**NABOKA RUSLAN**
PhD in Economics, Associate professor, Department of Management, Marketing and Tourism, Kherson National Technical University; ORCID: 0000-0002-3417-8216; *e-mail: rusnaboka@gmail.com*

**GERASYMOVA LIUDMYLA**
PhD in Economics, Associate professor Department of Enterprise Economics Odessa Polytechnic State University; 0000-0001-6909-2319 ORCID: *e-mail: l.m.gerasimova@opu.ua*

**ROZOVA ANASTASIIA**
Department of Management, Marketing and Tourism, Kherson National Technical University; ORCID: 0000-0001-9785-6064; *e-mail: anastasiarozova@gmail.com*

**NIKOLAIEV DMYTRO**
An expert of accreditation of the education programs of National Agency for Higher Education Quality Assurance, Bachelor in marketing, Odessa National Polytechnic University, ORCID:0000-0002-7563-5962; *e-mail: nikolaevdmytro0504@gmail.com*

s. 223-234

# EFFICIENCY IMPLEMENTATION AR - TECHNOLOGIES IN WAREHOUSE LOGISTICS

**DOI: 10.54264/0020**

ABSTRACT

The article is devoted to strategic approaches to the efficient use of AR-technologies in warehousing logistics. The necessity of automation of warehouse logistics due to the introduction of AR-technologies is substantiated. The calculation of the effectiveness of the introduction of AR-technologies in warehousing logistics on the example of warehousing infrastructure of the Odessa region. The strategic directions of development of warehouse logistics in the conditions of development of innovative technologies are offered.

KEYWORDS

AR-technologies, warehousing logistics, strategic directions of logistics development

## Introduction

Today, there is an increase in interest in parameterized and flexible solutions that allow you to respond to any changes in the transport and logistics business without using additional budgets for refining systems.
When choosing a system integrator, the important role is given to the stability and financial support of its business as a collateral when fulfilling obligations under the contract for the implementation of transport logistics management systems. Other trends characteristic of the digital logistics analytics and informatization market are „mobility" and „augmented reality." Many transport and warehouse operators use laptop computers, smartphones, and smartwatches to identify inventory in warehouses and during transportation.

In addition, to increase the productivity of personnel in non-robotic warehouse systems, vendors (that is, individuals or legal entities that request and supply goods under their own brand) have to use virtual reality (VR-glasses), Pickby-voice and Pick-by-light technologies.

The diversity of modern digital technologies used in various fields of human activity proves their need in solving several applications, in particular in logistics and supply chain management. The implementation of technology such as augmented reality (AR) is required when improving the user interface for visualizing 3D objects using the applied hardware and software. Real-time digital data is added to reality using computer tools to complement knowledge about the space or objects around us.

In logistics, AR - technology is at a relatively early stage of development, but now it brings significant benefits to those who use it. For example, AR can provide logistics providers with quick access to information that enables previous decisions or implementation preventive actions at any stage of the commodity flow process. This is vital for forward and accurate planning and management of tasks such as optimizing delivery and cargo handling and is critical for providing a higher level of customer service.

Augmented Reality (AR) is the result of adding additional digital objects to physical reality, which are usually displayed as auxiliary information, resulting in a mixed reality (Fig. 1).

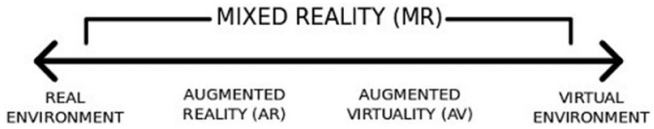


Figure 1. Mixed reality

In the field of logistics, it is possible to use AR - technology in the following areas: warehousing; optimization of transport; delivery at the „last mile" stage; enhanced value-added logistics services.
In warehouse operations, AR - technologies show the greatest potential for use in logistics (Fig. 2). Warehouse operations, according to experts, account for about 20% of all logistics costs, and the task of compiling qualifying information is from 55 to 65% of the total cost of warehousing operations.

Figure 2. AR - Logistics Warehouse Technologies

This indicates that the use of AR - technologies can significantly reduce costs by improving the picking process, as well as help in training new or temporary employees in the warehouse and in planning warehouses. In warehouse logistics, the most tangible AR solutions are systems to optimize the picking process [10].

The systems provided by Knapp, SAP and Ubimax are currently undergoing testing and testing on existing components and consist of mobile AR systems - technologies such as the main display (HMD), camera, laptop and battery packs that provide sufficient energy for at least one Image Acquisition Software includes realtime object recognition, barcode reading, internal navigation, and seamless integration of information with a warehouse management system (WMS). A key advantage of choosing a vision is providing intuitive digital support to employees during manual selection operations [15].

Using such a system, each employee can see the digital selection list in his field of view and, thanks to the capabilities of internal navigation, calculate the best route, reducing the time of their movement along the composition by effectively planning the path. By means of a possibility of automatic scanning of barcodes, the software of recognition of images of the Knapp KiSoft Vision7 system can check whether the worker of a necessary zone of a warehouse reached and to direct him for fast search of the necessary goods on a rack. The worker can then scan the barcode of the item and simultaneously register the process with the Warehouse Information System (WMS), updating the inventory data in real time. In addition, such systems can reduce the time required to guide and train new staff, as well as overcome any language barriers with working foreigners.

**The aim of the study is** evaluation of the effectiveness of the introduction of AR-technologies in warehousing logistics.

**The methodological basis of the research** is scientific works of many scientists, among which the following scientists have a significant contribution, such as: Ronald Lewis [12], Michael O'Guin [11], Robert Kaplan and Thomas Johnson [13]. M. Oklander [8, 9], E. Krikavsky [7], O. Chukurna [2, 3, 4, 5], T. Nestorenko [14, 20], K. Topolska [18].

Thus, M. Oklander [8, 9] formed the theoretical and applied provisions of logistics mechanisms of adaptation of enterprises to the external environment and proposed the principles and structure of the logistics system of the enterprise. E. Krikavsky substantiated the criteria for classification of logistics costs and proposed a system for evaluating them by place of origin; by cost carriers; on analytical cost accounts; by phases of the logistics process. [7].

O. Chukurna, V. Nitsenko, M. Mykhailova formed directions of improvement of warehouse logistics in the context of development of technologies of „Industry 4.0", emphasizing attention to modern systems of warehouse inventory management [5].

K. Topolska focused on the study of the use of logistics tools in assessing the effectiveness of management of transport companies [18].

Despite the huge contribution to the theory of logistics, there is a need to analyze the practice of improving logistics systems on the example of warehousing logistics in Ukraine.

**Result of the study.**
Today, there are many software products and applications for both business and entertainment based on AR - technologies. Recall at least the loud game created by Japanese developers, where it was necessary to catch Pokémon in buildings, parks, on the roads.

One of the most important advantages of augmented reality is the lack of the need to buy additional equipment or headsets. Programs are installed on almost any modern tablets, smartphones and stationary computers.

This technology is widely used in business and workflow management. Most often, augmented reality (AR) is used to record and play back steps taken during a job. It perfectly illustrates the process from start to finish, which allows you to quickly and efficiently analyze all stages of work.

The managers also use such software to demonstrate the work of the internal and external systems of the building. Created models help identify and predict the necessary repairs, and analyze the effectiveness of future improvements.

In addition, it is a powerful communication tool that allows users from different places to see one 3D image and communicate in real time.

In its annual study of Technotrends 2020, GFK called virtual reality one of the 5 main trends of this year.

According to the consulting firm Digital-Capital, in 2017, investors in the United States invested more than $3 billion in VR and AR startups. As a result, the market significantly exceeded forecasts. But, at the same time, the VR/AR market is quite unstable and is „warmed up" by one-time large transactions, and venture investors mainly invest in it. So, if in July 2017, IDC analysts believed that the global sales of goods and services related to augmented and virtual reality technologies (AR/VR), from $11.4 billion in 2017, would grow to almost $215 billion in 2021 and, on average, the market volume would grow by 113.2% annually, 15 then in 2018 their estimates changed. According to new forecasts, from 2017 to 2022, the global market for augmented (AR) and virtual (VR) reality technologies will grow by an average of 71.6% per year [1].

The development of AR / VR technologies involves interaction between the consumer and the manufacturer. The willingness of consumers to accept the proposed technologies is also an important factor for the development of the industry. Constraints, according to a Perkins Coie survey, are presented in Figure 3.

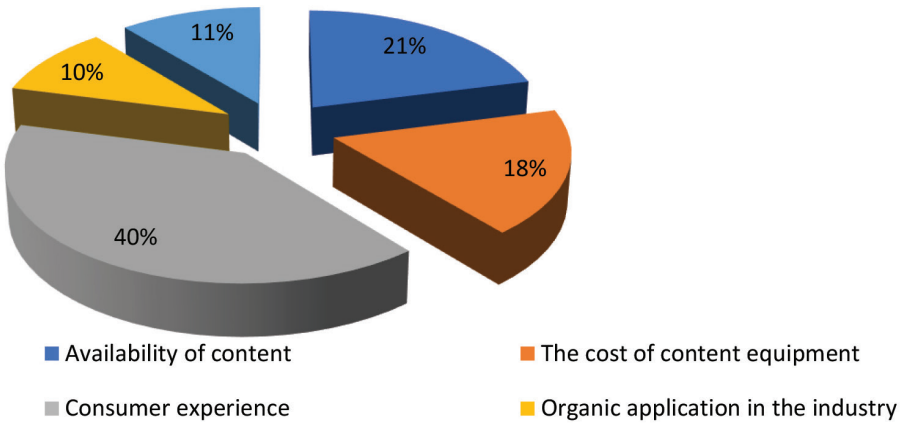


Figure 3. AR / VR industry growth inhibitors [4]

One of the features of this market is the high degree of business risk, as a result, the use of venture development strategies. First of all, this is manifested in the fact that large technology companies that want to enter the AR / VR market prefer not to spend the company's internal resources and funds on business diversification, but seek to buy an existing startup in this area.

In addition, the relative simplification of AR application development has led to the emergence of many venture-funded startups: Intel Capital has funded 7 startups, the largest of which are Eyefluence and Occipital; Qualcomm Ventures also funded 7 startups. The most successful are Blippar, Navdy and Magic Leap; Rotheberg Ventures funded 6 startups. The largest are 8i and Augmate. The largest transactions in 2016 were received by companies that develop AR devices, medical applications and marketing. These companies are: 1) Magic Leap (HMD Manufacturer) - $ 794M, Series C from Google, Alibaba Group, Qualcomm Ventures, Warner Bros., Morgan Stanley, Fidelity, JP Morgan, T. Rowe Price, Wellington; 2) MindMaze (Application - Medical) - $ 100M, Series A from Hinduja Group; 3) Blippar (Application - Marketing) - $ 54M, Series D from Khazanah Nasional Berhad and from other investors [4].

The cost of AR / VR technology deals is a trade secret, as many companies want to temporarily hide their intention to enter the augmented and virtual reality market, viewing this vector as an additional competitive opportunity in their diversification strategy.

Another important fact indicating the unconditional prospects of AR technologies is the creation in 2015 of the Augmented Reality for Enterprise Alliance (AREA). This alliance includes such large companies as Bosch and Boeing. The goal of the alliance is a free (for the American market) and open exchange of best practices, lessons learned and technological resources that will help enterprises effectively implement AR. In April 2017, the participants of this alliance announced the development of key industry guidance documents. The documents were developed with the assistance of UI Labs, Lockheed Martin, Caterpillar and Procter & Gamble [1].

In analyzing the application of AR - technologies, we obtained data that reveal the strengths and weaknesses of technologies, the possibilities of their use and the threats that companies may face, in particular, in the field of warehouse logistics. To organize the information, a SWOT matrix is constructed (Table 1).

Table 1. SWOT - analysis

| **Strengths** | **Weaknesses** |
|---|---|
| diversity of applications;<br>native management;<br>innovation;<br>powerful 3D - tool;<br>real-time interaction. | technological limitations and software imperfections;<br>lack of quality content;<br>high cost;<br>lack of qualified personnel;<br>negative effects on health. |
| **Opportunities** | **Threats** |
| high market potential, availability of free niches;<br>readiness of the environment (companies) to implement the technology;<br>increasing investor interest;<br>development of related markets. | competitive technologies (Internet of things, artificial intelligence, robotics);<br>Lack of information on experimental use results;<br>unpredictability of the external environment;<br>young market. |

ISSN 2082-7016; eISSN 2450-5552 2021, nr 13

Thus, augmented reality technologies have a few advantages, but only with the competent use of the potential of technology will companies be able to achieve the desired.

It is proposed to conduct an experiment using augmented reality and smart glasses in a warehouse located in Odessa. We believe that in order to make the picking process faster and reduce the number of personnel errors, informative images that workers can see using smart glasses will help.
Necessary support for the experiment: (Fig.4).
Necessary AR devices for experiment
1. MR Builder – glasses software (Fig. 4).

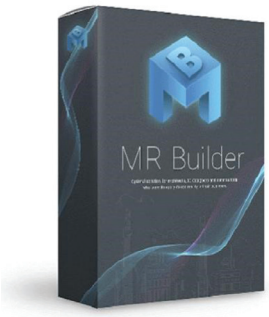


Figure 4. MR Builder – glasses software

MR Builder is a program for creating and demonstrating 3D architectural objects in AR.
MR Builder is a modern innovative development with several main features:
- convenience: allows you to show the developed three-dimensional model in the surrounding space without using additional equipment;
- allows you to show 3D models in mixed and augmented reality, combining 3D objects with surrounding space;
- Easy to use: allows you to use holograms using understandable user interaction rules using voice and hand movement;
- professional support: program manufacturers quickly help solve problems of any complexity.
2. Google Glass Enterprise Edition 2 Smart Glasses (Fig. 5).

Figure 5. Google Glass Enterprise Edition 2 Smart Glasses

Google Glass Enterprise Edition 2 is a new version of the famous smart glasses. They will become an indispensable assistant for your employees, thanks to augmented reality technology and the ability to activate their functions with voice commands.
The operation of these glasses is shown in the following images (Fig. 6.):


Figure 6. The operation of Google Glass Enterprise Edition 2 Smart Glasses

Table 2. Estimate for experiment

| № | Device AR Name | Quantity | Price per unit in UAH | S um | |
|---|---|---|---|---|---|
| | | | | UAH | $ |
| 1 | MR Builder – software for points | 1 | 22500 | 22500 | 802,36 |
| 2 | Smart glasses Google Glass Enterprise Edition 2 | 5 | 58000 | 290000 | 10353,82 |
| **In total** | | | | **312500** | **11156,18** |

Also, to ensure the operation of AR glasses you need to use a mobile phone or tablet computer.

For example, five employees of ZENAL LTD who collect orders will be given AR-glasses, which they will have to wear for two weeks. By putting on glasses, workers will receive information about their tasks, including data on the product, quantity and its location.

The course of the experiment in the process of assembling goods in the warehouse:
1. The worker puts on augmented reality glasses and includes special software;
2. Tasks for execution are displayed on the glasses screen;
3. The worker in real time begins to execute tasks, controlling them with the help of voice;
4. The worker receives all the necessary information about the product using the built-in bar code scanner;
5. After all operations are completed, the worker voice confirms this and turns off the glasses.

Using augmented reality technology, the picking process in the warehouse should reach a new level of organization and automation. So, when using the appropriate equipment, the warehouse employee can see in real time on the AR screen - glasses a digital list of goods during picking, as well as build the optimal route to them to reduce the time due to accurate planning of movements and the length of the route. Note that AR glasses can have a built-in barcode scanner, which helps the employee understand the correct location of the product and efficiently locate the necessary items on the shelves of the warehouse.

Evaluation of the cost-effectiveness of the proposed experiment
To assess the cost-effectiveness of the experiment, we will calculate for the beginning the costs of developing and implementing the proposed logistics process improvement at the warehouse of the ZENAL LTD enterprise

Table 3. Experiment Costs

| № | Device AR Name | Quantity | Price per unit in UAH | Sum in UAH |
|---|---|---|---|---|
| 1 | MR Builder – software for points | 1 | 22500 | 22500 |
| 2 | Smart glasses Google Glass Enterprise Edition 2 | 5 | 58000 | 290000 |
| **In total** | | | | **312500** |

Thus, we get that the amount of costs for implementing measures to improve the logistics process at the warehouse of the ZENAL LTD enterprise is UAH 312,500.
The calculation of costs before and after the introduction of logistics concepts and methods will allow you to calculate the possible economic effect, on the basis of which it should be concluded that it is advisable to implement activities.
We will compare the costs before and after the implementation of the measures, as shown in Table 4.

Table 4. Cost Comparison

| № | Name of expense item | Implementation Costs (UAH/month) | Expenses after implementation (UAH/month) |
|---|---|---|---|
| 1 | Raw material and material costs | 350000 | 332500 |
| 2 | Costs of storage of finished products | 60000 | 44250 |
| 3 | Costs related to downtime equipment and personnel | 18500 | 10000 |
| 4 | Transportation costs finished products | 88000 | 91500 |
| 5 | Raw Material Control Costs | 5500 | 3000 |

1. We calculate the profit before the experiment is introduced according to the formula: Before implementation = Revenue - Implementation Costs Before implementation = 750500 - 522000 = 228500 (UAH).
2. We calculate the profit after the implementation of the experiment according to the formula:
After Implementation = Revenue - Post Implementation Expenses; After implementation = 750500 - 481250 = 269250 (UAH).
3.1. The economic effect of introducing an experiment to improve the logistics process in the warehouse of the ZENAL LTD enterprise is calculated according to the formula:
E = Profit After implementation - Profit Before implementation; E = 269250 - 228500 = 40750 (UAH).
Thus, the economic effect of introducing an experiment to improve the logistics process in the warehouse of the ZENAL LTD enterprise amounted to UAH 41,000 per month.
3.2. The economic effect on expenses is calculated by the formula:
E = (Post-Implementation Costs/Pre-Implementation Costs) * 100%;
E = (481250 / 522000) * 100% = 92.19%
Expenses decreased by 92.19%, that is, savings.
3.3. We calculate the profitability from the introduced experiment:
R = (Post Implementation/Post Implementation Expense) * 100%
R = (269250 / 481250) * 100% = 55,94%
Based on the results of the calculations, we conclude that the developed measures are economically feasible for implementation at the enterprise of Zenal LTD.

**CONCLUSIONS**

The use of AR - technologies in the field of order picking allows you to significantly increase the performance of the composition, improve the quality of the set and reduce the time spent on picking the order, which will lead to more complete and timely servicing of customer orders. Based on the above information, examples, proposals, the following list of problems in the field of warehousing solved by augmented reality can be formulated:

1. AR - technology can solve the problem of complete or partial absence of address storage and system marking in the warehouse of product items, which complicate the identification process. With augmented reality technology, overall warehouse tasks can be significantly reduced.
2. The use of AR technology eliminates the use of outdated technologies and worn-out equipment, leading to a decrease in the possible efficiency of internal warehouse and maintenance logistics.
3. AR - technology eliminates a sufficiently high risk of error due to the influence of the human factor, which significantly affects efficiency. Thus, augmented reality technology affects the growth of efficiency in the use of capacities and features of the warehouse organization system, setting high standards of customer service, accuracy, efficiency in the use of composition resources.

The study was carried out on the basis of the logistics company ZENAL LTD. The warehouse in LLC Zenal LTD is a building designed to receive, place and store materials, incoming and stock finished products. The developed experiment using augmented reality and smart glasses in the warehouse will allow the picking process in the warehouse to reach a new level of organization and automation. Augmented reality is a new technology that can significantly expand the capabilities of warehouse activities, which requires constant modernization and automation of existing business processes.

Therefore, augmented reality occupies an important place in the field of logistics. Being integrated into visual selection systems in warehouses, AR can play a significant role at almost every stage of the logistics cycle and occupy strong positions. We are confident that these trends will develop and that more and more logistics companies in Ukraine will participate in intensive digitalization of business and will use AR - technologies in their activities.

**References**

[1] Augmented reality (AR): technologies, devices, financial indicators. [Electronic Resource] URL: *www.it.ua/ru/knowledge-base/technologyinnovation/dopolnennaja-realnost-ar*
[2] Chukurna O.P. Development of transport logistics of Ukraine in the context of globalization// Bulletin of Khmelnitsky National University. Economic sciences, №4, T2 (238), 2016. 276-280 *www.journals.khnu.km.ua/vestnik/pdf/ekon/pdfbase/2016/VKNU-ES-2016-N4-Volume2_238.pdf*
[3] Chukurna O.P., Nitsenko V.S., Ganzhurenko I.V., Goncharuk N.G. Directions of innovative development of transport logistics in Ukraine//Economic innovations TOM 21 №5 (70), 2019. p. 170-181
[4] Chukurna O.P., Baldyk D.A., Blazhko Yu.M., Sherpa I.V. Business model of using AR / VR-technologies in the field of education // Zeszyty_naukowe, Katowice: Wyższa Szkoła Techniczna w Katowicach. №11. 2019. 73-88
[5] Chukurna O.P., Nitsenko V.S., Mikhailova M.V., Odinokov R.D. Improving the warehouse logistics system in the context of „Industry 4.0" technologies // Collection of scientific works „Economic strategy and prospects for the development of trade and services". - Kharkiv: KhDUHT, 2018 - Issue 1 (27). 220-232. Journal access mode: *www.nzb.hduht.edu.ua/index.php/uk/nzb-e/arkhiv-nomeriv#section-4Features* of Global Logistics Services Market Development [Electronic Resource] URL: *www.economy.nayka.com.ua/pdf/6_2018/34.pdf*
[6] Frazelli E. World Warehouse Logistics Standards / Edward Frazelli. - Moscow: „Alpina Publisher", 2017. 330.
[7] Krikavsky E.V. New logistics paradigm: strategic status//Scientific works of DonNTU. Economic series, № 4(48), 2014. 240-247
[8] Oklander M.A. Logistics system of the enterprise: [Monograph] / Oklander M.A. - Odessa: Astroprint, 2004. 312. [Electronic resource] URL: *www.oklander.info/?p=282*
[9] Oklander M., Chukurna O., Oklander T., Yashkina O. METHODICAL PRINCIPLES TO CALCULATION INFORMATION VALUE IN PRICING POLICY IN SUPPLY CHAINS. Estudios de Economía Aplicada.2021 № 38-3(1) URL: *www.ojs.ual.es/ojs/index.php/eea/article/view/4009/4263*
[10] Logistics market of Ukraine 2020: the challenge is accepted. [Electronic Resource] URL: *www.logistics-ukraine.com/2020/11/05/рыноклогистики-украины-2020-вызов-приня/*
[11] Michael C.O`Guin. The Complete Guide to Activity-Based Costing. Englewood Cliffs, NJ: Prentice-Hall,1991
[12] Ronald L. Lewis Activity-Based Costing for Marketing and Manufacturing. Westport, Conn.: Quorum Books, 1993
[13] Robert S. Kaplan and H. Thomas Johnson. Relevance Lost: The Rise and Fall of Management Accounting. Boston: Harvard Business School Press, 1987
[14] Nestorenko T., Morkunas M., Peliova J., Volkov A., Balezentis T., Streimkiene D. A New Model for Determining the EOQ under Changing Price Parameters and Reordering Time. Symmetry 2020, 12, 1512. *www.mdpi.com/2073-8994/12/9/1512*
[15] Soldatov S. The interface of the future is augmented reality systems. //In the engineer's notebook. – 2016. № 1. 96-103
[16] State Statistics Service of Ukraine [Electronic Resource]. URL: *www.ukrstat.gov.ua/*
[17] Schwab K. Fourth Industrial Revolution/Klaus Schwab. - Moscow: EKSMO, 2016. 138c.
[18] Topolska K. The use of logistic instruments in Effective Efficient Management of a transport company. Zeszyty_naukowe, Katowice: Wyższa Szkoła Techniczna w Katowicach. 2018. №10. 187-196
[19] World Bank Rating [Electronic Resource] URL: *www.lpi.worldbank.org/international/global*
[20] Zeng S., Nestorenko O., Nestorenko T., Morkūnas M., Volkov A., Baležentis T., Zhang C. (2019). EOQ for perishable goods: modification of Wilson's model for food retailers. Technological and Economic Development of Economy, 25(6), 1413-1432. *www.doi.org/10.3846/tede.2019.11330*

ISSN 2082-7016; eISSN 2450-5552 2021, nr 13

# EFEKTYWNOŚĆ WDROŻENIE AR - TECHNOLOGIE W LOGISTYCE MAGAZYNOWEJ

STRESZCZENIE

Artykuł jest poświęcony strategicznemu podejściu do efektywnego wykorzystania technologii AR, w logistyce magazynowej. Konieczność automatyzacji logistyki magazynowej, w związku z wprowadzeniem technologii AR jest uzasadniona. Obliczenie skuteczności wprowadzenia technologii AR, w logistyce magazynowej, na przykładzie infrastruktury magazynowej regionu Odessy. Oferowane są strategiczne kierunki rozwoju logistyki magazynowej, w warunkach rozwoju innowacyjnych technologii.

SŁOWA KLUCZOWE

technologie AR, logistyka magazynowa, strategiczne kierunki rozwoju logistyki