companies are actively implementing innovative technologies in their operations, which allows them to optimize transportation, warehousing, and inventory management processes. This helps to increase the competitiveness of enterprises and strengthen their market positions. At the same time, the implementation of technological innovations is accompanied by a number of challenges, which necessitates a comprehensive approach to risk management and strategic planning of the digital transformation process.

The prospects for the further development of logistics are linked to the expanded use of intelligent systems, automation, and the integration of digital solutions into unified information ecosystems. Thus, the effective implementation of modern technologies becomes a key factor in ensuring the sustainable development of enterprises and enhancing their competitiveness in the context of globalization.

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## THE LAST-MILE LOGISTICS REVOLUTION: DRONES, ROBOTS AND THE FUTURE OF URBAN DELIVERY

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*INTRODUCTION* Ask anyone who has ever waited at home for a parcel and they will tell you: the last mile is the most frustrating part of delivery. For logistics companies, it is also the most expensive. Last-mile delivery — the final step that brings a package from a local distribution centre to the customer's doorstep — accounts for

53% of total shipping costs on average, yet it covers only a small fraction of the overall transport distance [1].

The explosion of e-commerce has made this problem impossible to ignore. Global parcel volumes surpassed 160 billion shipments in 2023 and are projected to reach 256 billion by 2027 [2]. Traditional delivery methods — vans, couriers, postal services — are struggling to keep up. Traffic congestion, rising labour costs, failed delivery attempts and growing customer expectations for same-day or even same-hour delivery are pushing companies to look for radically different solutions.

Two technologies have emerged as the most promising answers: unmanned aerial vehicles (drones) and autonomous ground delivery robots. Both have moved beyond the prototype stage and are now operating in real commercial environments. This article examines how these technologies work, where they are already being used, what they cost, and what obstacles stand between them and mainstream adoption.

*WHY LAST-MILE LOGISTICS IS SO DIFFICULT* To understand why drones and robots are attracting billions of dollars in investment, it helps to first appreciate exactly what makes last-mile delivery so challenging.

*The Cost Problem* Delivering a single parcel in an urban area can cost anywhere from $8 to $20 depending on the city, distance and speed of service [3]. A significant portion of that cost is labour: a human driver can typically complete 80–120 stops per day in a dense city, but each stop requires parking, walking to the door, handling the package and dealing with access issues. Failed deliveries — when no one is home — add further cost, as the parcel must be re-routed or returned [4].

*The Congestion Problem* Delivery vans are a major contributor to urban traffic congestion. Studies in major European cities have found that logistics vehicles account for up to 25% of urban traffic while carrying only 8% of passengers [5]. As city centres grow denser and municipalities impose low-emission zones and delivery time restrictions, the viability of traditional van-based delivery is increasingly under pressure.

*The Expectation Problem* Customers today expect fast, free and flexible delivery. Amazon's Prime service has set a benchmark — next-day delivery as standard — that

competitors are compelled to match. Meeting these expectations with conventional methods requires a dense network of micro-fulfilment centres and large fleets of drivers, an infrastructure that is economically unsustainable at scale for most retailers [6].

*3. DELIVERY DRONES: TAKING TO THE SKY* Delivery drones are unmanned aerial vehicles (UAVs) designed to carry small parcels — typically up to 2–5 kg — directly to a customer's location. The concept sounds like science fiction, but it is rapidly becoming commercial reality.

*3.1. How It Works in Practice* The operational model is straightforward. A customer places an order online; the item is packed at a nearby fulfilment hub; a drone is loaded and dispatched, flying autonomously using GPS and onboard sensors to navigate to the delivery point; the parcel is either lowered on a tether or dropped in a designated landing zone; the drone returns to base. A typical delivery takes 10–30 minutes and covers a radius of up to 10–15 kilometres [7].

Alphabet's Wing division has been the most commercially active player. By 2024, Wing had completed over 350,000 commercial deliveries in Australia, Finland and the United States, partnering with retailers including Walgreens, FedEx and local grocery chains [8]. Amazon's Prime Air programme has been more cautious, facing repeated regulatory delays, but began limited commercial operations in Texas and California, delivering packages weighing up to 2.25 kg in under 60 minutes [9].

*3.2. The Economics of Drone Delivery* The business case for drones rests on the elimination of labour costs. Once the infrastructure is in place, each additional delivery costs very little — electricity for the flight, some maintenance, and software overhead. ARK Invest estimates that the marginal cost of a drone delivery could eventually fall below $0.25 per package, compared to $8–10 for a human courier [10]. However, these projections assume high delivery density and mature regulatory frameworks, neither of which exists at scale today.

*3.3. Limitations* Drones face real constraints. Payload capacity is limited; bad weather — strong winds, rain, snow — grounds fleets; battery life restricts range; and the noise generated by multi-rotor drones raises legitimate concerns in residential areas. Most critically, airspace regulation remains fragmented and complex. In the European

Union, the EASA drone regulatory framework is still evolving, and beyond-visual-line-of-sight (BVLOS) operations — essential for commercial viability — require individual waivers in most jurisdictions [11].

*4. AUTONOMOUS GROUND ROBOTS: ROLLING TO THE DOOR* While drones grab headlines, autonomous ground delivery robots are quietly proving themselves in cities and campuses around the world. These compact six-wheeled vehicles travel on pavements at pedestrian speed (typically 6 km/h), carrying parcels in an insulated compartment that opens only for the authorised recipient.

*4.1. Starship Technologies and the Pavement Revolution* Estonian start-up Starship Technologies is the undisputed leader in this space. Founded by Skype co-founders Janus Friis and Ahti Heinla, the company had completed over 7 million autonomous deliveries across the United States, United Kingdom and several European countries by the end of 2024 [12]. Its robots operate in university campuses, suburban neighbourhoods and urban high streets, delivering groceries, fast food and retail parcels within 15–30 minutes.

The economic model is compelling. A single human operator can monitor a fleet of up to 100 robots simultaneously, reducing the labour cost per delivery to a fraction of that of a traditional courier. In Milton Keynes, UK — one of Starship's most established markets — the company has achieved delivery costs comparable to or below those of human couriers for orders within a 3-kilometre radius [13].

*4.2. Other Players and Use Cases* Beyond Starship, companies including Nuro (larger road-going autonomous delivery vehicles), Serve Robotics (operating on Uber Eats in Los Angeles) and Kiwibot (active on university campuses across the US) are expanding the market. FedEx and Amazon have both tested proprietary ground robot prototypes, signalling that the technology is taken seriously at the highest levels of the logistics industry [14].

*4.3. Challenges for Ground Robots* Ground robots face their own set of obstacles. Pavements are not designed for robots: kerbs, roadworks, cyclists, and unpredictable pedestrian behaviour all create navigation challenges. In dense urban environments, a robot moving at 6 km/h can become a nuisance or even a hazard. Several cities in the

United States have passed local ordinances restricting pavement robots, citing pedestrian safety and accessibility concerns for people with disabilities [15].

*5. DRONES VS. ROBOTS: WHICH TECHNOLOGY WILL WIN?* The honest answer is: both, in different contexts. Drones and ground robots are not competing technologies — they are complementary tools suited to different delivery scenarios. Drones excel in low-density suburban or rural environments where distances are long and pavement infrastructure does not exist. A drone can cross fields, rivers and highways with equal ease. They are ideal for urgent deliveries — medicines, medical devices, emergency supplies — where speed is paramount and payload weight is low [7].

Ground robots are better suited to dense urban and campus environments with consistent pavement infrastructure. They can carry heavier loads than most drones, operate in rain and moderate wind, and are far quieter. Their slower speed is less of a disadvantage when the delivery zone is compact [12].

A realistic picture of last-mile logistics in 2030 may look something like this: a customer orders groceries from their phone; a warehouse robot picks and packs the order; a ground robot collects it and delivers it autonomously to the customer's doorstep; for a rural address or an urgent pharmaceutical item, a drone is dispatched instead. Human couriers remain for complex deliveries — large parcels, items requiring signatures, high-rise apartments — but their share of total delivery volume shrinks significantly [6, 16].

*6. CONCLUSIONS* Last-mile logistics is at an inflection point. The combination of surging e-commerce volumes, rising labour costs and mounting environmental pressure has created powerful economic incentives to automate the final delivery step. Drones and autonomous ground robots have demonstrated that they can deliver parcels reliably, cheaply and with a fraction of the carbon footprint of a diesel van.

Yet the transition will not be instantaneous. Regulatory frameworks for drone airspace and pavement robot operation are still maturing. Public acceptance — particularly regarding noise, privacy and pavement safety — requires careful management. And the infrastructure investment required to deploy these systems at

scale is substantial [11, 15].

What is clear is that the companies and cities that engage seriously with these technologies today — testing, iterating, building regulatory relationships — will be best positioned when the tipping point arrives. Last-mile logistics may never be glamorous, but it is about to become one of the most technologically exciting frontiers in the global economy.

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## PROBLEMS IN GLOBAL SUPPLY CHAINS AND POSSIBLE SOLUTIONS

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Nowadays, global supply chains play a crucial role in our everyday life. Almost everything we use is produced in different parts of the world and then delivered to consumers. This complex system connects countries, companies, and millions of people, making international trade possible.

However, despite all the advantages, global supply chains face many serious problems. In my opinion, these challenges not only complicate business operations but also directly affect people's daily lives.

First of all, one of the biggest problems is transportation delays. Goods often travel thousands of kilometers across continents, using different types of transport such as ships, trucks, trains, and airplanes. Any disruption in this process can lead to serious consequences. For example, bad weather conditions, overloaded ports, or customs issues can significantly slow down deliveries.

This problem became especially visible during the COVID-19 pandemic, when many ports and factories were temporarily closed. However, an even more striking example is Ukraine after the full-scale invasion in 2022. Due to the blockade of Black Sea ports, grain exports were severely disrupted, which affected not only Ukraine but also global food markets. Ukraine had been one of the world's leading grain exporters, supplying a significant share of wheat and corn globally [1].

As a result of the war, port operations were halted, infrastructure was damaged, and logistics routes were destroyed or blocked [2.] This caused delays, increased transportation costs, and forced many countries to look for alternative suppliers.

Another important problem is the lack of flexibility in supply chains. Many companies try to reduce costs by relying on only one or two suppliers. In my opinion, this strategy is very risky. If one supplier fails, the entire supply chain can collapse.