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INNOVATIVE DIRECTIONS OF DEVELOPMENT OF CARGO HANDLING SYSTEMS IN AIRPORT TERMINALS

ІННОВАЦІЙНІ НАПРЯМКИ РОЗВИТКУ СИСТЕМ ОБРОБКИ ВАНТАЖІВ В ТЕРМІНАЛАХ АЕРОПОРТІВ

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Abstract. *The article is devoted to the analysis of promising innovative systems designed for total automation of technological processes in airport cargo terminals, which are already presented on the world market, but are not widely used today. At the same time, the relevance of their implementation in view of the constant growth of air cargo volumes is quite obvious.*

Key words: *cargo terminal, airport, artificial intelligence, cargo handling, air transportation, robotics, unmanned aerial vehicle, autonomous mobile robot, cobot, warehouse, technological process.*

Introduction.

The introduction of modern cargo handling technologies allows to significantly increase the efficiency of cargo management at airports, ensuring fast and accurate movement, reducing costs and increasing the overall productivity of operations.

Today, the air transport industry is undergoing a major transformation, driven by growing trade volumes, changing customer expectations, regular monitoring and the need for greater resilience and sustainability. Traditional cargo complexes, often limited by outdated infrastructure and manual processes, must adapt to the growing demands for efficiency, productivity and compliance with modern standards.

Cargo terminals are critically important components of the airport logistics chain. They are a complex of facilities that combines many areas that must guarantee the efficient handling, storage and transportation of cargo, provide a diverse range of services and ensure a high level of customer service.

Main text.

Air transportation includes a number of services from the point of departure to the point of destination of cargo and mail [1]. In general, air cargo transportation can be divided into certain stages, which are presented in Figure 1.

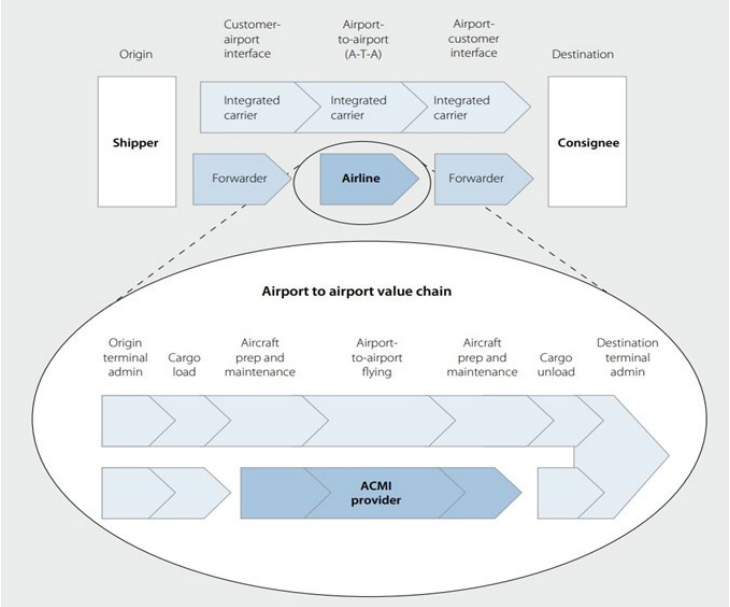

Figure 1 - Air cargo transportation chain

Source: [1]

In the future, airport cargo terminals should become safer, more reliable, with a high level of automation and robotization of technological processes, the basis of which should be actively used artificial intelligence systems.

As automation accelerates and the introduction of artificial intelligence, the transformation of labor force involvement will be critically important, requiring advanced training and new models of cooperation between human operators and intelligent systems.

The essence of this article is to analyze promising innovative systems designed for total automation of technological processes in airport cargo terminals, which are already presented on the world market, but do not have mass application today. At the same time, the relevance of their implementation in view of the constant growth in air cargo volumes is quite obvious.

The active use of artificial intelligence is predicted with positive annual dynamics, and at almost all stages of cargo complexes. The integration of such technologies into

the logistics operations of airport terminals provides numerous advantages, going beyond the automation of warehouses, which can vary from the simplest options for cargo handling to complex logistics transformations.

As is known, artificial intelligence is a simulation of human intelligence in machines that can learn, reason and independently correct the situation, as well as perform tasks such as visual perception, speech recognition, decision-making and language translation.

The potential applications of AI in air transport are very diverse. Robotics and automated equipment based on artificial intelligence are becoming increasingly popular, and the use of chats with humanized voices is replacing real employees. Artificial intelligence will help with route planning in cargo terminal areas, load planning, automation and improvement of ULD accumulation, as well as tracking and monitoring the condition of cargo (temperature, humidity, etc.) in real time.

There is growing interest in using AI to optimize cargo space and cargo operations and predictive maintenance of cargo equipment. Another important function of AI is dynamic workforce and equipment planning, as well as automated anomaly detection during cargo security checks. Resource management and cargo flow forecasting based on artificial intelligence also demonstrate high efficiency, as there is no human factor and all data is processed at high speed.

Key uses of AI in airport cargo terminal management include resource management, order fulfillment, and forecasting, which are some of the main areas where AI can help improve the accuracy and efficiency of mail and cargo processing, packaging, and flight picking. The above information suggests that the implementation of AI will lead to fully automated terminals and “smart” warehouses, where the impact of the human factor on the management of complex technological processes will be minimized.

One of the innovative solutions that will contribute to increasing the efficiency of the operation of aviation terminals, which is currently in the testing stage, is the use of unmanned aerial vehicles (UAVs), which are widely known as «drones».

In the air transport sector, UAVs can provide fast, flexible and cost-effective

movement of light and urgent cargo, as well as operational support in other ways [2]. In airport terminals, drones are likely to be used for inter-terminal and intra-terminal transportation of small cargo, as well as for scanning and tracking cargo in the warehouse. It is important to emphasize that inspection of cargo, various terminal infrastructure facilities using UAVs equipped with cameras and sensors is another possible function.

Efficient and compact high-bay racks are the standard in warehousing. Goods are moved to and from the warehouse, and staff must constantly check the degree of fullness of the rack storage and the availability of free spaces. The potential for automation in such processes is significant, and drones are seen as a viable solution to such tasks, which are labor-intensive, time-consuming and therefore expensive. Instead of staff scanning codes and tracking storage locations, UAVs can quickly solve these tasks without the need for large warehouse vehicles to inspect the upper segments of multi-tiered racks. Equipped with cameras and scanning technology, drones can simultaneously capture barcodes and transmit them to a warehouse management system, which compares the target and actual fullness levels, detects the absence of goods in the warehouse, analyzes the availability of free spaces and provides recommendations.

A significant number of drones can be deployed autonomously in a warehouse, and only a few employees need to take action based on the data collected. And when it comes to inventory in large warehouses, there is no need for overtime or support staff, as the actual loading of the warehouse spaces is regularly checked, or, if necessary, the drones make a few additional flights.

Another innovative solution for air terminals is the use of autonomous mobile robots (AMRs), which are self-navigating robots that dynamically move in environments without fixed paths. Unlike AGVs, AMRs use advanced sensors, artificial intelligence, and real-time data to adapt to changes in the environment, which makes them versatile for possible use in air transportation [3]. Dynamic transportation of goods between facilities without the need for fixed infrastructure such as tracks or predefined routes becomes their obvious advantage, and free navigation allows them

to move throughout the entire warehouse. Thanks to dynamic navigation between cargo storage locations, such robots can significantly optimize the picking, sorting, and warehouse management processes by seamlessly moving goods between airport terminals or between neighboring warehouses within a single terminal. They ensure safe and efficient handling of temperature-sensitive cargo by integrating with IoT monitoring systems and track terminal occupancy in real time using barcodes and/or RFID scanners for precise cargo location management.

Using advanced sensor technology, code-free programming, and state-of-the-art batteries, autonomous mobile robotics can navigate independently, safely detect obstacles, navigate around them, and create alternative routes. The result is 24/7 operation and 99% availability.

AMR vehicles transport palletized goods within a facility, taking on the role of or working alongside traditional forklifts, conveyors and electrified monorails. They add flexibility and safety to a facility by reducing the amount of manual equipment. Autonomous robots speed up the internal movement of ready-to-pick goods, effectively connecting picking, consolidation and packaging stations with the shipping area.

It is also worth mentioning stationary robotics, which encompasses automated machines that perform tasks that humans typically perform from a fixed, stationary position or defined workspace. These machines improve the efficiency, safety, and accuracy of cargo handling and air cargo equipment management. They are used for repetitive, high-precision tasks, including loading, stacking, sorting, stacking, and destacking of ULDs and pallets [4].

In other words, their scope of application in air transportation is to automate the scanning and sorting of parcels, containers and packages based on size, weight, destination and other parameters; handling, palletizing and depalletizing cargo, optimizing space utilization, stability of cargo handling and reducing manual labor; assisting with loading and unloading goods from conveyor belts to warehouse or transport units, improving e-commerce and postal services by performing repetitive tasks such as weighing, labeling or checking parcels [5].

Collaborative robots, or cobots, are designed to work together with humans in shared environments, unlike traditional industrial robots that work in isolated areas. In other words, it is a robotic arm designed to work together with humans on a production line. The use of these robots is aimed at increasing productivity in the supply chain. Cobots work with the help of a programming system and integrate new technologies to achieve a certain goal in collaboration with humans. The idea of development is to combine human and machine capabilities, that is, robots work in collaboration with humans in production and processing tasks [6].

Cobots are equipped with advanced safety features, sensors and artificial intelligence, which allows them to perform repetitive or physically demanding tasks, while ensuring human collaboration and robot in operations. The scope of possible applications of cobots in air transportation, according to ICAO experts, is to assist people in performing repetitive tasks, reducing the workload on workers; work together with employees to efficiently sort packages and stack cargo; perform quality checks, scan barcodes or apply labels to shipments. Such robots can also assist in the safe packaging of delicate or irregularly shaped cargo units and be used as a training aid in training and adaptation, demonstrating the performance of a task to new employees.

Finally, the integration of cobots is changing the automation landscape, highlighting the importance of combining human skills with robotic technologies. These trends are shaping the future of airport cargo terminals and supply chains, making technological operations more efficient and environmentally friendly.

Conclusions.

Thus, thanks to the introduction of innovative technologies, airport cargo terminals have additional opportunities to significantly increase the volume of mail and cargo processing while complying with safety and environmental requirements.

Artificial intelligence is beginning to play a decisive role in increasing the efficiency of warehouse operations, analyzing data to improve the efficiency of decision-making and reduce costs. The use of automated guided vehicle systems provides a significantly higher level of productivity of cargo terminals, also leads to a reduction in costs and optimization of warehouse processes. Modern software products

are a key component of supply chain management and ensure maximum efficiency of the entire logistics system for delivering cargo and mail. Robotics is actively capturing the air cargo market, optimizing the functioning of airport terminals taking into account the principles of sustainable development, focusing on the environmental friendliness and energy efficiency of technological processes for handling and transporting cargo by air.

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Анотація. *Стаття присвячена аналізу перспективних інноваційних систем, призначених для тотальної автоматизації технологічних процесів у вантажних терміналах аеропортів, які вже представлені на світовому ринку, проте не мають масового застосування на сьогоднішній день. У той же час актуальність їх впровадження з огляду на постійне зростання обсягів вантажних авіаперевезень цілком очевидна.*

Ключові слова: *вантажний термінал, аеропорт, штучний інтелект, обробка вантажів, авіаперевезення, робототехніка, безпілотний літальний апарат, автономний мобільний робот, кобот, склад, технологічний процес.*

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