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Resilience of Robotic Solutions under Extreme Conditions

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Abstract. This study is devoted to the problems of the use of modern advanced technologies by logistics companies in their efforts to increase the speed of their technological operations and transform their business processes; this is aimed at reducing their financial costs, increasing the efficiency of their use of labor resources, and minimizing their risks. Today, this is a decisive factor in increasing a company's competitiveness in the market, increasing its profitability, and realizing its long-term leadership. Innovative logistics is an effective tool for streamlining flow processes through the introduction of high-tech innovations in the operational and strategic management of the market structures that are aimed at improving the quality of their customer service, increasing the efficiency of their flow processes, and reducing the total cost of their implementation in order to achieve key business objectives.

The paper examines approaches to the automation of business processes in the logistics sector in the context of the robotization of technological operations while taking those features that are due to the functioning of enterprises under conditions of constant exposure to extreme risks into account. The concept of the robotization of processes has been developed, which will increase the productivity and efficiency of businesses, help reduce their operating costs, reduce their likelihood of personnel errors, and contribute to improving their business security. The results are implemented in the practice of a number of logistics companies in the real sector of the economy.

Keywords: industrial robots, robotics, extreme risks, logistics enterprises, business process optimization

Mathematics Subject Classification: 91B38

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1. INTRODUCTION

It is impossible to imagine the rapid development of the modern world economy without constant innovative solutions. Nowadays, there is a trend toward constant steady progress in both research and innovation in various industries, and the field of logistics is no exception. The use of modern advanced technologies by logistics companies guarantees the high speed of the executions of necessary operations and operations, thus reducing their financial costs and labor costs; this serves as a decisive factor in increasing the companies' competitiveness in the market, increasing their profitability, and realizing their long-term leadership. Innovative logistics is the most relevant component of logistics activities. This is an effective tool for streamlining flow processes through the introduction of high-tech innovations in the operational and strategic management of market topologies that are aimed at improving the quality of customer service, increasing the efficiency of flow processes, and reducing the total cost of their implementation in order to achieve key business objectives.

Moreover, constant work on implementing innovative solutions in the flow processes of logistics companies is the key to business stability in the face of constant pressure (risks of a very diverse nature). First of all, companies are aimed at administering the minimization of classic business risks: organizational, commercial, financial, legal, etc. However, events such as the SARS-CoV-2 pandemic, the full-scale war between Ukraine and Russia, and Israel's war with Hamas require a separate study regarding the problems of the sustainable functioning of business processes under conditions of extreme risks.

Actually, this study is devoted to the study of the problems of extreme risks and building a strategy for the sustainable functioning of business processes under the influence of destabilizing internal and external factors.

2. LITERATURE REVIEW AND PROBLEM STATEMENT

The problems of optimizing, minimizing risks, and improving the efficiency of logistics-channel management are urgent tasks that are in the constant focus of the attention of the world's leading researchers.

Ho et al. (2015) provided a fairly broad comprehensive overview of SCRM publications. The article presented a classification of studies, a detailed overview of risk types, risk factors, and risk-management strategies in supply chains. The application of artificial intelligence algorithms to the supply-chain- management system through the implementation, visualization, automation, and intelligent management of all links in the supply chain was explored in (Lin et al. 2022). In Altiparmak et al. (2006), the authors proposed a new procedure for finding the optimal solution for the functioning of the network of a supply chain based on genetic algorithms for finding the Pareto set-optimal solutions to the multipurpose design problem.

In Nezamoddini et al. (2020), the authors considered a supply chain to be a network of suppliers, manufacturing enterprises, distribution centers, and markets. The researchers proposed a model that, in the face of the uncertainty that is associated with demand, facility disruptions, turnaround times, and disruptions in supply, production, and distribution channels, aimed to achieve risk-based optimization by the processing strategic, tactical, and operational decisions of a functioning supply chain. For a representative European supply chain, a model for the design and planning of backflow supply chains was proposed in Cardoso et al. (2013) using mixed integer linear programming (MILP). An expert approach to risk assessment in logistics systems was investigated in Aqlan & Lam (2015).

For the stochastic model of achieving global optimality, Baghalian et al. (2013) presented a transformation based on the method of piecewise linearization. The authors illustrated the initial data of the model with the help of several numerical examples and practical applied research in the agrifood industry. The proposed model took the uncertainties on the supply and demand sides into account at the same time, which made it quite applicable when compared to the other similar models that have been described in the existing literature.

One of the key roles in minimizing risks is played by the problem of ensuring the functional stability of business processes and technological processes under the influence of internal and external destabilizing factors. Studies of this problem were carried out in detail in Barabash et al. (2023), Obidin et al. (2017), Pichkur & Sobchuk (2021), Sobchuk et al. (2021).

The resilience of critical infrastructure from unauthorized external intrusions was studied in Laptiev et al. (2023), Pichkur et al. (2022), Svynchuk et al. (2021), Yevseiev, et al. (2021), Yevseiev et al. (2023). In the data from the studies, the authors studied the approaches to ensuring the minimization of the risks of information loss in detail; these can lead to critical consequences for the functioning of the information systems of enterprises, the prohibited methods of minimizing such impacts, and the developed algorithms that were aimed at increasing the cybernetic stability of information systems.

In recent decades, industrial robots have been developing rapidly in the leading sectors of the global economy; these cover many new industries such as aerospace, military, medical, etc. The development trend of industrial robots in the future should focus mainly on the following areas of development: human-robot collaboration, artificial intelligence, new industrial users, digitization, and facilitation. Dzedzickis et al. (2022) described the current state of the development of new industrial robots and described the trends in their future development. The work aimed to create a theoretical basis for the development of companies that special in the development of industrial robots.

In Bernardo et al. (2022), the authors provided an overview of the advanced applications of robotic technologies in the real industrial sector. A review of survey publications and technical reports (classified according to the criteria for their application) was carried out. The results of the analysis revealed the prerequisites for the existing obstacles and problems in this innovation sector. In particular, the problems that were related to the spheres of psychology, human nature, the introduction of special artificial intelligence, and the paradigm of the robot-oriented design of objects were disclosed.

An overview of the prospects of existing robotic systems for the intralogistics of companies (which aimed to determine which research paths had been used to date and highlight current and future research directions) was made in Bernardo et al. (2022). The authors of the paper focused on the study of localization and route planning, task scheduling, optimization, and the representation of knowledge in robotic systems. Given the rapid growth in the amount of information that robotic agents must process, the application of strategies that are based on semantic knowledge is becoming increasingly important. Transforming domain knowledge and minimizing ambiguity will allow agents to reason and facilitate the exchange of knowledge between robotic agents and humans. In the near future, it will be increasingly important to rethink production and logistics systems from a human perspective. Business processes will facilitate the balanced use of automation and digital technologies in order to enhance the unique and irreplaceable capabilities of their operators, who will continue to play fundamental roles for the companies of the future (Cimini et al. 2022). The rapid development of robotics is impossible without effective collaboration. The authors in Atzeni et al. (2021) paid special attention to this issue in the context of the challenges that were faced in the Logistics 4.0 environment.

Despite the significant interest in the problems of automating the processes in logistics, the problems of minimizing risks in the face of extreme risks that are caused by hostilities and the operations of the logistics infrastructure under the constant risk of damage or complete destruction are extremely important and have been poorly studied. This work is specifically devoted to this problem.

3. FORMULATION OF PROBLEM

To explore approaches to the automation of business processes in the logistics sector in the context of the robotization of technological operations. Taking the peculiarities that are caused by the functioning of some enterprises when under the constant influence of extreme risks into account, developing a concept of robotic-process automation will increase the productivity and efficiency of businesses, help reduce their operating costs, reduce their likelihood of personnel errors, and contribute to their improving business security.

4. MAIN SECTION

It should be noted right away that robotization and automation are not panaceas in the processes of minimizing the risks of modern enterprises. Moreover, an extremely important place in this process is further given to the development and implementation of various measures that are aimed at minimizing risks such as clear safety procedures, the training of employees, the regular monitoring of equipment, etc. At the same time, robotics is a powerful tool that can help companies better protect themselves from risks under extreme conditions. This is especially true when it comes to enterprises that operate under constant exposure avoiding extreme risks – these companies include those enterprises in the chemical, nuclear, military, and other particularly vulnerable sectors of the economy. Even though ordinary logistics companies do not classify such risk groups at first glance, this is not the case. Numerous examples have confirmed that the processing of the most innocent postal messages can be accompanied by the risk of processing parcels that contain toxic substances, explosive devices, bacterial infections, etc. When developing strategies for the long-term development of companies in a wide variety of industries, it is therefore necessary to proceed by default from the reality of the most extreme risks.

It is useful for investors, visionaries, and business leaders to understand that robotization in our time is the key to the success of their enterprises in the future. Let us consider a number of specific examples of how robotics can be used to minimize risks under the extreme conditions of modern enterprises:

– *In industry*, robots are used to perform hazardous tasks such as working with toxic materials and working under the conditions of elevated temperatures, radiation, pressure, etc. They are used to monitor and manage critical infrastructure, e.g. power plants, water supply systems, etc.
– *In logistics*, robots can perform the tasks of transporting goods, sorting goods, maintaining warehouses, and delivering goods under extreme conditions (during natural disasters, pandemics, etc.).
– *In healthcare*, robots are used to provide first aid, care for patients, and disinfect facilities. They can also be used to develop new drugs and medical products that can help people survive under extreme conditions.

It is extremely important to note that robotization is designed to have a significant impact on minimizing risks under the conditions of a company's operation. First of all, a number of such advantages should be highlighted:

– *Increased productivity and efficiency.* Robots perform tasks faster and more accurately than humans can; they help increase the productivity and efficiency of the company. Among other things, large-scale robotization aims to help the company better respond to the effects of extreme conditions, as this will allow for faster recovery from them.
– *Reducing the likelihood of human error.* Robots are less-prone to human-like errors, resulting in reduced risks of accidents, and other problems.
– *Increased safety.* Robots can perform tasks in hazardous environments that are hazardous to humans. This can help companies protect their employees from the risks of injury and damage under extreme conditions.
– *Cost reduction.* Robots can help the company reduce its labor, training, and other personnel costs; therefore, this has the direct effect of increasing the company's profits. The company gains new opportunities in investment activities via the implementation of sustainable development strategies while minimizing risks, costs, etc.

5. CASE STUDY – NOVA POST

NOVA is a group of companies that provide a full range of logistics, financial, and IT-related services in Ukraine and around the world. The group includes Ukrainian and international companies: Nova Post in Ukraine, Nova Post Europe (with its own branches and offices in 11 European countries), SuperNova (its own cargo airline company), NovaPay (a financial company), Nova Digital (an IT company), and Nova Global (which provides cross-border services around the world).

Among other things, Nova Post uses robots from Deus Robotics in its warehouses in Ukraine for handling logistics tasks inside their sorting rooms and hubs. In the discussed case, transport robots were analyzed that made it possible to transport entire racks with postal parcels on them. Each robot can carry 500 kg and move along designated routes (Figure 1), optimizing each route at a maximum speed of 1.2 M/s thanks to AI. The robots are electrically powered, and their charging time is two hours; they can work without interruption for eight hours at full load.

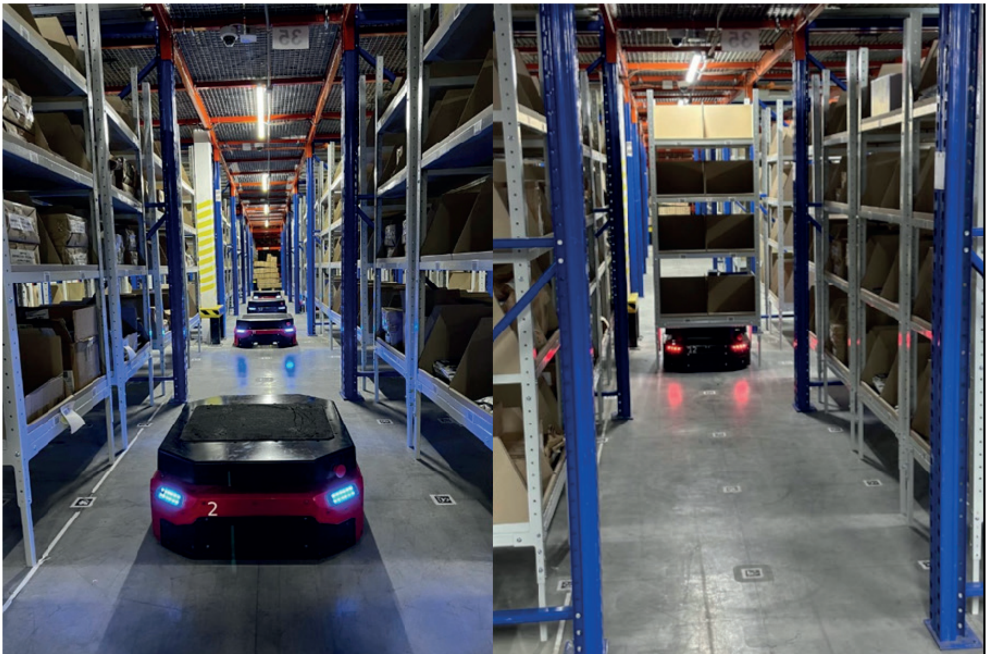

Fig. 1. *Robots at work in warehouses of Nova Post – photo by Deus Robotics*

Logistics robots such as those that are used by Nova Post enable the introduction of self-service sorting functions. Using advanced artificial intelligence (AI) and routing algorithms, the robots independently plan and implement optimal routes in warehouses; this eliminates the need for employees to manually sort packages and speeds up the entire process of preparing packages for shipment. Thanks to AI, the robots are able to dynamically optimize routes in real time. The system analyzes data on route load, parcel location, and current warehouse traffic, which allows the robots to adjust their routes depending on the current conditions. This not only speeds up the process but also minimizes the risks of collisions and disruptions.

Thanks to the use of advanced vision systems and sensors (as well as the use of QR codes), the robots are able to precisely identify, lift, and move packages. This eliminates the risk of manual handling errors, thus improving customer service and reducing losses. Automation also enables the constant monitoring of logistics processes and their continuous reporting. The systems collect data on efficiency, routes, numbers of shipments handled, etc.; this allows for the continuous improvement of the processes and quick responses to any possible problems.

Additionally, the data that is collected in this way is indispensable for AI, which learns to react in emergency situations for improving route-optimization algorithms based on previous events and increases the effectiveness and efficiency of the transport. In conclusion, the use of robots in the logistics of Nova Post not only accelerates the processes of sorting and moving parcels but also introduces flexibility and scalability to its logistics operations; this translates to improved efficiency and increased customer service quality.

The use of Deus Robotics robots in the logistics process of Nova Post seems to be a comprehensive approach for automating and optimizing operations; this translates to efficiency, precision, and sustainable development in the area of logistics. Apart from the logistic aspect e.g., the ecology-related ones, this shows the benefits of the solutions that have been proposed by Deus Robotics. The robots that are used by Nova Post in Ukraine are electrically powered, which has several key benefits. An electric power supply is in line with sustainable development trends, minimizing greenhouse gas emissions and other air pollutants in the workplace. Compared to traditional power sources such as internal-combustion engines, electric robots are more friendly to people and the environment – especially in closed facilities such as warehouses. Electric power can lead to savings in operating costs in the long run.

Electricity prices are often more stable than fossil fuel prices, and electric drives can be more energy-efficient when compared to traditional combustion drives. The short charging time (two hours) compared to the long working time (eight hours) means that the robots can work for longer periods of time without the need for long charging breaks. This increases the overall efficiency of the logistics system.

Electric robots generate less noise and do not emit harmful substances, which helps to keep internal working environments such as warehouses and sorting rooms clean. This may also affect the comfort of the staff and the general atmosphere in the workplace. Importantly, electrically powered systems easily integrate with renewable energy sources such as solar or wind energy. This opens the way for logistics companies toward more-sustainable energy models.

An example route diagram in a warehouse with postal parcels is presented in Figure 2. The green points represent the positions of key QR codes on the map (the robots moves between these points), while the red points represent additional QR codes for better navigation. Those points with four red wheels and one green one are the positions where shelves can be stored.

The statistics so far: as of August 2022, each deployed Deus robot has traveled more than 1000 KM and moved more than 5000 items with an accuracy above 99.99% and an uptime of 99.9%.

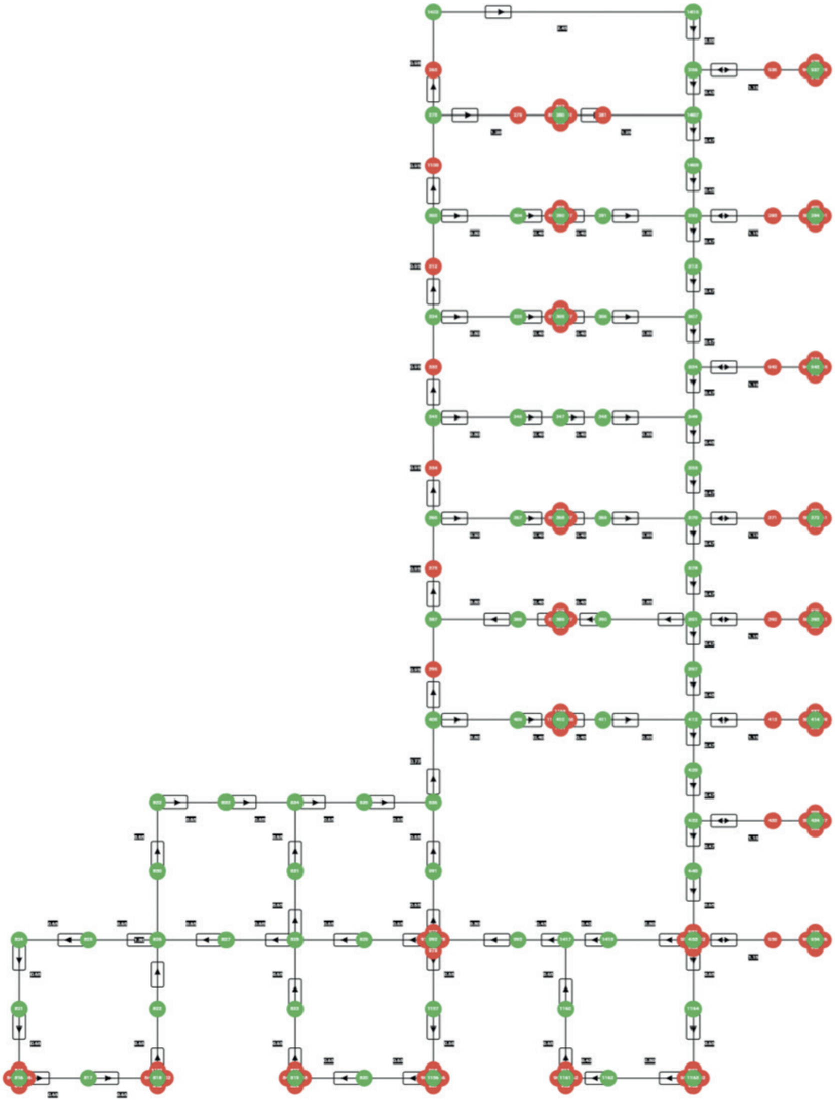

Fig. 2. *Robot-moving layout in Nova Post warehouses – layout by Deus Robotics*

6. DISCUSSION

Let us illustrate an analysis of real data (Figures 3 and 4) from a Tier 1 manufacturing company in the United States. As of now, the company's warehouse employs a small number of employees in one daily shift. At the same time, the company doubles its operational efficiency annually thanks to the robotization of its technological processes for processing commodity resources and raw materials.

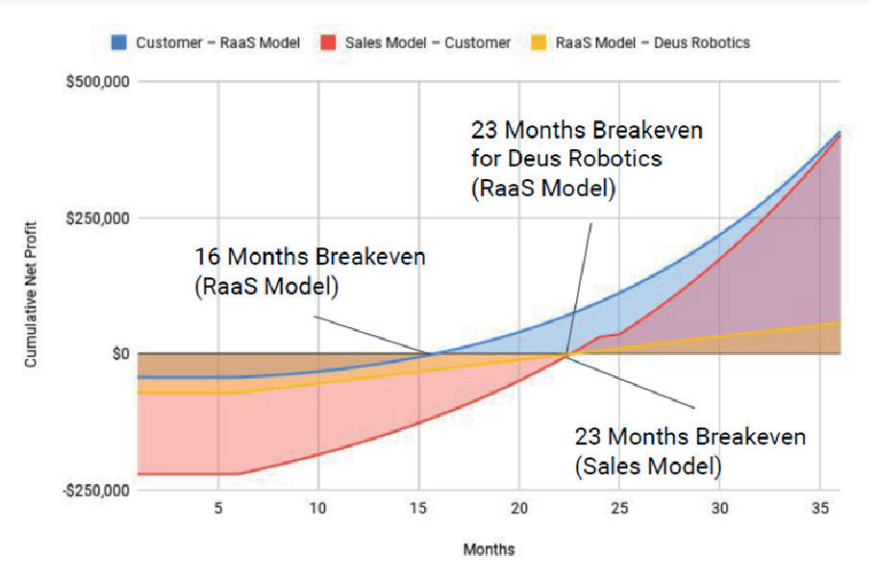

Fig. 3. *RaaS model & sales model dynamics graphs – Deus Robotics*

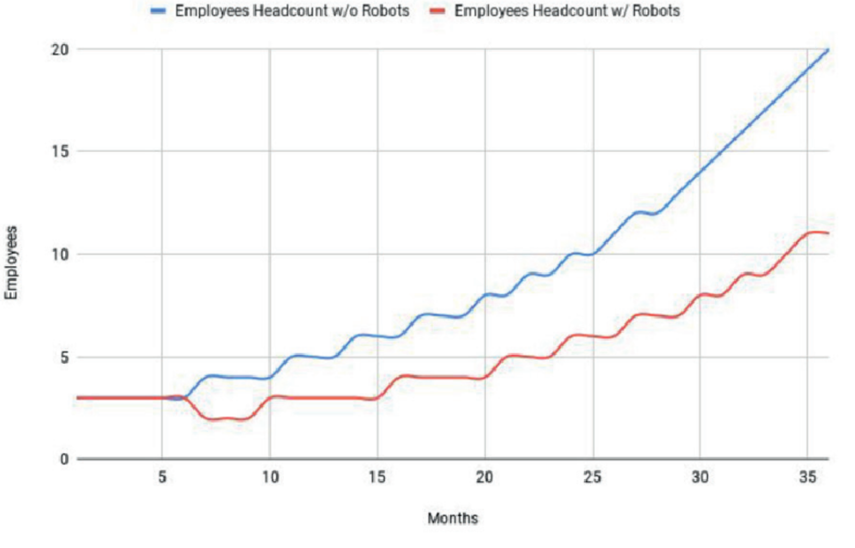

Fig. 4. *Graphs of dynamics of number of employees after taking robotization into account – graphs by Deus Robotics*

At the same time, the dynamics of the numbers of employees are shown in Figure 4 after taking the robotization of the technological processes into account (with and without them).

Let us illustrate the effect that occurs if we assume that the company increases its number of employees to 100 people working in two shifts instead of one (Figure 5). In this scenario, the return on investment (ROI) is shown in Figure 6.

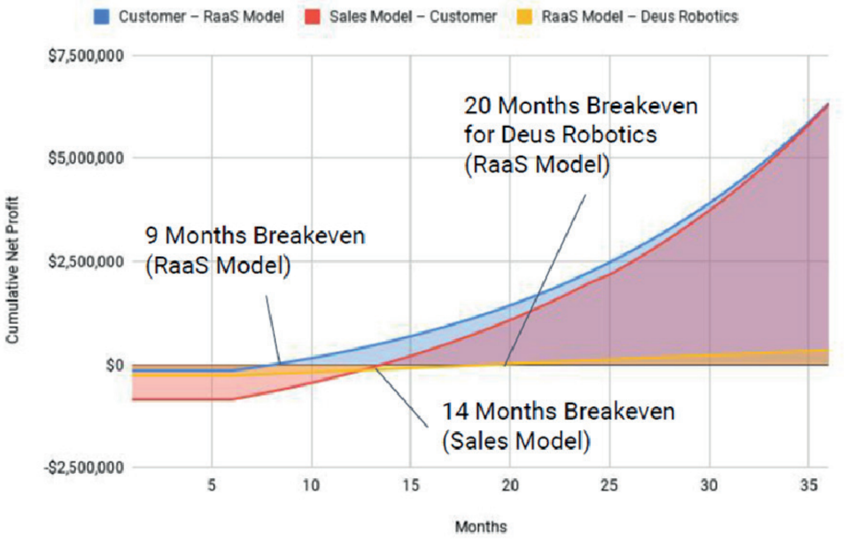

Fig. 5. *Graphs of dynamics of RaaS model & sales model with 100 employees – model by Deus Robotics*

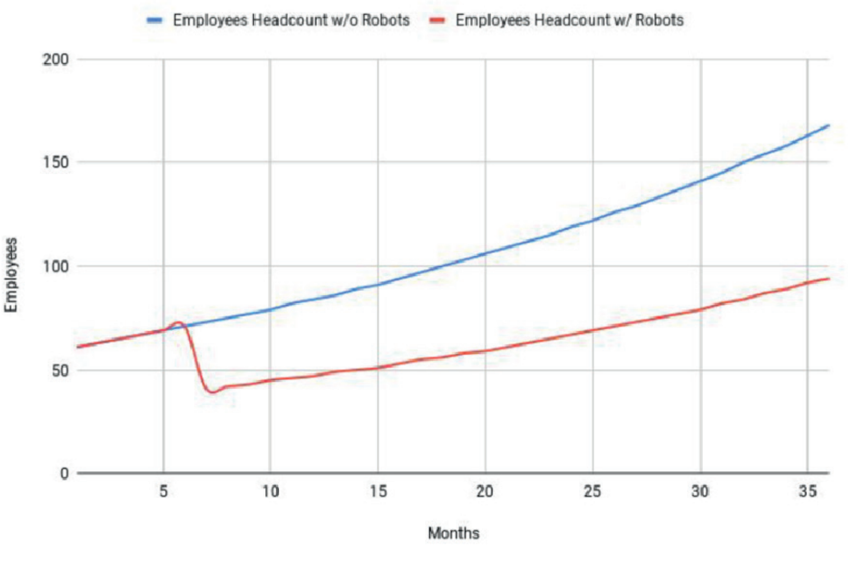

Fig. 6. *ROI dynamics charts – graph by Deus Robotics*

Similar modeling should be carried out for all localizations where large-scale robotization programs are being implemented. Such calculations are especially important for those industries where the robots operate in aggressive environments or where they operate under constant exposure to extreme risk factors. In particular, the management of Deus Robotics implemented a multi-component strategy after conducting relevant research in order to minimize risks under conditions of extreme risks, the focus of which was aimed at the following:

1. Improving employee safety:
   – relocation of employees and their families to safe places;
   – implementation of software for management of robotic sections of logistics complexes;
   – taking specifics of work during war period into account in current business processes.
2. Compensation for impact of labor shortages:
   – implementation of online training programs for clients;
   – minimization of queues of receiving parcels by means of warning system.

Therefore, a combination of measures that are aimed at organizing a safe workplace for employees through the large-scale implementation of cloud technologies for order administration and the robotization of cargo-handling processes became the key for successfully minimizing the extreme risks that arose as a result of the acute phase of the armed invasion of the aggressor country.

The carried-out full-scale modeling illustrates that the automation of the technological processes through the introduction of robotic solutions allowed them to both obtain an immediate effect of increasing productivity (use of working times) and guarantee a sustainable effect of the return on investment in the long term.

7. CONCLUSIONS

This paper examines the current state of the results that highlight the problems of using modern advanced technologies by logistics companies in attempts to increase the speed of their technological operations and transform their business processes; their ultimate goals were reducing their financial costs, increasing the efficiency of the use of their labor resources, and minimizing their risks. In today's economic realities, this is a decisive factor in increasing a company's competitiveness in the market, thus increasing its profitability and realizing its long-term leadership.

It is innovative logistics that is an effective tool for streamlining flow processes through the introduction of high-tech innovations in the operational and strategic management of market structures that are aimed at improving the quality of customer service, increasing the efficiency of flow processes, and reducing the total cost of their implementation in order to achieve key business objectives.

The paper examines approaches to the automation of business processes in the logistics sector in the context of the robotization of technological operations, taking into account the features of to the functioning of enterprises under the constant impacts of the extreme risks that were caused by the SARS-CoV-2 pandemic and are still being caused by the full-scale war between Ukraine and Russia. Actually, the experimental part describes the effects that illustrate the results of the study of the problems of extreme risks and the construction of a strategy for the sustainable functioning of business processes under the influence of destabilizing internal and external factors.

The proposed concept of robotic process automation will increase the productivity and efficiency of a business, helping it reduce its operating costs, reduce the likelihood of personnel errors, and contribute to improving its business security. The results have been implemented in the practices of a number of logistics companies in the real sector of the economy.

The real effect of the robotization of technological processes in clients warehouses has made it possible to accomplish the following:

- increase process productivity by 300%;
- reduce distance of movement of employees by 72%;
- increase usable warehouse space by 20%;
- reduce frequency of personnel errors five-fold;
- increase productive workload of each employee by +3.5 hours per employee per shift.

Similar effects can be obtained for other enterprises that use logistics complexes with auto-lubricated complexes for the handling and storage of goods and the robotization of technological processes. In the future, it is planned to improve the concept of the robotization of business processes, develop new route-management algorithms, and develop strategies for minimizing the impacts of extreme risks.

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