

MUHANDISLIK

& IQTISODIYOT

ijtimoiy-iqtisodiy, innovatsion texnik,
fan va ta'limga oid ilmiy-amaliy jurnal

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- 05.01.00 – Axborot texnologiyalari, boshqaruv va kompyuter grafikasi
- 05.01.01 – Muhandislik geometriyasi va kompyuter grafikasi. Audio va video texnologiyalari
- 05.01.02 – Tizimli tahlil, boshqaruv va axborotni qayta ishlash
- 05.01.03 – Informatikaning nazariy asoslari
- 05.01.04 – Hisoblash mashinalari, majmualari va kompyuter tarmoqlarining matematik va dasturiy ta'minoti
- 05.01.05 – Axborotlarni himoyalash usullari va tizimlari. Axborot xavfsizligi
- 05.01.06 – Hisoblash texnikasi va boshqaruv tizimlarining elementlari va qurilmalari
- 05.01.07 – Matematik modellash
- 05.01.11 – Raqamli texnologiyalar va sun'iy intellekt
- 05.02.00 – Mashinasozlik va mashinashunoslik
- 05.02.08 – Yer usti majmualari va uchish apparatlari
- 05.03.02 – Metrologiya va metrologiya ta'minoti
- 05.04.01 – Telekommunikatsiya va kompyuter tizimlari, telekommunikatsiya tarmoqlari va qurilmalari. Axborotlarni taqsimlash
- 05.05.03 – Yorug'lik texnikasi. Maxsus yoritish texnologiyasi
- 05.05.05 – Issiqlik texnikasining nazariy asoslari
- 05.05.06 – Qayta tiklanadigan energiya turlari asosidagi energiya qurilmalari
- 05.06.01 – To'qimachilik va yengil sanoat ishlab chiqarishlari materialshunosligi
- 05.08.03 – Temir yo'l transportini ishlatish
- 05.08.06 – "G'ildirakli va gusenisali mashinalar va ularni ishlatish" (texnika fanlari)
- 05.09.01 – Qurilish konstruksiyalari, bino va inshootlar
- 05.09.04 – Suv ta'minoti. Kanalizatsiya. Suv havzalarini muhofazalovchi qurilish tizimlari
- 10.00.06 – Qiyosiy adabiyotshunoslik, chog'ishtirma tilshunoslik va tarjimashunoslik
- 10.00.04 – Yevropa, Amerika va Avstraliya xalqlari tili va adabiyoti
- 08.00.01 – Iqtisodiyot nazariyasi
- 08.00.02 – Makroiqtisodiyot
- 08.00.03 – Sanoat iqtisodiyoti
- 08.00.04 – Qishloq xo'jaligi iqtisodiyoti
- 08.00.05 – Xizmat ko'rsatish tarmoqlari iqtisodiyoti
- 08.00.06 – Ekonometrika va statistika
- 08.00.07 – Moliya, pul muomalasi va kredit
- 08.00.08 – Buxgalteriya hisobi, iqtisodiy tahlil va audit
- 08.00.09 – Jahon iqtisodiyoti
- 08.00.10 – Demografiya. Mehnat iqtisodiyoti
- 08.00.11 – Marketing
- 08.00.12 – Mintaqaviy iqtisodiyot
- 08.00.13 – Menejment
- 08.00.14 – Iqtisodiyotda axborot tizimlari va texnologiyalari
- 08.00.15 – Tadbirkorlik va kichik biznes iqtisodiyoti
- 08.00.16 – Raqamli iqtisodiyot va xalqaro raqamli integratsiya
- 08.00.17 – Turizm va mehmonxona faoliyati

Ma'lumot uchun, OAK
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MUNDARIJA

IQTISODIYOTGA TO'G'RIDAN-TO'G'RI XORIJIY INVESTITSİYALARNI JALB ETISHNING SAMARALI DAVLAT BOSHQARUVI.....	9
Amirov Otabek Xudoyberdi o'g'li	
РОЛЬ БУХГАЛТЕРСКОГО УЧЕТА В СИСТЕМЕ ФИНАНСОВОГО КРИЗИС-МЕНЕДЖМЕНТА ПРЕДПРИЯТИЯ.....	14
Маннапова Раъно Абборовна	
METROPOLITEN SANOATIDA MAHALLIYLASHTIRISH SAMARADORLIGINI BAHOLASHNING INTEGRAL METODOLOGIK MODELİ	22
Mansurov Xamrokul Ilxomovich	
INVESTMENT COOPERATION BETWEEN UZBEKISTAN AND CHINA: CHALLENGES AND PROSPECTS ..	29
Liu Qing	
O'ZBEKISTON RESPUBLIKASI BANK TIZIMI: MARKAZIY BANK VA UNING VAZIFALARINING IQTISODIY ASOSI.....	36
Sherkulova N.B., Fayzullayeva Maxliyo	
MINTAQAVIY IQTISODIYOT: MUAMMOLAR VA XALQARO TAJRIBA.....	41
Yorqin Xudoyberdiev	
BIZNES SUBYEKTLARINING EKSPORT FAOLIYATINI MOLİYALASHTIRISH TIZIMINI TAKOMILLASHTIRISHNING ASOSIY OMILLARI	45
Karamatdinova Aysawle Paraxatovna	
YOSHLAR TADBIRKORLIGINI RIVOJLANTIRISHNING PDCA TAMOIYILIGA ASOSLANGAN 7 BOSQICHLI TAKOMILLASHTIRILGAN TASHKILIY-IQTISODIY MEXANIZMI	53
Xojiyev Ma'murjon Muxsinjon o'g'li	
HUDUDIY SPORT-SOĞ'LOMLASHTIRISH TURIZMINING RIVOJLANISHIGA TA'SIR ETUVCHI OMILLAR..	62
Misirxonov Habibxon Iskandar o'g'li	
TRANSPORT SOHASIDA AYOLLAR BANDLIGINI TA'MINLASHNING INTEGRATSIYALASHGAN BOSHQARUV MODELINI TAKOMILLASHTIRISH	71
Abdukarimova Dilnozaxon Mamurjon qizi	
QALMOQIR KONI MIS-MOLIBDEN RUDASINING GRANULOMETRIK TARKIBI VA METALLARNING YIRIKLIK SINFLARI BO'YICHA TAQSIMLANISHINI TAHLIL QILISH	78
Samadov Alisher, Abdusamiyeva Lobarxon	
VELOCITY CALCULATION AND ANALYSIS OF MANIPULATOR MOTION BASED ON THE DIFFERENTIAL APPROACH	83
Egamberdiev Azimjon, Djuraev Sherzod	
PAXTA-TO'QIMACHILIK KLASSTERLARIDA INNOVATSION MAHSULOTLAR ISHLAB CHIQRISHNI RAG'BATLANTIRISH OMILLARINI BAHOLASH.....	88
Tojiyev Sa'dulla Muhitdinovich	
KICHIK BIZNES VA TADBIRKORLIK BARQAROR RIVOJLANISHINI EKSPORT SALOHİYATINI OSHIRISH ORQALI TA'MINLASH.....	93
Jo'raxonov Muzaffar Eskandarovich	
MILLIY TURIZM EKOTIZIMINI XALQARO RAQAMLI PLATFORMALARGA INTEGRATSIYA QILISHNING STRATEGIK MEXANIZMLARI.....	101
Temirov E.I.	
TO'G'RIDAN-TO'G'RI XORIJIY INVESTITSİYALARINING EKSPORT SALOHİYATINI OSHIRISHDAGI TA'SIRINI BAHOLASH	109
Mutorov Ilhom Avazjon o'g'li	
TIJORAT BANKLARI AKTIVLARINI BOSHQARISHNING METODOLOGIK ASOSLARI.....	116
Ziyodullayev Sodiqjon Mamadillayevich	



ВЛИЯНИЕ ЦИФРОВОЙ ЭКОНОМИКИ НА ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ УПРАВЛЕНИЯ ПРЕДПРИЯТИЯМИ МИНЕРАЛЬНО-СЫРЬЕВОГО КОМПЛЕКСА РЕСПУБЛИКИ УЗБЕКИСТАН.....	121
Худайбердиева Камила, Абдурахманова Мунаввар	
СОВРЕМЕННЫЕ ИСТОЧНИКИ ФИНАНСИРОВАНИЯ ИНВЕСТИЦИОННЫХ ПРОЕКТОВ ТЕКСТИЛЬНЫХ ПРЕДПРИЯТИЙ И НАПРАВЛЕНИЯ ПОВЫШЕНИЯ ИХ ДОСТУПНОСТИ	127
Дадабоева Муштари Хамидиллаевна	
СОВЕРШЕНСТВОВАНИЕ МЕТОДИКИ УПРАВЛЕНИЯ КОНКУРЕНТНЫМ ПОТЕНЦИАЛОМ ПРЕДПРИЯТИЙ В УСЛОВИЯХ ИННОВАЦИОННОГО РАЗВИТИЯ	138
Ташмухамедова Карима Саматовна	
ИНТЕГРАЦИЯ ОЦЕНКИ КОРПОРАТИВНОГО РИСК-МЕНЕДЖМЕНТА В ИНДЕКС КОРПОРАТИВНОГО УПРАВЛЕНИЯ СТРОИТЕЛЬНЫХ ПРЕДПРИЯТИЙ РЕСПУБЛИКИ УЗБЕКИСТАН.....	143
Маманазаров Ойбек, Аблаева Валентина	
TURIZMDA PROFESSIONAL TA'LIM VA O'QITISH (VET) TIZIMLARINING QIYOSIY TAHLILI: O'TISH DAVRI IQTISODIYOTLARI UCHUN SINGAPUR VA AVSTRALIYA TAJRIBASI.....	150
Abdullabekova Noilaxon G'ofurjon qizi	
TIJORAT BANKLARI FAOLIYATINI CAMELS TIZIMIDA BAHOLASHNING NAZARIY VA METODOLOGIK TADQIQI	156
Safaraliyev Basir Norboyevich	
TIJORAT BANKLARI FAOLIYATINI RIVOJLANTIRISH STRATEGIYASINI ISHLAB CHIQISH MEKANIZMI VA TRANSFORMATSIYA NATIJADORLIGINI BAHOLASH	162
Vafiyev Raxim Xalimjonovich	
JINCHAN REAGENTI YORDAMIDA KVARSLI-PIRIT KONSENTRATIDAN OLTINNI TANLAB ERITIB AJRATIB Olish.....	169
Rahmonova Umida, Xasanov Abdurashid, Saidahmedov Aktam	
QALMOQQIR MIS-MOLIBDEN RUDALARI MINERALLARINING OCHILISH DARAJASINI BAHOLASH VA BOYITISH TEXNOLOGIYASINI ASOSLASH.....	174
Samadov Alisher, Abdusamiyeva Lobarxon	
ФАКТОРЫ МОЛОДЕЖНОЙ БЕЗРАБОТИЦЫ В УЗБЕКИСТАНЕ: ЭКОНОМЕТРИЧЕСКИЙ АНАЛИЗ ВЛИЯНИЯ ДЕМОГРАФИЧЕСКИХ, МАКРОЭКОНОМИЧЕСКИХ И ОБРАЗОВАТЕЛЬНЫХ ПОКАЗАТЕЛЕЙ	179
Мусаева Шоира, Усмонова Дилфуза	
QARZ KAPITALI ASOSIDA LOYIHALARNI AMALGA OSHIRISHDA DAVLAT-XUSUSIY SHERIKLIK (DXSH) AMALIYOTINING AHAMIYATI	183
Xushvaqov Islombek Muxammadi o'g'li	
ANGREN VA YANGI ANGREN IESLARINING KUL-SHLAK AG'DARMALARI TEXNOLOGIK NAMUNALARNING MODDIY TARKIBINI O'RGANISH	189
Almatov Ilxomjon, Xatamov G'ayrat, Jabborov Ergash, Sodiqov Farrux	
AXBOROT-KOMMUNIKATSIYA TEXNOLOGIYALARI SOHASIDA MOLIVAVIY NATIJALAR HISOB METODOLOGIYASINI TAKOMILLASHTIRISHNING YAXLIT TIZIMI	195
Bekchanov Faxriddin Atabekovich	
XIZMATLAR SOHASINI RIVOJLANTIRISHDA TIJORAT BANKLARI FAOLIYATINI O'RNI	200
Safaraliyev Suyun Sheraliyevich	
RESEARCH AND DESIGN OF ANAEROBIC REACTORS FOR EFFECTIVE FERMENTATION OF AGRICULTURAL RESIDUE	204
Dilbar Ramazonova	
"TARMOQLARDAN FOYDALANISH" BOBINI O'QITISHDA MUALLIFLIK TA'LIM PLATFORMASIDAN FOYDALANISHNING PEDAGOGIK IMKONIYATLARI	209
Allaberganova Muyassar, Po'lotova Sevinchov	
RAQAMLI MARKETING PLATFORMALAR ASOSIDA KICHIK BIZNES SUBYEKTLARI TADBIRKORLIK FAOLIYATINI RIVOJLANTIRISHNING TASHKILIY-IQTISODIY MEKANIZMLARI	216
Pirmatov Oybek Shovkat o'g'li	



TIJORAT BANKLARIDA ICHKI AUDITNI TASHKIL ETISH VA O'TKAZISH JARAYONLARINING AMALDAGI HOLATI	223
Yuldashev Xurshidbek Mamirjonovich	
ELEKTRON SAVDO PLATFORMALARIDA MOLIYAVIY TAHLIL AMALIYOTINING MUAMMOLARI VA UNI RIVOJLANTIRISH ISTIQBOLLARI.....	232
Amanqulova Muxlisa Narsafar qizi	
SURXONDARYODA YASHIL TURIZM SOHASINI RIVOJLANTIRISH YO'LLARI.....	240
Mamatov Sardor, Rashidova Nargiza	
XORIJIY MAMLAKATLARDA UY-JOY NARXLARIGA TA'SIR ETUVCHI OMILLARNI BAHOLASH TAJRIBASI... ..	246
Sadikova Dildora Abdulla qizi	
XORIJIY INVESTITSİYALAR ASOSIDA KORXONA INVESTITSIYA LOYIHALARINI MOLIYALASHTIRISH TAHLILI	252
Almanov Xurshid Ismoilovich	
ECONOMIC EFFICIENCY OF IMPLEMENTING ARTIFICIAL INTELLIGENCE IN WAREHOUSE OPERATIONS.....	257
Abdulazizova Shakhrizoda Azizbek kizi	



ECONOMIC EFFICIENCY OF IMPLEMENTING ARTIFICIAL INTELLIGENCE IN WAREHOUSE OPERATIONS

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Abstract: Artificial Intelligence (AI) is transforming warehouse management by improving efficiency, inventory control, and decision-making. This study evaluates the economic efficiency of AI implementation in warehouse operations through a qualitative and comparative analysis of academic literature, industry reports, and international case studies, with Amazon's fulfillment network serving as a benchmark. The findings show that AI technologies such as robotics, predictive analytics, and computer vision significantly increase productivity, improve inventory accuracy, reduce operational errors, and lower logistics costs. Although AI adoption requires substantial initial investment, the long-term benefits outweigh the costs. The study also examines challenges to AI implementation in Uzbekistan and proposes a phased adoption strategy focused on digitalization, workforce development, and smart warehouse technologies. The results indicate that AI-driven warehouse modernization can enhance logistics performance, supply chain resilience, and digital transformation.

Keywords: warehouse management system (WMS), smart warehouse, internet of things, inventory optimization, stock-out, automation, demand forecasting, logistics, digital transformation.

Annotatsiya: Sun'iy intellekt (SI) omborlarni boshqarish samaradorlikni oshirish, zaxiralarni nazorat qilish va qarorlar qabul qilish jarayonlarini takomillashtirish orqali transformatsiya qilmoqda. Mazkur tadqiqot Amazon kompaniyasining buyurtmalarni bajarish tarmog'ini benchmark sifatida qabul qilgan holda, ilmiy adabiyotlar, sanoat hisobotlari va xalqaro amaliy misollarni sifat va qiyosiy tahlil qilish orqali ombor operatsiyalarida sun'iy intellektni joriy etishning iqtisodiy samaradorligini baholaydi. Tadqiqot natijalari robototexnika, prediktiv tahlil va kompyuter ko'rishi kabi sun'iy intellekt texnologiyalari mehnat unumdorligini sezilarli darajada oshirishini, zaxiralar hisobining aniqligini yaxshilashini, operatsion xatolarni kamaytirishini va logistika xarajatlarini pasaytirishini ko'rsatadi. Sun'iy intellektni joriy etish dastlab katta miqdordagi investitsiyalarni talab qilsa-da, uzoq muddatli manfaatlar xarajatlardan ustun keladi. Tadqiqot, shuningdek, O'zbekistonda sun'iy intellektni joriy etishdagi muammolarni ko'rib chiqadi hamda raqamlashtirish, ishchi kuchini rivojlantirish va aqlli ombor texnologiyalariga yo'naltirilgan bosqichma-bosqich joriy etish strategiyasini taklif qiladi. Natijalar sun'iy intellekt asosida omborlarni modernizatsiya qilish logistika samaradorligini, ta'minot zanjirining barqarorligini va raqamli transformatsiyani oshirishi mumkinligini ko'rsatadi.

Kalit so'zlar: omborlarni boshqarish tizimi (WMS), aqlli ombor, buyumlar interneti, zaxiralarni optimallashtirish, tovar taqchilligi, avtomatlashtirish, talabni prognozlash, logistika, raqamli transformatsiya.

Аннотация: Искусственный интеллект (ИИ) трансформирует управление складскими операциями за счёт повышения эффективности, совершенствования контроля запасов и улучшения процессов принятия решений. В данном исследовании оценивается экономическая эффективность внедрения ИИ в складские операции посредством качественного и сравнительного анализа научной литературы, отраслевых отчётов и международных практических примеров, при этом сеть центров выполнения заказов компании Amazon используется в качестве эталона для сравнения. Результаты исследования показывают, что такие технологии искусственного интеллекта, как робототехника, предиктивная аналитика и компьютерное зрение, значительно повышают производительность, улучшают точность учёта запасов, сокращают операционные ошибки и снижают логистические затраты. Несмотря на то, что внедрение ИИ требует значительных первоначальных инвестиций, долгосрочные преимущества превышают связанные с ним затраты. В исследовании также рассматриваются проблемы внедрения ИИ в Узбекистане и предлагается поэтапная стратегия его внедрения, ориентированная на цифровизацию, развитие кадрового потенциала и использование технологий интеллектуальных складов. Результаты показывают, что модернизация складской деятельности на основе ИИ способна повысить эффективность логистики, устойчивость цепочек поставок и уровень цифровой трансформации.

Ключевые слова: система управления складом (WMS), интеллектуальный склад, Интернет вещей, оптимизация запасов, дефицит запасов, автоматизация, прогнозирование спроса, логистика, цифровая трансформация.

INTRODUCTION

Traditional warehouse management refers to the conventional methods used to control the storage, movement, and tracking of goods inside a warehouse. In modern business environments traditional warehousing faces many limitations such as slow operations, high labor costs, lost products, high error rates, late decision-making, poor demand forecasting. The rapid growth of global trade, e-commerce, delivery services and customer expectations has created the need for smart warehouse systems. Smart warehouse can facilitate inventory processes through automation, artificial intelligence and digital technologies. A modern customer expects same-day or next-day delivery, businesses need fewer inventory mistakes, more reliable operations, lower costs, less inventory errors. Artificial Intelligence (AI) has become a groundbreaking technology that is transforming warehouse operations by automating processes, optimizing resource utilization, and enabling data-driven decision-making. This article examines how AI-powered solutions are reshaping warehouse management through key technologies such as robotics, predictive analytics, intelligent sorting systems, and computer vision. These advancements enhance operational efficiency, streamline workflows, and minimize errors, allowing warehouses to transition from reactive management approaches to proactive and predictive operations. For instance, AI-driven robots can perform repetitive tasks such as picking and packing, while predictive analytics helps forecast inventory demand, reducing the risks of stock shortages and excess inventory.¹

Artificial Intelligence (AI) is transforming warehouse operations through a range of advanced technologies that improve efficiency, accuracy, and productivity. One of the most significant applications of AI is in robotics, where intelligent robots automate repetitive tasks, such as picking, packing, and sorting products. Unlike traditional automated systems, AI-powered robots can adapt to changing warehouse environments, handle a variety of product types, and operate continuously without fatigue. A notable example is Amazon's Kiva robotic system, which transports entire shelves to workers, significantly reducing order processing times while improving space utilization and operational efficiency.

Another important AI application is predictive analytics, which uses historical data and machine learning algorithms to forecast future demand patterns. By accurately predicting inventory requirements, warehouses can maintain optimal stock levels, reducing the risk of stockouts and excess inventory. This approach minimizes waste, lowers storage costs, and ensures product availability during periods of high demand. For instance, retailers such as Costco employ AI-based demand forecasting systems to better anticipate customer needs and manage inventory effectively during peak seasons.

Computer vision technology also plays a crucial role in modern warehouse management. AI-powered cameras and imaging systems monitor products in real time, detecting defects, tracking item movement, and verifying barcode accuracy. These capabilities help reduce human error, improve inventory visibility, and enhance overall product quality. As a result, warehouse operations become more reliable and efficient.

The implementation of AI technologies provides numerous benefits for warehouse management. AI streamlines workflows, accelerates order fulfillment, and reduces operational delays, leading to greater efficiency. It also lowers labor costs, minimizes errors, optimizes warehouse space, and reduces waste. Real-time monitoring and automated error detection improve inventory accuracy and reliability, while predictive analytics enables warehouses to scale their operations and respond effectively to seasonal demand fluctuations.

Despite these advantages, several challenges can hinder AI adoption in warehouses. The initial investment required for AI hardware, software, and infrastructure can be substantial, making implementation costly for some organizations. Employee resistance may also arise due to concerns about job displacement or a lack of technical skills needed to work alongside AI systems. Additionally, the extensive use of data in AI-driven operations increases exposure to cybersecurity threats and data privacy risks. To overcome these challenges, organizations should invest in workforce training, adopt phased implementation strategies, and establish strong cybersecurity measures to ensure the successful integration of AI technologies into warehouse operations.²

REVIEW OF LITERATURE ON THE SUBJECT

Jantapoon (2025), in "The Impact of Smart Warehousing and Last-Mile Delivery on E-commerce Supply Chain Performance" found that smart warehousing significantly improves inventory management, order fulfillment, and logistics responsiveness. The study also highlighted that efficient last-mile delivery enhances customer satisfaction and strengthens competitive advantage. The author concluded that investments in advanced technologies and logistics partnerships are essential for improving e-commerce supply chain

1 Sabareesan Shankaran, Revolutionizing Warehouse management: how AI drives operational efficiency, 2023

2 Sabareesan Shankaran, Revolutionizing Warehouse management: how AI drives operational efficiency, 2023



performance.

Sarkar, in the article “Artificial Intelligence-Enabled E-commerce Systems and Automated Warehousing: Economic Effects from Amazon FBA in the U.S. Market” found that AI adoption within the Amazon FBA ecosystem improves supply chain resilience, increases productivity, and lowers entry barriers for small and medium-sized enterprises. The study also highlighted that AI-driven warehouse automation contributes to economic growth and employment transformation while presenting challenges related to data governance, workforce reskilling, and automation regulation.

Yarlagadda, in “Cutting-Edge Developments in Robotics for Smart Warehousing and Logistics Optimization,” highlighted that robotics technologies such as AMRs and AS/RS improve warehouse efficiency and accuracy, while AI enhances demand forecasting and logistics optimization. The study also noted challenges related to implementation costs, system integration, and data security.

RESEARCH METHODOLOGY

This study employs a qualitative and comparative research methodology to evaluate the economic efficiency of artificial intelligence (AI) implementation in warehouse operations. The research is based on a comprehensive review of academic literature, industry reports, and case studies related to smart warehousing, warehouse management systems (WMS), robotics, predictive analytics, and inventory optimization.

The study uses secondary data obtained from published research articles, reports of logistics companies, and international organizations. Comparative analysis is applied to examine the differences between traditional warehouse management and AI-enabled warehouse systems in terms of labor productivity, order processing time, inventory accuracy, and operational costs. Particular attention is given to AI technologies such as machine learning-based demand forecasting, intelligent inventory management, computer vision systems, and warehouse robotics.

To assess the economic impact of AI adoption, a cost-benefit analysis is conducted. The analysis considers both direct costs, including software acquisition, hardware investments, system integration, and employee training, and indirect benefits, such as reduced labor requirements, lower error rates, improved inventory turnover, and enhanced customer service. Key performance indicators (KPIs) commonly used in warehouse management are utilized to evaluate operational improvements.

Furthermore, the study examines the challenges associated with implementing AI-driven warehouse solutions in developing countries, with a particular focus on Uzbekistan. Factors such as technological infrastructure, data availability, workforce competencies, and investment capacity are analyzed to identify barriers to adoption and potential strategies for successful implementation.

The findings are synthesized to determine the overall economic viability of AI-based warehouse systems and their potential contribution to logistics sector modernization, digital transformation, and sustainable economic development.

ANALYSIS AND RESULTS

To evaluate the economic efficiency of artificial intelligence in warehouse operations, this study uses Amazon's fulfillment network as a benchmark case. Amazon is recognized as one of the world's most advanced users of warehouse automation technologies. As of 2025, the company has deployed more than one million robots across over 300 fulfillment facilities worldwide, making it the largest operator of mobile warehouse robotics globally. Furthermore, approximately 75% of Amazon's deliveries are supported by robotic systems. Recent developments include the implementation of the DeepFleet AI platform, which improves robot travel efficiency by approximately 10%, resulting in faster order processing and lower operational costs.

The comparative analysis demonstrates substantial differences between traditional warehouses and AI-enabled warehouses. In conventional warehouse environments, inventory movement, order picking, and sorting activities rely heavily on manual labor, leading to longer processing times and higher error rates. In contrast, Amazon's automated fulfillment centers employ Autonomous Mobile Robots (AMRs), robotic sorting systems, machine learning algorithms, and computer vision technologies to automate repetitive tasks and optimize warehouse workflows. These technologies increase storage density, improve inventory accuracy, and reduce labor-intensive activities.

The cost-benefit analysis indicates that AI implementation requires substantial initial investments in robotics, software infrastructure, data management systems, and employee training. However, the long-term economic benefits outweigh these costs. Amazon reports significant operational improvements through warehouse automation, including faster order fulfillment, reduced human errors, optimized inventory management, and

lower logistics costs. Industry estimates suggest that Amazon's robotics and automation initiatives could generate billions of dollars in annual savings by the end of the decade.

The analysis further reveals that AI technologies contribute to productivity growth through:

- Reduction of manual handling activities;
- Faster inventory retrieval and storage operations;
- Improved demand forecasting accuracy;
- Better warehouse space utilization;
- Lower order processing errors;
- Enhanced responsiveness to fluctuations in customer demand.

These improvements increase overall warehouse throughput while reducing operational costs per order processed.

The proven benefits observed in Amazon's operations demonstrate the potential for implementing similar technologies in Uzbekistan. First, warehouse automation requires significant capital investment, which can support many local logistics operators and small businesses in developing modern and efficient warehouse systems. Second, AI systems depend on high-quality operational data, while the increasing adoption of digital inventory management practices in Uzbekistan creates opportunities for more effective and data-driven warehouse operations. Third, the growing demand for specialists with expertise in artificial intelligence, robotics, data analytics, and warehouse automation can contribute to the development of qualified human capital in the logistics sector. In addition, cybersecurity and digital infrastructure provide important opportunities for strengthening large-scale implementation.

Based on the findings of the comparative analysis, several measures can facilitate the gradual introduction of AI-enabled warehousing technologies in Uzbekistan:

Implementation of Smart Warehouse Management Systems (WMS).

Warehouses should first digitize inventory and logistics processes through modern WMS platforms before introducing advanced automation technologies.

Deployment of AI-Based Demand Forecasting.

Machine learning algorithms can be used to predict inventory demand and reduce stockouts and excess inventory, particularly in retail and e-commerce sectors.

Pilot Introduction of Autonomous Mobile Robots (AMRs).

Large logistics centers and distribution hubs can begin with small-scale AMR projects for inventory transportation and sorting operations.

Integration of IoT and Computer Vision Technologies.

Sensors, RFID systems, and AI-powered cameras can improve inventory visibility, warehouse security, and quality control.

Development of Human Capital.

Universities, logistics companies, and government agencies should cooperate to create training programs in AI, robotics, warehouse automation, and data analytics.

Tax incentives, innovation grants, and public-private partnerships can encourage investment in smart warehouse technologies and accelerate digital transformation.

The results of this study confirm that artificial intelligence significantly improves warehouse efficiency by increasing productivity, reducing operational errors, and optimizing inventory management. Evidence from Amazon's fulfillment network demonstrates that AI-enabled warehouses achieve superior operational performance compared to traditional warehouse systems. Although the adoption of such technologies in Uzbekistan requires substantial investment and institutional support, a phased implementation strategy focused on digitalization, workforce development, and pilot automation projects can generate substantial economic benefits. Consequently, AI-based warehouse modernization can strengthen the competitiveness of Uzbekistan's logistics sector, improve supply chain resilience, and support the country's broader digital transformation agenda.

CONCLUSIONS AND SUGGESTIONS

The findings of this study demonstrate that artificial intelligence has significant potential to improve the efficiency and economic performance of warehouse management. AI-powered technologies, including robotics, predictive analytics, computer vision, and intelligent warehouse management systems, can reduce manual operations, improve inventory accuracy, accelerate order fulfillment, optimize warehouse space utilization, and reduce operational costs. The comparative analysis indicates that AI-enabled warehouses can achieve higher operational efficiency and responsiveness than traditional warehouse systems.



The analysis of Amazon's fulfillment network confirms the practical effectiveness of warehouse automation and AI technologies. The use of robotic systems, machine learning, and computer vision contributes to faster inventory processing, fewer operational errors, and more efficient resource utilization. However, the experience of Amazon cannot be directly transferred to Uzbekistan without considering the country's existing technological, financial, and human-resource conditions.

The study identifies several major barriers to the implementation of AI-based warehouse technologies in Uzbekistan, including high initial investment requirements, insufficient digital infrastructure, limited availability of high-quality operational data, continued reliance on manual inventory management, and a shortage of specialists in artificial intelligence, robotics, data analytics, and warehouse automation. These factors indicate that the transition to smart warehousing should be implemented gradually rather than through immediate large-scale automation.

Overall, AI-based warehouse modernization can contribute to the competitiveness and resilience of Uzbekistan's logistics sector by improving operational efficiency, reducing costs and errors, and strengthening supply chain responsiveness. A phased and economically justified approach to AI adoption can provide a practical foundation for the digital transformation and modernization of warehouse management in Uzbekistan.

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