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Research Article

Industrial and technological security with drones in logistics centers

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Abstract **–** The security challenges of logistics centers are becoming increasingly complex due to increasing warehouse capacity, increasing automation, and dynamic growth in goods traffic. Traditional security solutions, such as static camera systems and human guards, often do not provide sufficient flexibility and efficiency for comprehensive surveillance and rapid emergency response. Autonomous drone technology offers new opportunities to enhance industrial and technological security, especially in warehouse logistics environments.

The aim of this study is to present the application of drones in the security system of logistics centers, highlighting their role in surveillance, emergency response, inventory management, and occupational health and safety inspections. The research analyzes the advantages of drone-based security systems, such as real-time data collection, night vision and thermal imaging surveillance, and autonomous patrol capabilities. In addition, the challenges of the technology are explored, including indoor navigation problems, data protection issues, regulatory and infrastructure barriers.

Based on the research results, the integration of drones can significantly increase the security and operational efficiency of logistics centers, especially in the areas of inventory control, intrusion detection and rapid response to emergencies. The combination of drone technology and industrial security systems can provide a long-term sustainable and cost-effective solution for modern logistics infrastructures.

Keywords – Security, Autonomous Drone Technology, Drone-Based Security Systems, Health And Safety Inspections, Security Solutions.

I. INTRODUCTION

Modern logistics centers are critical elements of supply chains, ensuring the fast and efficient storage, handling and transportation of goods. As the industry continues to evolve, there is an increasing emphasis on automation, the use of intelligent systems and data-driven operations. At the same time, security challenges are also increasing, as the complex infrastructure of logistics centers contains a number of potential risks. Unauthorized intrusion, theft, inventory management errors, fires and other emergencies are all problems that can significantly affect the efficiency of operations and the financial stability of companies [1].

Traditional security solutions, such as camera systems, access control systems and human-based guarding, often do not provide sufficient flexibility and efficiency to fully manage risks. Drone technology creates new opportunities in the field of industrial and technological security, especially for

large warehouses and logistics centers. Autonomous drones can quickly and efficiently monitor facilities, detect anomalies, collect data in real time, and help automate security systems [2].

The aim of this study is to present the role of drones in enhancing the security of logistics centers, with a particular focus on surveillance systems, emergency management, inventory control, and occupational health and safety inspections. The research analyzes the benefits and challenges of drones, and presents current and future opportunities for the application of the technology. The ultimate goal of this study is to provide guidance to logistics companies on optimizing the integration of drone-based security systems, taking into account technological, economic, and legal factors.

II. DRONE TECHNOLOGY IN THE SERVICE OF INDUSTRIAL SECURITY

Drone technology has undergone significant development in recent years and is increasingly being used in the field of industrial security. Unmanned Aerial Vehicles (UAVs) provide logistics centers with the opportunity to develop more advanced surveillance, emergency management, and inventory control systems. Drones are equipped with advanced sensors, cameras, and artificial intelligence-based analytics that can make security tasks more efficient and faster [3].

A. Basic technological features of drones

Security drones use specialized technological solutions that enable precise and efficient operation in industrial environments.

- Camera systems and sensors: Modern drones are equipped with night vision, thermal imaging, and high-resolution optical cameras that allow detailed surveillance even in low light conditions.
- Laser scanners and LiDAR technology: To navigate inside warehouses, drones can use LiDAR sensors that create a three-dimensional map of the environment [4].
- RFID and QR code reading: Some drones can identify goods and cargo using RFID or QR codes, which is especially useful during inventory.
- Autonomous navigation and AI integration: Drones supported by artificial intelligence can make autonomous decisions, such as avoiding obstacles, identifying intruders, and responding to emergencies.

These technological elements allow drones to function more effectively in logistics center security systems and complement or partially replace traditional monitoring and inspection methods [5].

B. Advantages of drones over traditional security systems

Traditional security systems, such as fixed cameras and human guards, have several limitations that drones can effectively overcome.

- Flexibility and mobility: Drones can quickly scan the entire area of a logistics center, including hard-to-reach areas such as high racking or large warehouses.
- Rapid response: In the event of an emergency, drones can arrive on site within minutes and transmit recorded data to the security center in real time.
- Automatic data collection and analysis: Drones can continuously record and transmit data, which can be analyzed using artificial intelligence and analytics systems. This allows for faster detection of potential threats and more effective decision-making.
- Cost-effectiveness: Although the introduction of drones requires an initial investment, in the long run they can reduce the number of security personnel and operating costs.

These benefits are particularly important in logistics centers, where security and efficiency are both key factors. Drones can not only help prevent unauthorized intrusion and theft, but also optimize warehouse operations [6].

C. Integration of Drones and Smart Security Systems

The effectiveness of drones in logistics centers can be further enhanced by integrating them with smart security systems.

- IoT-based networks: Drones can be connected to Internet of Things (IoT) networks, which allow for a continuous flow of data between different security systems.
- AI-based surveillance and analysis: With the help of AI, drones can identify suspicious behaviors, such as people or vehicles repeatedly appearing in a given area.
- Automated alarm systems: Drones can be directly connected to alarm and access control systems, allowing for automated alerts and immediate responses.
- Collaboration with ground robots: Drones can also be combined with ground robots, which can autonomously control the movement of goods and workers and help remove physical obstacles.

The integration of intelligent security systems and drone technology can increase the safety and efficiency of logistics centers in the long term, while reducing the risks of human error [7][8].

D. Challenges and development directions

Although drones offer significant benefits, their application still faces technological and regulatory limitations.

- Indoor navigation challenges: In warehouses, GPS signals can be weak or unavailable, so drones need more advanced indoor navigation systems (e.g. LiDAR-based positioning) [9][10].
- Power supply and battery efficiency: Drones have limited operating time, which requires the development of automated charging stations and replaceable battery systems [11].
- Data protection and regulatory issues: The protection of data collected by drones and their legal regulation are important factors for widespread industrial adoption.
- Integration challenges: Connecting to existing security infrastructures can encounter technical and organizational barriers [12].

Despite the above challenges, the continuous development of drone technology and the rise of artificial intelligence provide an opportunity for drones to play a central role in logistics center security systems.

The industrial and technological security application of drones represents a significant step forward in increasing the efficiency and protection of logistics centers. Drones with advanced sensors, AI-based analytics, and autonomous operation capabilities can provide faster response times, wider coverage, and more cost-effective operation. However, for a successful implementation, it is important to consider technological challenges as well as regulatory and data protection issues. In the following, we will present in detail the specific application possibilities of drones in logistics center security systems.

III. DRONE APPLICATIONS IN LOGISTICS CENTERS

Continuous and reliable security monitoring, optimization of inventory management and compliance with occupational health and safety regulations are key to ensuring the efficient operation of logistics centers. Traditional security systems, such as static camera networks and human security personnel, are not always sufficient to handle dynamic and rapid response situations. The integration of drone technology can bring significant benefits in this area, as it enables autonomous surveillance, automated data collection and real-time analysis.

The main areas of application of drones in logistics centers are presented in detail below, highlighting their advantages and the associated challenges.

A. Security patrolling and surveillance

Security monitoring of large logistics centers can be a major challenge, especially at night or in poor visibility conditions. Traditional camera systems have limited field of view and human guards cannot cover the entire area at all times.

Drones, on the other hand, can:

- Autonomously patrol pre-defined routes, ensuring regular monitoring of the entire facility.
- Capable of night vision and thermal imaging, they can immediately detect unauthorized intruders or suspicious movements.
- Respond immediately to alarms and support security personnel with live video feeds in making quick decisions.

- Can be integrated with existing access control systems to automatically control the movement of cargo and vehicles.

This solution can be particularly effective in situations where rapid response time is critical, such as theft attempts or sabotage [13].

B. Emergency management and disaster relief

Emergencies in logistics centers, such as fires, chemical leaks, or structural damage, require rapid and effective intervention. Drones can help identify emergencies and minimize damage.

Drones in emergencies can:

- Use fire detection sensors and thermal imaging cameras to identify fire outbreaks and help firefighters identify the most vulnerable areas.
- Use air quality sensors to monitor hazardous material leaks, which is especially important in warehouses where chemicals or other toxic materials are stored.
- Assist in evacuation processes, for example by determining the safest escape routes for workers.
- Support emergency response teams by providing live video and thermal imaging data to aid decision-making on the scene.

These applications enable faster response times, reducing property damage and the risk of human injury [14].

C. Inventory Management and Inventory Taking with Drones

One of the biggest challenges for logistics centers is accurate inventory management and efficient inventory taking. Manual inventory control is time-consuming and error-prone, while drones can automate and speed up these processes.

The use of drones in inventory management:

- They can quickly identify goods stored in the warehouse using RFID and QR code scanners, minimizing human errors [15].
- They can check goods placed on high shelves without the need for labor or special lifting equipment.
- They can provide real-time data on inventory status, enabling fast reordering and optimization of logistics processes [16].
- They can be connected to enterprise resource planning (ERP) systems, so they can automatically update inventory data.

These automated processes can significantly reduce time and human errors during inventory, thus increasing warehouse efficiency.

D. Workplace safety and health inspections

In large logistics centers, compliance with health and safety regulations is of paramount importance, as abandoned cargo, unstable shelving systems or insufficient fire protection measures can pose serious risks to workers.

Occupational safety applications of drones:

- They can monitor worker compliance with safety regulations, for example, by checking whether they are wearing appropriate protective equipment.
- They can automatically detect and report potential sources of danger, such as improperly placed objects or unstable pallets.
- In the event of accidents, they can arrive at the scene immediately, documenting the incident and assisting in rescue operations.
- They can assist in health inspections, for example by monitoring the air quality, noise levels or temperature of the warehouse.

The use of drones in occupational health and safety inspections not only increases safety, but also facilitates regulatory compliance and reduces the number of workplace accidents.

The widespread use of drones in logistics centers can significantly contribute to increasing safety, improving efficiency and reducing costs. From security patrols to inventory control to occupational health and safety tasks, drones can take logistics center operations to a new level. In the next chapter, we discuss

in detail the technological and regulatory challenges related to the use of drones and their potential solutions [17][18].

IV. TECHNOLOGICAL AND REGULATORY CHALLENGES

The use of drone technology in logistics centers brings many benefits, but various technological and regulatory challenges must be overcome for effective integration and operation. The introduction of drones in an industrial environment not only requires technological developments, but also raises data protection, security and legal issues.

A. Navigation and technological constraints

The complex infrastructure of logistics centers presents several navigation challenges for drones. Warehouses and industrial facilities often feature narrow aisles, high shelving, and dynamically changing environments that make it difficult for autonomous drones to navigate.

The main technological challenges include:

- Indoor navigation and lack of GPS: Most GPS-based drones are optimized for outdoor use, while the poor quality of GPS signals in enclosed spaces requires alternative navigation systems. Solutions include LiDAR-based positioning, ultrasonic sensors, and visual SLAM (Simultaneous Localization and Mapping) algorithms.
- Obstacle avoidance and autonomous movement: Due to the constantly changing warehouse environment, drones need advanced artificial intelligence-based obstacle avoidance systems that can adapt to environmental changes in real time.
- Flight time and power supply: Current drones have limited battery capacity, requiring regular charging or battery replacement. The development of automated charging stations and batteries with higher energy density is key to achieving longer operating times.

Technological developments in this area are occurring at a rapid pace, and significant advances in autonomous indoor drone operation are expected in the coming years [19].

B. Data protection and legal regulation

Visual and sensory data collected by drones can contain sensitive information about the operation of the logistics center, the activities of employees and the goods stored. This raises data protection and legal issues, especially in terms of the GDPR (General Data Protection Regulation) set by the European Union and other national data protection regulations.

The main legal and data protection challenges are:

- Protection of personal data: Video and images recorded by drones can contain personal data that must be handled and stored appropriately.
- Employee rights and surveillance: Employees have the right to know how workplace surveillance systems work. Transparent regulation and the development of appropriate data management protocols are important.
- Aviation regulations: When using drones in industry, local and international aviation regulations must be taken into account, which determine the flight altitude, movement restrictions and use of drones in confined spaces.

The regulatory framework is still evolving, but companies need to proactively address these issues to comply with legal requirements and avoid data breaches [20].

C. Cost and infrastructure development issues

The introduction of drones requires a significant initial investment, which includes the acquisition of drones, the development of the necessary software and hardware infrastructure, and the training of employees. Although the technology can result in cost savings in the long run, the initial implementation costs can be a barrier for smaller companies.

The most important cost factors are:

- Acquisition of drones and sensor systems: The price of more advanced industrial drones can vary significantly, depending on the sensors and navigation technologies they are equipped with.
- Integration with existing security and inventory management systems: Ensuring compatibility with ERP (Enterprise Resource Planning) and other enterprise management systems is necessary for drones to operate effectively.
- Maintenance and operating costs: Drones require regular maintenance and software updates to ensure long-term reliability.
- Employee training: When introducing new technology, it is necessary to educate and train employees to use drones and the systems they connect to effectively.

To reduce costs, some companies may test drone technology on a smaller scale with pilot projects before implementing full integration.

The introduction of drone technology into logistics centers offers many benefits, but it also faces significant technological and regulatory challenges. Indoor navigation, power supply, data protection, and cost implications are all factors that need to be considered during system integration. Future developments, such as artificial intelligence-based obstacle avoidance systems, more advanced privacy protocols, and 5G communication technology, may help overcome these barriers [21].

V. FUTURE DEVELOPMENT DIRECTIONS AND OPPORTUNITIES

The rapid development of drone technology and the rise of artificial intelligence (AI), as well as 5G and IoT (Internet of Things) create many new opportunities for industrial and technological security. In the coming years, logistics centers may increasingly use automated, autonomous decision-making drones, which can make warehouse management and security processes even more efficient and secure.

A. Artificial intelligence and machine learning in security drones

Artificial intelligence is playing an increasingly important role in the autonomous operation of drones, especially in industrial environments. AI-based drones are capable of:

- Real-time image processing and object recognition, which can help identify unauthorized intruders, sources of danger or inventory shortages.
- Predict security risks using machine learning, for example by detecting anomalies or evaluating recurring events.
- Automated decision-making, which allows drones to respond to certain situations without human intervention, such as sending alerts or focusing surveillance on specific areas.
- Using self-learning algorithms that make drones increasingly efficient by continuously learning from the data they capture.

The integration of AI-based analytics systems can significantly increase the accuracy and efficiency of security and inventory control services provided by drones [22].

B. 5G and IoT integration for faster communication

5G networks will enable industrial drones to transmit data in real time, with high bandwidth, which is crucial for their use in large logistics centers.

Advantages of 5G-based drone systems:

- Faster and more reliable data transmission, which allows for the transmission of real-time video and sensor data.
- Lower latency, which results in more accurate and faster reaction times.
- Better collaboration with other industrial IoT devices, such as automated warehouse management systems, robots, and security systems.

With IoT integration, drones will be able to communicate directly with warehouse infrastructure, such as smart access control systems or warehouse temperature monitoring sensors. This will allow drones to participate not only as monitoring tools but also as active elements in warehouse security and operational processes [23].

C. Combined use of drones and ground robots

The combined use of drones and autonomous ground robots is expected to play an increasingly important role in the future of warehouse and industrial logistics. The collaboration of the two technologies can result in significant efficiency gains in security and inventory management processes.

- Drones will be able to detect potential problems, such as a damaged or poorly stored item.
- Autonomous ground robots can then perform corrective actions, such as moving goods or arranging pallets.
- Complex logistics processes can be automated, such as tracking and sorting goods completely without human intervention.

The development of such systems allows logistics centers to create a fully automated, intelligent ecosystem that operates with minimal human resource requirements [24].

D. More advanced indoor navigation systems

One of the biggest challenges of current drone technology is indoor navigation, which can be a major obstacle in a GPS-free environment. Future developments include:

- LiDAR-based mapping and navigation, which allows drones to create an accurate 3D model of the warehouse environment.
- Combining ultrasonic and infrared sensors, which provide more accurate obstacle avoidance and location.
- Using visual SLAM (Simultaneous Localization and Mapping) technologies, which allow drones to create their own map and continuously update it based on environmental changes.

These developments will significantly increase the autonomous operation of drones and allow them to be used reliably in closed industrial environments.

The future of industrial applications of drones holds many innovative opportunities. AI-based autonomous decision-making, 5G and IoT integration, collaboration between drones and ground robots, and advanced indoor navigation systems can all revolutionize the operation of logistics centers. These new technologies will not only improve the efficiency of security systems, but also optimize goods handling and inventory processes [25].

In the coming years, the focus of research and development will be on further fine-tuning autonomous operations, increasing energy efficiency, and adapting to industry standards. The challenge for companies is how to integrate these new technologies into industrial and logistics processes in a cost-effective and sustainable manner.

VI. DISCUSSION

The use of drones in logistics centers offers many advantages, especially in the areas of security monitoring, emergency management, and inventory control. Autonomous drone systems provide fast response times, perform accurate data analysis, and can reduce the costs of manual inspections. Combined with artificial intelligence and IoT technologies, drones can predict security risks and respond to problems in warehouse operations in real time. However, the implementation of the technology is not without challenges.

Due to the lack of GPS, indoor navigation requires more advanced sensing technologies such as LiDAR or visual SLAM-based positioning, which are expensive and under development. Battery life is also limited, making automated charging stations or battery swapping systems essential for continuous operation. Integrating industrial drones with existing enterprise management systems poses additional technological hurdles, as compatibility and data connectivity are not yet fully mature.

Legal and data protection issues are also challenging, especially due to the strict requirements of data management regulations (e.g. GDPR). Unobtrusive monitoring of workers can raise legal and ethical issues, so drone use must be aligned with transparent regulations. In addition, aviation regulations for industrial use of drones are not yet fully mature, which can create uncertainty for companies.

From an economic perspective, the introduction of drone systems requires a significant initial investment, including equipment acquisition, maintenance and operating costs. While they can reduce human labor requirements and optimize safety processes in the long term, the payback period may vary, especially for smaller companies.

Drone technology can bring significant improvements in the safety and operational efficiency of logistics centers, but technological, legal and economic barriers still need to be overcome for its widespread adoption. In the following chapter, we provide a summary and recommendations for effective integration.

VII. CONCLUSION

The use of drones in logistics centers can revolutionize security inspection, inventory management and emergency response. Autonomous drones enable rapid data collection, real-time analysis and more efficient decision-making, while reducing the burden on human labor and safety risks. The integration of artificial intelligence and IoT technology will further enhance the efficiency of drones, enabling intelligent, automated operations.

However, the introduction of the technology still presents many challenges. Indoor navigation, power supply, data protection and legal regulations are all factors that need to be considered before widespread industrial adoption. In addition, the high initial investment costs and the need to build infrastructure mean that the return on investment may vary from company to company.

Future developments such as 5G communication, more advanced autonomous navigation systems and intelligent security integration could facilitate the wider use of drones. To ensure effective implementation, companies must gradually integrate drones into their existing systems while ensuring appropriate data protection and legal compliance. As the technology continues to evolve, drones could become an essential safety and operational tool for logistics centers.

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