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ORGANIZATIONAL AND MANAGERIAL FACTORS OF DRONE INTEGRATION INTO LAST-MILE DELIVERY

ОРГАНІЗАЦІЙНО-УПРАВЛІНСЬКІ ЧИННИКИ ІНТЕГРАЦІЇ ДРОНІВ У ДОСТАВКУ «ОСТАННЬОЇ МИЛІ»

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Крупський О.П., Остапюк А.Ф., Стасюк Ю.М. Організаційно-управлінські чинники інтеграції дронів у доставку «останньої милі». Науково-методична стаття.

У статті досліджено організаційно-управлінські чинники, що впливають на успішну інтеграцію дронів у систему доставки «останньої милі». Наголошено на стратегічній ролі менеджменту у подоланні регуляторних, технологічних і соціальних викликів, пов'язаних із впровадженням дронів. Визначено ключові напрями управління – менеджмент ризиків, регуляторне забезпечення, планування інтеграції, розвиток людських ресурсів та операційну координацію. Особливу увагу приділено формуванню адаптивних бізнес-моделей і розвитку технічної інфраструктури, зокрема систем штучного інтелекту, відстеження в реальному часі та мереж підзарядки. Результати дослідження підкреслюють, що ефективна інтеграція дронів потребує міжфункціональної співпраці, управління інноваціями та стратегічного лідерства змін для підвищення ефективності та сталості логістичних систем.

Ключові слова: ризики безпілотних операцій, інфраструктура U-Space, підготовка персоналу, соціальне сприйняття, упровадження інновацій, регуляторне середовище

Krupskyi O.P., Ostapiuk A.F., Stasiuk Yu.M. Organizational and Managerial Factors of Drone Integration into Last-Mile Delivery. Scientific and methodical article.

The article examines the organizational and managerial factors that influence the successful integration of drones into last-mile delivery systems. It emphasizes the strategic role of management in addressing regulatory, technological, and social challenges associated with drone implementation. The study identifies key areas, including risk management, regulatory compliance, integration planning, human resource development, and operational coordination. Special attention is given to the creation of adaptive business models and the development of technical infrastructure, including AI-based navigation, real-time tracking, and charging networks. The findings highlight that effective drone integration requires cross-functional collaboration, innovation management, and strategic change leadership to enhance logistics efficiency and sustainability.

Keywords: risks of unmanned operations, U-Space infrastructure, personnel training, social perception, innovation implementation, regulatory environment

Modern logistics is undergoing a profound transformation driven by the rapid development of Industry 4.0 and artificial intelligence [1]. These technological shifts contribute to the emergence and integration of autonomous vehicles, including drones, which are considered as key catalysts for a revolution in delivery processes, especially in what is often referred to as the "last mile". The growing global volume of e-commerce [18] highlights the urgent need for efficient and innovative logistics solutions. The COVID-19 pandemic has further accelerated interest in contactless and automated delivery methods, reinforcing the relevance of drone implementation [10, 21].

Drone management in logistics offers notable advantages alongside ongoing challenges. Studies indicate that unmanned aerial vehicles reduce costs [9, 14, 19], increase operational efficiency [5, 9, 10, 13, 14, 18], and have certain environmental benefits [5, 7, 14, 15, 19]. Using drones can substantially lower operating expenses, as last-mile delivery accounts for approximately 30% of total transportation expenses [21]. Compared to traditional delivery, using UAV can reduce total delivery time by up to 20% [14]. Despite this, there are still obstacles. The main challenges include regulatory uncertainties, in particular the requirement to keep drones within visual line of sight (VLUS), while flights beyond visual line of sight (BVLOS) are complicated [3, 16]. Technical limitations such as dependence on GNSS (Global Navigation Satellite System), limited battery capacity and the complexity of route planning should also be taken into account [2, 3, 5, 8-11, 16, 19]. Last-mile delivery plays a crucial role in logistics chains and has significant potential for optimization of expenses and efficiency improvement. The high cost of this segment makes the introduction of drones not only a technological innovation but also a necessary condition for forming and maintaining a competitive advantage in the market. However, this technology has a dual nature: on the one hand, it offers vast opportunities for automation and reduction of operating expenses; on the other hand, its development is constrained by battery autonomy, payload capacity, and regulatory barriers.

At the same time, the role of management is to strategically overcome these limitations by developing a phased integration plan, forming adaptive business models, and aligning operational goals with available technical resources. Management provides comprehensive risk analysis, economic feasibility assessment, and integration of drones into business processes, which requires a high level of coordination between engineering, logistics, and regulatory subsystems. Considering the above, this study aims to identify and systematize the key organizational and managerial factors that determine the successful implementation of drones in the last-mile delivery system. The article focuses on the managerial aspects of integrating drones into business processes, emphasizing their importance for increasing the flexibility and sustainability of logistics systems.

To achieve this goal, a systematic literature review (SLR) was conducted. This approach made it possible to identify major trends, gaps in knowledge, and key concepts that are critical for drawing scientifically sound conclusions. The search for scientific sources was carried out in two authoritative databases: Semantic Scholar and Google Scholar. Most of the sources, namely 20 articles, were identified in the Semantic Scholar database, chosen for its advanced filtering capabilities, and one in Google Scholar. The search followed a plan that used keyword combinations to accurately identify relevant articles.

At the initial stage, broad and universal queries were used to identify the main body of literature: the query "drones last-mile delivery logistics" yielded 1,330 results, of which 20 were analysed and 2 relevant articles were included in the sample [16, 18]; the query "drones UAV last-mile delivery logistics" yielded 303 results, 20 of which were analyzed and 3 articles were included [2, 10, 20]; the query "drone UAV drones last-mile delivery" yielded 828 results, 30 of which were analysed and 3 articles were included in the sample [10, 19, 21]. At the next stage, a series of specialized search queries was used to analyze individual aspects of the topic in greater depth. In particular, the query "drone challenges delivery" yielded 33,100 results, from which 1 relevant article was selected after analysis [13]; "drones challenges logistics" yielded 13,700 results, with 1 article included [4]; "drone greenhouse gas emissions" – 39 600 results, with 1 article included [7]; "drone multimodal logistics" – 1 600 results, with 1 article included [6]; "drones parcel delivery" – 3 170 results, with 1 article included [8]; "drone city logistics" – 4 310 results, with 1 article included [15]; "unmanned aerial delivery vehicle" – 40 200 results, with 1 article included [12]. A series of targeted search queries was used to identify organizational and managerial aspects. In particular, the query "management multimodal logistics" yielded 15,800 results, from which 1 article was selected after analysis [3]; the query "management drones logistics" yielded 16,600 results, from which 2 relevant articles were included [9, 11]. To identify review papers that formed the theoretical basis of this study, the query "drones last-mile delivery literature review" was used, yielding 213 results, of which 30 were analyzed and 2 articles were included in the sample [1, 14]. The search covered the period from 2021 to 2025. The analysis included open-access scientific articles published in the fields of engineering, business, environmental sciences, and computer sciences. During the search, a significant overlap in results was noted between different queries, confirming the interrelatedness of the topics studied. Duplicate articles were excluded, and the analysis continued to identify additional unique works.

Thus, the final selection of 21 articles was made based on their narrow specialization and direct relevance to the research topic, i.e., identifying organizational and managerial factors in the implementation of drones in last-mile delivery. At the same time, additional scientific and analytical sources were also used to form a broader literature review, including policy reports, analyses by international organizations, and review articles, which helped to broaden the context of the analysis and provide a deeper understanding of industry trends.

Analysis of recent research and publications

The integration of drones into last-mile delivery represents complex interactions between organizational and managerial factors that significantly influence the success of their implementation and scaling [22, 23]. Last-mile delivery, the final link in the supply chain, is characterized by high expenses and significant environmental impact, making drone technology a promising solution for improving efficiency and sustainability [22, 24-26]. However, realizing these benefits requires careful consideration of internal and external organizational and managerial aspects [23].

Organizational factors encompass the internal structure, resources and competencies that determine an enterprise's readiness to implement new technologies. An important component is the development of powerful Big Data Analytics Capabilities (BDACs) [27]. The conceptual model proposed by Huynh, Nippa, and Aichner [27] highlights the following prerequisites for BDAC: basic organizational resources (data, technology, human skills) and a data-oriented culture. Human competencies (managerial, technical, business, and HR skills) are critical for the effective use of data and technology [27]. A culture based on analytics promotes organizational learning, internal knowledge development, and continuous improvement of analytical processes. In addition, resources specific to Big Data (aggregation, management and data architecture) ensure the availability and quality of data required for drone operation [27].

The process of integrating disruptive technologies, particularly drones, also depends on individual dynamic capabilities, interaction with external partners, adaptation, and the use of new ecosystem opportunities [28]. These elements, in accordance with the conceptual model of innovative technology integration, form an ecosystem-oriented business model, which is key to the effective use of drones in last-mile delivery. It is important for SMEs to develop evolutionary, devolutionary, or revolutionary digital transformation strategies, taking into account the specific features of these technologies [28].

Managerial factors relate to leadership, decision-making processes, and strategic vision. The willingness of managers to overcome information barriers and support the implementation of AI technologies is a key condition for the effective use of unmanned systems [29]. Trust and acceptance of AI decisions among managers remain important. It is necessary to have a clearly defined AI strategy aligned with overall business goals, as well as a specific implementation methodology that covers technology selection, integration with existing systems, and personnel training [29].

The model of factors influencing innovation performance emphasizes the role of entrepreneurial culture, internal organization, management style (centralization of decisions, performance-based pay), and management strategies (R&D, investment in intangible assets, financing) [30]. An entrepreneurial culture characterized by risk-taking and proactivity creates the conditions for innovation, including the introduction of drones [30]. Managers should balance short-term gains with long-term strategic goals, avoiding managerial myopia that can hinder change and company development [31].

Organizational resilience, shaped by adaptive capabilities, minimizes the impact of external uncertainty and supports strategic change [31].

Among the main challenges of integrating drones into last-mile delivery are operational safety and reliability [32], air traffic control, load capacity, regulatory support, and public perception [23]. Security and privacy risks are particularly important, as drones operate outside a controlled environment [33]. In urban environments, perceptions of drones are sensitive to technological, privacy, and functional aspects [34]. Consumer acceptance determines the success of drone delivery services and depends on factors such as perceived usefulness, privacy concerns, regulatory restrictions, and trust in the organization [35-37]. Public acceptance is critical to the implementation of urban air mobility, so public expectations should be taken into account [38].

Using drones also requires significant investment in infrastructure and its maintenance, although, according to the research, these aspects are less significant compared to proper cargo handling and regulatory compliance [18]. At the same time, proper handling of goods is considered the most important factor (62%), while investment in technology and maintenance accounts for 21% [39].

To optimize last-mile delivery, hybrid models combining trucks and drones are being actively researched [40-43]. Such systems allow trucks to be used for long-distance transport and drones for short local routes, reducing costs and increasing customer satisfaction [42, 43]. For example, a truck can deliver several drones to a specific area where they perform individual deliveries, reducing transport costs by up to 55% in the case of low flight costs ($0.01/mile) [42].

At the organizational and managerial levels, successful integration of innovation requires strong leadership, effective resource allocation and a supportive culture [44]. The research shows that these levels account for up to 32.5% of the factors that influence the quality of working life [45].

Therefore, the successful integration of drones into last-mile delivery depends on a strategic approach that encompasses both organizational capabilities (analytical infrastructure, adaptive culture) and managerial effectiveness (strategic vision, readiness for technological change, risk management systems) [27, 29, 31, 46]. Given the development of urban computing and the Internet of Drones, effective management of airspace and communications infrastructure is becoming essential, requiring a comprehensive integrated strategy [46].

The main part

Strategic factors for the implementation of drones.

The implementation of drones into logistics is a complex strategic task that requires careful consideration of regulatory frameworks, risk management systems, and integration planning processes. These factors form the basis for the successful scaling and sustainable operation of drone operations.

The framework for regulatory compliance.

One of the most significant obstacles to the widespread use of drones in logistics is the lack of adequate regulation and clear rules for applying civilian drones in airspace. [2, 4, 5, 11, 15, 18-21]. This problem is complicated by the fact that regulations are often developed independently in each country, leading to incompatible or even conflicting rules [1]. For example, in Ukraine, the legal framework does not define drones as an independent transport unit. [3]. In the USA, drones are restricted to flights only during daylight hours and below an altitude of 400 feet [11]. The restrictions also address issues related to unauthorized flights, loss of communication, cyberattacks, and physical threats [5]. Existing research highlights the urgent need to develop flexible, risk-based regulatory frameworks that take into account the specific nature of drone operations. Leading regulatory bodies, such as the Federal Aviation Administration (FAA) in the United States and the European Union (EU), are actively working to establish such rules [16]. An important organizational requirement is to include the legal department in the team developing the business case for drone implementation, as regulatory documents are one of the initial costs [17]. Successful implementation also requires approval from local authorities [13].

The effective formation of a regulatory framework requires continuous dialogue between government authorities and market participants. Businesses cannot remain passive; they must actively engage with regulators by providing information and expertise to ensure that legislation aligns with the real needs and capabilities of drones. Public authorities possess a critical resource for stimulating economic growth in this sector. Therefore, lobbying and building relationships with regulators are essential for the successful implementation of drones in delivery services.

Risk management systems.

The implementation of drones into logistics processes is accompanied by a complex set of multi-level risks, which necessitates the development and implementation of reliable risk management systems. To ensure the efficiency and safety of drone operations in last-mile delivery, it is important to identify key threats and categorize them systematically. The main types of risks are listed in Table 1.

Table 1. Classification of risks associated with the implementation of drones in last-mile delivery

Risk category	Description of risks
Security risks	Threats to public safety during flights [14], risk of drone crashes and injuries [20], collisions with other flying objects, especially near airports [3], crashes into pedestrians [3], as well as the risk of accidents or misuse [19].
Technical risks	Limited payload capacity [5, 9, 14, 18] and flight time [5, 18], insufficient battery charge [5], rotor or battery failure [5], general technical errors [11], and dependence on GPS [8, 12].
Operational risks	The impact of weather conditions [10, 11, 18], the inability to reach the destination due to obstacles, interference from birds [11], as well as problems with route planning [8, 11].
Financial risks	High cost of purchasing and maintaining drones [18], as well as high initial costs for implementing and configuring the system [12].
Data privacy and security risks	Perceived risks include privacy [21], trespassing on private property [18], cyberattacks and hacking/hijacking of drones for unauthorized purposes [2, 5, 9, 11, 19, 20], and data theft [20].
Social risks	Possible negative attitude of people due to noise or the presence of drones [14].

Source: authors' own elaboration

The risks associated with drones are not limited to technical aspects, but cover a wide range from physical safety to cybersecurity and social perception, requiring a comprehensive approach to risk management. The list of risks, which includes technical failures, weather conditions, cyber attacks, privacy, and social perception, shows that a simple technical solution will not solve all problems; an integrated strategy that takes all these risks into account is needed.

Integration planning processes.

Effective integration of drones into logistics systems requires a comprehensive and interdisciplinary approach to planning. Successful integration involves creating a team that includes stakeholders from various departments, such as accounting, procurement, IT, maintenance, aviation, security, and legal [17].

One of the key aspects is the integration of drones into existing logistics systems, particularly hybrid models that combine drones and trucks. This approach significantly reduces overall expenses (by up to 62%) and increases delivery speed [18]. The development of new logistics management software and the integration of these technologies into existing delivery networks pose certain challenges [16]. The feasibility of cooperation between drones and trucks remains an open question [19]. The study [11] provides valuable recommendations for modelling and optimizing issues related to drones and unmanned aerial vehicles (UAVs), in particular regarding the synchronization of drones with other vehicles. Infrastructure planning is also critically important, involving the need to develop a network of charging [19] or battery-swapping stations [2], which represents a significant technical and financial challenge. Coordination with external parties, such as local authorities and medical institutions (for medicine deliveries), is important for optimizing routes and take-off/landing locations [13]. In addition, integration planning should take into account the interaction between the drone and the recipient after delivery, as well as the possibility of cooperation with the courier [1].

Drone integration planning is a complex interdisciplinary project that affects nearly all aspects of a company's operations, including the involvement of multiple departments, the development of new software, synchronization with other modes of transport, and infrastructure planning.

The successful integration of drones, especially in hybrid models (drone + truck), can accelerate the transition of logistics companies to the 'logistics as a service' model. It will also enable them to offer comprehensive, optimized and high-tech services, resulting in significant cost reductions, increased speed and a sustainable competitive advantage in the market.

Elements of operational management.

Effective operational management is essential for the successful implementation of drones into logistics processes. This includes coordinating complex technical infrastructure, developing reliable safety management systems, and optimising resource allocation mechanisms.

Coordination of technical infrastructure.

Coordination of technical infrastructure is fundamental to the effective operation of drones. Using artificial intelligence-based algorithms to optimize routing directly points to the need for a developed technical infrastructure that supports such advanced technologies. [18]. An unmanned aerial system (UAS) is a complex set of components that includes the drone itself, control stations, software, monitoring systems, communication devices, data processing terminals, landing systems, launch and recovery systems, maintenance equipment, as well as storage and transportation systems [3].

Drone management software must take into account a wide range of functionalities, such as the use of GPS, APIs, audio/video sensors, 5G, 4G, LTE, Bluetooth Low Energy (BLE) communications, payload management, cloud storage, collision avoidance, and real-time HD video sharing [12]. A reliable wireless communication infrastructure is crucial for the success of drone delivery operations, while the widespread use of built-in wireless interfaces has greatly facilitated their implementation [19]. Real-time tracking systems provide greater visibility and control over the delivery process [16]. The support infrastructure includes the need to deploy a network of charging or battery-swapping stations [2]. Technical limitations, such as battery limitations, payload capacity, and flight time, are key challenges [8, 20]. Additional GPS trackers and radio frequency modules can be used to solve communication loss problems, and automatic cargo disconnection systems are also being developed [13]. The importance of software platforms such as U-Space, which include surveillance, communication and geofencing systems, is also emphasized [8].

The development of the technical infrastructure for integrating drones into last-mile delivery requires systematic interaction with technology providers, software developers, and telecom operators to create a comprehensive and adaptive ecosystem. The success of such integration depends on an organization’s ability not only to innovate, but also to integrate into the broader technological infrastructure and contribute to its development (Table 2).

Table 2. Key Technological Components of the Last-Mile Drone Delivery Ecosystem

Technology	Purpose	Strategic importance for operations
AI-algorythms	Intelligent routing optimization and flight management	A basic tool for enhancing the efficiency, accuracy, and safety of delivery
GPS trackers and radio frequency modules	Continuous tracking of drone locations and resolution of communication loss issues	Ensure the reliability and stability of flights in real time
5G, 4G, LTE, BLE-connection	High-speed wireless communication between drones, stations and control centres	Critically essential for continuous data exchange and the successful execution of operations
Programme platforms (for example, U-Space)	Centralized drone management, monitoring, and geofencing	Enable airspace coordination and ensure compliance with regulatory requirements
Real-time tracking systems	Monitoring and control of the delivery process	Increase operation transparency and optimize routes
Battery charging/replacement stations	Ensuring an uninterrupted power supply for drones	Increase autonomy, resilience and scalability of operations
Sensors (audio/video) and collision warning systems	Collecting environmental data and avoiding obstacles	Increase safety level and support autonomous navigation

Source: elaborated by the authors based on [2, 3, 8, 12, 13, 16, 18-20]

Systems for security management.

Safety is one of the most critical aspects that requires careful management when introducing drones into logistics. Ensuring public safety is a key factor that must be considered when planning drone flight paths [18]. There are a number of risks associated with the use of drones (Table 3).

Effective management of these risks requires the development of analytical methods and tools for analysing data on obstacles and ensuring safe air navigation [2]. It is also recommended to develop new security concepts, route optimization algorithms and real-time monitoring systems [11].

An important measure is to plan flight routes away from densely populated areas [13]. A positive aspect is that using drones can help to reduce traffic congestion and the overall number of accidents [2].

Table 3. Main Categories of Risks Associated with the Use of Drones in Last-Mile Delivery

Risk category	Description
Physical risks	The risk of drones falling on pedestrians [3], collisions with aircraft near airports [3], as well as risks related to the physical safety of parcels [10].
Cybersecurity risks	The Internet of Drones (IoD) network is vulnerable to cyber threats, and standard cybersecurity tools prove insufficient for its protection [10].

Source: authors’ own elaboration

The safety of drones is a complex challenge that encompasses physical, cybernetic, and operational security. It requires management systems that cover both hardware and software. Furthermore, effective safety systems are not only an operational necessity but also a critical factor in building public trust. As public concerns about drone crashes and privacy issues can undermine trust and slow implementation, security becomes not only a technical but also a social and reputational aspect.

Mechanisms for resource allocation.

Efficient resource allocation is critically important for optimizing drone operations, especially given their inherent limitations. The main technical constraints affecting resource allocation include limited payload capacity (typically up to 3-4 kg) and limited flight time/autonomy (up to 30-40 minutes) due to battery capacity [2, 3].

To adapt to these restrictions, companies can change their approach to resource use. For example, different operations may require different load capacities, and teams can adapt resources by using smaller 0.5 kg boxes instead of standard ones [13].

Managing a drone fleet, including determining its size and optimization, is a priority task [8]. Study [19] refers to research dedicated to determining the size of a drone fleet for urban delivery operations.

It is necessary to develop strategic plans that integrate drones into existing logistics workflows, particularly focusing on how to effectively manage vessels, drones, and port facilities [6].

Managers also need to consider tactical planning, such as determining the number and specifications of drones required based on transportation data [6]. Route planning is a critical aspect related to capacity management [11], and it is also necessary to balance battery weight and energy requirements to ensure sufficient range [16]. The implementation of charging docking stations for drones to improve operational sustainability is an open challenge [19]. Optimizing VRP (Vehicle Routing Problem) and capacity planning, for example, forecasting the volume of parcels for the next day, are also important aspects [10].

The limitations of drone payload capacity and flight time require companies to rethink their logistics network, transforming it from a linear structure into a more dynamic and distributed one.

This forces companies to seek innovative approaches to resource allocation, including adapting parcel sizes, optimising routes and developing new infrastructure. Efficient resource allocation and strategic hub locations are becoming critical to operational efficiency and competitiveness.

Human resource factors.

The successful implementation of drones in logistics largely depends on effective human resource management, which includes training and development programmes, approaches to change management, and adaptation of the organizational structure.

Training and development programmes.

The operations of drones require skilled technicians and operators, which in turn may lead to increased personnel costs [2]. The availability of qualified and experienced resources in the field of drone delivery is currently limited, creating a workforce shortage [2, 3, 12].

Training and raising awareness about drone technology is one of the strategies for overcoming barriers, with the aim of helping to increase public confidence in the new technology and ensuring its proper use [20]. It is necessary to ensure drone pilots' comprehensive recruitment and training and ground support operators with all the necessary skills [12]. Personnel training is an important step in helping them adapt to new technologies. Management should clearly communicate to employees how the introduction of drones will enable them to perform more valuable work, transforming their roles [17]. Key categories of personnel and their competencies for the introduction of drones in last-mile delivery are reflected in Table 4.

Table 4. Key Personnel Categories and Their Competencies for Implementing Drones in Last-Mile Delivery

Personnel category	Necessary skills/knowledge	Importance of training
Drone pilots	Piloting skills, knowledge of aviation law, navigation	Ensuring flight safety and compliance with regulations
Technicians	Service, repair, diagnostics of drones	Maintaining equipment performance, minimizing downtime
Ground support operators	Monitoring, mission management, data processing	Ensuring operational efficiency and safety
Managers	Understanding technology, change management, strategic planning	Effective implementation and integration of drones into business processes

Source: elaborated ny the authors based on [2, 3, 12, 20]

Approaches to change management.

The integration of drones and unmanned vehicles is still in its early stages of development. It requires significant research and development, and it will take some time before this technology is widely accepted and fully integrated into the industry [16]. The successful implementation of such technology requires effective communication at all levels of the organization: with managers, subordinates, and colleagues [17].

Adaptation of the organizational structure.

The introduction of drones requires significant adaptation of organizational structures to ensure effective interdisciplinary cooperation [5, 16]. Companies are already creating new divisions, such as UPS Flight Forward, to develop their drone delivery initiatives, which is a direct example of such adaptation [16]. Moreover, the proposed concepts envisage transforming the entire logistics system into a two-tier (two-level) system to improve efficiency [15]. Successful integration of drones also requires the involvement of stakeholders from various departments, including accounting, procurement, IT, maintenance, aviation, security, and legal [17]. Companies' ability to adapt their structures is essential for innovation, which will facilitate the transition from traditional hierarchical models to more flexible, networked ones, where teams are formed around projects and interdisciplinary collaboration becomes the norm. This approach allows for the rapid integration of new opportunities, as rigid structures hinder innovation, while flexible and adaptive organizations respond more quickly to change and achieve competitive advantage.

Discussion

This study aimed to identify key organizational factors for the successful integration of drones into last-mile delivery. Five main factors were identified: regulatory control, risk management, integration planning, human resources policy, and operational management. These factors form a closely interrelated system, where ignoring one of them can cause disruptions in other areas, emphasizing the need for a holistic approach. For example, regulatory uncertainty creates legal and operational risks, while technical constraints such as load capacity affect strategic decisions and integration plans. In turn, a shortage of qualified personnel can hinder risk management and the implementation of technological solutions.

The identified factors serve as a roadmap for management, allowing them to minimize risks and optimize processes. Success in this area depends on the ability to effectively balance regulatory, risk, technical, and human resource challenges. Companies that can harmoniously integrate these elements will gain a competitive advantage by offering faster, more cost-effective and reliable services, facilitating the transition to a "logistics-as-a-service" model.

The study mentions "perceived privacy risk" and ‘fear of accidents’ in risk management, but the use of drones with cameras raises deeper questions related to surveillance, collection and protection of personal data, which go beyond simple perception and require consideration of ethical dilemmas. Noise pollution and visual intrusion into residential areas can raise concerns about life quality. Companies therefore, need to develop clear ethical principles and transparency policies regarding data collection, use, and storage. Active engagement with communities on noise reduction and flight path optimization is an important part of social acceptance. The study also highlights the need for new skills and role transformation. Although new jobs are being created (pilots, technicians), traditional roles in the delivery sector, particularly truck drivers on certain routes, will inevitably be displaced. The ethical responsibility of business is to manage this transition through retraining and reskilling programmes. Companies need to develop comprehensive workforce support strategies by investing in employee training and education, which will mitigate the social impact and help to build a positive image.

The main limitation of the study is its qualitative nature, which is based on a systematic review of the literature and does not allow for a quantitative assessment of the impact of each factor. The study notes that most sources are based on the experience of developed countries, which may limit the applicability of the findings in developing countries.

In such countries, regulatory frameworks are often less developed or non-existent, making regulatory oversight particularly critical. Technical infrastructure can be underdeveloped, creating additional operational challenges. At the same time, in developing countries, less developed traditional logistics infrastructure can create opportunities for rapid drone adoption, especially in remote or underserved regions. Managers in such environments should focus on regulatory advocacy, infrastructure development, and finding unique niche applications for drones, such as delivering medicines to hard-to-reach areas.

Conclusion

The study confirms that the integtation of drones into last-mile delivery is a complex task. Despite significant advantages – cost reduction, increased efficiency and environmental benefits – implementation is accompanied by significant challenges, including regulatory uncertainty, technical limitations and a wide range of risks, from physical to cyber ones.

The success of drone integration depends not only on technological investments, but also on management’s ability to strategically manage these factors, ensuring cross-functional collaboration and proactive adaptation. The results are of practical importance for business, especially logistics companies, providing a structured model for identifying key aspects of drone implementation. The factors identified in the study form the basis for developing strategies that minimize risks, optimize processes and ensure a smooth technological transition. This allows not only to enter the drone delivery market, but also to gain a sustainable competitive advantage.

A key methodological limitation of this study is its predominantly qualitative design, which limits the ability to accurately quantify the impact of individual factors. An additional limitation is the dominance of developed countries in the sources of experience used, which narrows the possibilities for extrapolating the results obtained to emerging markets. Based on the identified limitations, promising directions for further research are: conducting quantitative analyses of the influence of key factors; studying the peculiarities of the introduction of drones, taking into account the specifics of national markets and legislative conditions, in particular Ukraine; as well as the impact analysis of public perception on the success of technological adoption via using sociological surveys.

Abstract

The article provides an in-depth analysis of the organizational and managerial factors influencing the integration of drone technology into last-mile delivery systems under the conditions of digital transformation and Industry 4.0. As e-commerce continues to expand and consumer expectations for speed and sustainability increase, drones are emerging as a promising innovation for optimizing logistics processes, reducing delivery times, and minimizing environmental impact. However, the adoption of such disruptive technologies involves not only

technical readiness but also the effective coordination of managerial decisions, organizational structures, and regulatory frameworks.

The study is based on a systematic literature review (SLR) that covered the period from 2021 to 2025, using the databases Semantic Scholar and Google Scholar. The selection process resulted in 21 specialized scientific articles, which served as the core analytical base for identifying management-related factors in drone delivery integration. These publications are narrowly focused on the topic of organizational and managerial issues in drone logistics. In addition, other academic and analytical sources, including review papers, reports, and policy documents, were used to provide broader contextual support for the literature review. The analysis included publications in the fields of engineering, business, environmental sciences, and computer science.

The research identified five key management dimensions crucial for the successful adoption of drones in logistics: regulatory control, risk management, integration planning, human resource development, and operational management. From an organizational standpoint, the study highlights the importance of developing Big Data Analytics Capabilities (BDACs), creating adaptive business models, and cultivating a data-driven culture that supports evidence-based decision-making. Cross-departmental collaboration – particularly between engineering, IT, logistics, safety, and legal units – is seen as essential for managing the complexity of drone operations and ensuring compliance with international aviation and cybersecurity standards.

At the managerial level, leadership commitment and the ability to manage change play a decisive role. The paper emphasizes that managers must promote the acceptance of AI-driven technologies, ensure ethical and regulatory compliance, and develop strategies that balance innovation with risk mitigation. Furthermore, an entrepreneurial and innovative culture fosters flexibility and long-term competitiveness, while organizational resilience enables firms to adapt to uncertainty and sustain strategic growth.

The study also addresses practical challenges in drone implementation, including air traffic management, battery endurance, payload limitations, cybersecurity threats, privacy protection, and public acceptance. Public trust and social perception are recognized as critical determinants of the scalability of drone-based delivery systems, especially in urban environments. To gain public support, companies should develop transparent communication strategies and engage communities in discussions about safety, noise levels, and data protection.

Additionally, the article examines hybrid delivery models that combine trucks and drones to optimize delivery networks. Such models demonstrate the potential for cost reductions of up to 55% compared to truck-only logistics, if infrastructure – such as charging stations, real-time tracking systems, and 5G connectivity – is sufficiently developed.

Overall, the study concludes that the integration of drones into last-mile delivery requires not only technological innovation but also strategic managerial transformation. The success of this process depends on effective governance, risk management, and human capital development within adaptive organizational structures. The findings contribute to the broader discourse on sustainable and intelligent logistics systems and offer practical insights for managers, policymakers, and researchers seeking to enhance the efficiency, safety, and resilience of future delivery ecosystems.

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