thus, we can make the main conclusion regarding the conducted research: the proposed set of models allows, when planning a project for diversification of high-tech production, to justify the relocation of the enterprise to a new location, to approve the composition of suppliers, to form rational and relatively safe ways of supplying components, in conditions of threats. This will ensure the effectiveness of the process of restoring high-tech production during the period of special and post-war state of the country.

Contribution of authors: system analysis of diversification of high-tech production – **O. Fedorovych**; study of possible strategies of diversification of production – **L. Lutai**; formation of a set of places of relocation of the enterprise – **A. Rybka;** optimization of the composition of suppliers of components – **Ye. Polishchuk;** formation of supply routes – **V. Solovyov;** simulation modeling of relocation of the enterprise – **V. Fedorovych**.

Conflict of Interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, author ship or otherwise, that could affect the research and its results presented in this paper.

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Data Availability

Data will be made available upon reasonable request.

Use of Artificial Intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

All the authors have read and agreed to the published version of this manuscript.

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МОДЕЛЮВАННЯ ДИВЕРСИФІКАЦІЇ ВИСОКОТЕХНОЛОГІЧНОГО ПІДПРИЄМСТВА ЗА РАХУНОК РЕЛОКАЦІЇ ТА ВІДНОВЛЕННЯ ПОСТАЧАЛЬНИКІВ КОМПЛЕКТУЮЧИХ

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Формується та вирішується актуальна задача дослідження диверсифікації підприємства для відновлення високотехнологічного виробництва (авіаційна техніка, БПЛА, ракетобудування, тощо) за рахунок релокації та зміни постачальників комплектуючих. Дослідження, яке проводиться спрямоване на відновлення високотехнологічних підприємств в період особливого та поствоєнного стану країни. Тому, актуальна тема запропонованої публікації, в якій досліджуються заходи, які необхідні для планування проєктів щодо диверсифікації підприємств в умовах загроз. **Метою публікації** є створення комплексу математичних, імітаційної та агентної моделей, за допомогою яких можна планувати процес диверсифікації та відновлення постачання високотехнологічних підприємств в умовах особливого стану країни. Проаналізовані існуючі проблеми диверсифікації підприємства, які пов’язані з його можливою релокацією з-за загроз, у тому числі військових. Проводиться системний аналіз щодо логістики диверсифікації високотехнологічного підприємства. Формується множина стратегій диверсифікацій, в яких особлива увага приділяється релокації підприємства та відновленню постачання комплектуючих. Проводиться аналіз можливих місць нового розташування підприємства з урахуванням якісних оцінок основних логістичних показників (рівень безпечності нового місця, наявність інфраструктури виробництва, близькість до постачальників, тощо). Формується множина альтернативних варіантів для вибору нового місця розташування підприємства. Вибір найбільш підходящого нового місця проводиться за допомогою лексикографічного впорядкування варіантів. Велика увага приділяється формуванню множини постачальників комплектуючих, що пов’язано з переміщенням підприємства, а також з новими, актуальними замовленнями щодо випуску високотехнологічної продукції, у тому числі військового призначення. При виборі нових постачальників ураховуються можливі шляхи постачання в транспортній мережі. Вирішується оптимізаційна задача пошуку потрібних постачальників та шляхів постачання за допомогою цілочисельного (булевого) програмування, з урахуванням основних логістичних показників (запаси комплектуючих, час, витрати, ризики постачання). Для аналізу динамічного процесу перевезень технологічного обладнання та комплектуючих високотехнологічного підприємства створюється імітаційна модель за допомогою агентної платформи Any Logic. Формується множина агентів, які дозволяють представити основні логістичні події для планування переміщення підприємства. За результатами імітаційного моделювання оцінюються показники релокації підприємства (вибір місця розташування, множина постачальників комплектуючих, обрані шляхи постачання, час постачання та запаси комплектуючих, тощо). **Наукова новизна** дослідження пов’язана зі створенням оригінальних та нових моделей, які дозволяють визначити нове місце розташування високотехнологічного підприємства, множину постачальників для виконання актуальних виробничих завдань, шляхи постачання комплектуючих, оцінити можливість та ризики виконання плану диверсифікації підприємства для відновлення виробництва в особливий період країни. **Результати дослідження** доцільно використовувати при плануванні процесу диверсифікації високотехнологічного виробництва, об-

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ґрунтуванні релокації підприємства на нове місце розташування, затвердженню складу постачальників з формуванням раціональних та відносно безпечних шляхів постачання комплектуючих в умовах загроз. Це забезпечує ефективність процесу відновлення високотехнологічного виробництва в період особливого та поствоєнного стану країни.

Ключові слова: релокація; диверсифікація виробництва; постачальники комплектуючих; раціональні шляхи постачання; оптимізація; імітаційне та агентне моделювання.

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