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DRONE APPLICATIONS IN URBAN DEVELOPMENT AND SMART CITIES: GOVERNANCE, TECHNICAL PROFILES, AND SERVICE INTEGRATION PATHWAYS

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Drones are becoming a practical component of contemporary urban development, not merely an experimental technology. Drawing on the 2024 review by Dubravova, Bures, and Velfl, this article reorganizes the evidence base on drone use into a manuscript framed explicitly for the Journal of Urban Development and Smart Cities. *The analysis emphasizes the urban service domains in which drones already demonstrate operational value: policing and traffic governance, fire and rescue operations, medical response, parcel logistics, infrastructure inspection, environmental monitoring, and emerging urban air mobility. Rather than introducing speculative scoring models or hypothetical empirical results, the article synthesizes the concrete comparative content reported in the source review, including the Czech "Rapid Response" policy context, selected technical parameters of drones used in security, rescue, and transport, and the governance conditions required for safe municipal deployment. The central argument is that the urban relevance of drones depends less on novelty than on institutional fit. Regulatory clarity, interoperable information systems, airspace coordination, cybersecurity, pilot training, stakeholder communication, and human supervision determine whether drone-enabled services become scalable public infrastructure. The article therefore develops a staged municipal integration pathway that begins with inspection and emergency applications, expands to health and logistics services, and only later advances toward passenger urban air mobility. This framing aligns drone adoption with the core concerns of urban development: resilience, infrastructure performance, mobility, public safety, and residents' quality of life.*

Index Terms — smart cities; urban development; drones; emergency management; infrastructure inspection; urban air mobility; digital twins; public safety

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INTRODUCTION

Urban development and smart-city policy increasingly depend on technologies that can improve the speed, reach, and coordination of public services. Within this broader transformation, drones have moved from a niche innovation to a credible operational tool for city governments, emergency services, infrastructure managers, logistics operators, and public safety agencies [1]. The most important urban question is no longer whether drones can fly; it is how cities can integrate them into real service systems without weakening safety, accountability, or public trust.

The review by Dubravova *et al.* provides a broad cross-domain assessment of how drones are used in security, rescue work, transport, and related smart-city functions [1]. Its value lies in its comparative scope: it links concrete applications in the Czech Republic and abroad with discussions of technical specifications, legislation, crisis management, and emerging digital systems. For a journal focused on urban development and smart cities, however, the strongest contribution of that review is not simply the cataloguing of use cases. It is the implicit lesson that drone deployment is a problem of urban governance, service design, and infrastructure integration.

This article develops that urban-development framing in a self-contained form. It removes unsupported hypothetical scoring and replaces it with source-grounded synthesis, using the original review's substantive evidence, comparative tables, and policy discussion as the basis for a cleaner and more directly applicable manuscript. The article is organized around four objectives:

- **O1.** to consolidate the principal smart-city domains in which drones already create measurable operational value;
- **O2.** to identify the governance and technical conditions that make these applications viable in urban settings;
- **O3.** to summarize the comparative technical profiles of selected drones discussed in the literature; and
- **O4.** to translate the evidence into a phased municipal integration pathway consistent with the priorities of resilient urban development.

The resulting manuscript falls clearly within the scope of the *Journal of Urban Development and Smart Cities*. It addresses urban resilience, mobility, infrastructure management, service modernization, digital governance, and the quality of life of residents—all central concerns in contemporary smart-city scholarship [1, 2].

DRONES IN URBAN SERVICE DELIVERY

Public Safety, Policing, and Traffic Governance

One of the most established urban applications of drones is public safety. In the reviewed evidence, police forces use drones to monitor road traffic on high-risk roads and motorways, document accidents from an overhead perspective, reduce incident-processing time, search for missing persons in difficult terrain, detect environmental offences, and monitor high-risk public events [1]. These are not marginal tasks. They sit at the core of everyday urban governance, where response time, visibility, and situational awareness directly affect citizen safety.

The policing examples reported in the source review demonstrate three distinct urban advantages. First, aerial visibility improves incident documentation. A traffic accident or crime scene can be captured from angles that are impossible to reconstruct reliably from the ground, which improves evidence quality and speeds operational decisions [1]. Second, drones extend the reach of police services into terrains or built environments that are difficult to access quickly, including protected landscape areas, winter cottage zones, and large event spaces [1]. Third, drones strengthen field coordination because they can transmit live video and thermal imagery to officers and command staff in real time [1].

The institutional uptake described in the review also indicates that this is not an isolated phenomenon. The article reports that more than 1,172 police departments in Minnesota use drones and reproduces statistics showing 347 U.S. agencies using drones across sheriff, police, fire, city/county, and state functions, alongside a reported 518% increase in drone use over 24 months [1]. For urban development scholars, the significance of these statistics is not merely technological diffusion; it is the incorporation of drones into the routine operating model of public authorities.

At the same time, the policing domain exposes the most immediate governance tensions. Surveillance, privacy, evidentiary use, and emergency intervention all raise questions about legal authority, proportionality, data handling, and public legitimacy. These concerns make policing one of the most operationally attractive yet institutionally sensitive areas of urban drone deployment.

Fire, Rescue, and Medical Emergency Support

The evidence is especially strong in rescue and emergency response. Firefighters use drones to identify fire outbreaks, detect obstacles that complicate intervention, locate the hottest points within a fire scene, map emergency perimeters, and support evacuation planning during large-scale incidents [1]. The practical benefit lies in the combination of overhead visibility, thermal imaging, and immediate transmission of information to the intervention commander. In emergency management terms, drones improve both the speed and the quality of command decisions.

The review also reports a distinctive Czech example: the DOFEC system, designed to support firefighting in high-rise buildings. This drone uses multiple sensors and an infrared camera to identify fire within upper floors and can discharge a half-kilogram extinguishing capsule to suppress heat and reduce fire intensity before firefighters physically reach the scene [1]. In urban-development terms, this is important because high-rise environments are among the most technically demanding and risk-intensive spaces in smart cities.

Emergency medical use is equally consequential. The source review discusses ongoing German and Swedish trials involving drone delivery of automated external defibrillators (AEDs), including a Swedish case in which the drone reached the scene in about three minutes, ahead of the ambulance, allowing resuscitation to begin sooner [1]. The review also highlights the use of drones for transporting blood, vaccines, medical devices, and time-sensitive biological cargo, including Polish projects such as AtraxM and AirVein [1]. These applications link directly to urban resilience, because they reduce the operational penalty imposed by road congestion, network disruption, and distance.

For city governments, the key implication is that rescue and medical drone services can be framed not as luxury innovation but as resilience infrastructure. They improve service reach during precisely those moments when terrestrial systems are under the greatest strain.

Logistics, Parcel Delivery, and Urban Air Mobility

The transport domain extends the smart-city case for drones from public services to broader urban mobility and supply systems. In goods delivery, drones are being tested or deployed by large logistics and retail firms such as UPS, DHL, Amazon, Walmart, and Tesco [1]. The source review reports that the number of packages delivered by drones increased by more than 80% from 2021 to 2022, reaching nearly 875,000 deliveries worldwide [1]. This is a meaningful indicator of market maturation.

The urban relevance of logistics drones lies in three areas. First, they can reduce delivery time for high-priority goods. Second, they can partially bypass traffic congestion, which is a persistent urban productivity constraint. Third, when paired with appropriate routing and charging systems, they may reduce environmental burdens associated with conventional last-mile delivery in selected contexts [1, 5].

The review also discusses passenger transport in the form of electric vertical take-off and landing aircraft (eVTOLs), linking these systems to the broader urban air mobility agenda [1]. Examples include Volocopter's VoloCity air taxi and EHang's connected aerial vehicle systems. The article reports that the global eVTOL market was valued at approximately USD 13.16 billion in 2023 and projected to reach approximately USD 38.24 billion by 2032, with an estimated compound annual growth rate of 12.58% between 2024 and 2032 [1]. Although these figures indicate economic momentum, the same review makes clear that passenger transport introduces more demanding safety, regulatory, and systems-integration requirements than smaller service drones.

From an urban-development perspective, parcel logistics is already close to operational service design, while passenger urban air mobility remains strategically relevant but more dependent on future infrastructure, regulation, and public acceptance.

Infrastructure, Environment, and Urban Monitoring

The source review also documents drone use in infrastructure and environmental management, two areas that align directly with the remit of urban development journals [1]. Drones are used to inspect bridge structures, water-management facilities, chimneys, high-rise buildings, photovoltaic panels, sewers, and pipelines. In the Czech context, the review specifically notes drone-based bridge inspection in Pilsen and drone use in water-management structures [1].

These applications are important because they reposition drones as tools of asset stewardship rather than only emergency response. Cities manage large networks of critical physical infrastructure, much of which is expensive to inspect using conventional means. Drone-based inspection can reduce access costs, improve visual coverage, and allow more frequent condition assessment.

The environmental case is similarly strong. Drones can help assess river flows, identify illegal waste dumps, inspect sewer systems, support ecological conservation, and contribute to environmental monitoring and data collection [1]. In smart-city terms, this connects drones to urban sustainability, regulatory enforcement, and environmental risk management.

GOVERNANCE AND OPERATIONAL PRECONDITIONS

Institutional Requirements for Municipal Deployment

The reviewed evidence consistently shows that the success of urban drone programs depends on governance quality at least as much as on airframe capability. The source article identifies five practical management requirements for drone use in smart cities: defining policies and standards, risk management, compliance assurance, measurement and monitoring, and stakeholder communication [1]. These are foundational institutional tasks rather than optional administrative add-ons.

A city that deploys drones without clear operating procedures risks converting a promising innovation into a liability. Policies and standards determine the legal and procedural limits of use. Risk management determines how authorities identify operational hazards and prepare contingency plans. Compliance assurance ensures conformity with local, national, and international regulation. Measurement and monitoring enable continuous service improvement. Stakeholder communication protects public legitimacy by clarifying what drones do, why they are used, and how risks are controlled [1].

This governance emphasis is consistent with the Czech "Rapid Response" concept discussed in the source review, where drone use is embedded in a broader resilience framework involving integrated security, preparedness for extreme events, technical equipment for disaster response, data integration across municipalities and regions, and coordinated action when critical infrastructure is disrupted [1, 2]. For urban development research, this is a crucial point: drones become meaningful when they are inserted into existing service systems and intergovernmental coordination structures.

Regulation, Airspace Management, and Cybersecurity

Municipal drone deployment is also shaped by airspace regulation. The source review notes that the European Union introduced a new legislative framework for all drone types in 2020, creating a harmonized classification system across EU member states, while the United States had already introduced a more unified regulatory structure through the Federal Aviation Administration in 2017 [1, 3, 4]. This regulatory background is especially important in urban environments, where airspace density, built obstacles, and competing uses make informal flight practices untenable.

The review further notes that EASA member states define geographical zones in which drones may not fly, may fly only under specified conditions, or require special authorization. In the Czech Republic, operators can use the DronView web application to prepare flights, understand local airspace, and identify conflicts in advance [1]. These measures are not merely technical conveniences. They are part of the urban governance architecture that makes safe, predictable service operation possible.

Cybersecurity adds another layer of complexity. The source review discusses hijacking, jamming, GPS spoofing, denial-of-service attacks, supply-chain vulnerabilities, and botnet risks, while also noting that drones can become weak entry points into wider digital networks when their own security is underdeveloped [1]. For smart cities, which rely on interconnected information systems, this means drone procurement cannot be separated from cybersecurity design, software governance, and network integrity.

Digital Twins, Electronic Conspicuity, and Human Supervision

A particularly important contribution of the source review is its discussion of advanced digital integration. It identifies electronic conspicuity (EC) as a technology that improves airspace safety by transmitting live information such as GPS position and speed, thereby enhancing "detect and be detected" capability in addition to traditional visual separation [1]. In dense urban areas, where low-altitude operations may involve multiple drones and complex obstacles, EC has clear value for collision avoidance and emergency coordination.

The article also links EC to the broader concept of digital twins. In this context, digital twins provide real-time simulation and visualization of traffic and infrastructure conditions, enabling predictive control, conflict anticipation, and more effective response to emergencies [1]. The review extends this argument by discussing teleoperation, telemanipulation, and the integration of human operators into autonomous systems. This human-in-the-loop principle is particularly important for urban deployments, where ethical judgment, situational nuance, and accountability remain essential even as automation expands.

Finally, the review highlights swarm technologies and the SHARKS protocol as examples of how coordinated multi-agent systems could support tasks such as infrastructure maintenance without relying on a single centralized control point [1]. For urban development scholars, the implication is clear: the long-term value of drones will depend on how well they are embedded in digital governance systems, not only on how well they fly.

COMPARATIVE TECHNICAL PROFILES FOR SMART-CITY DEPLOYMENT

The source review compares drones used in policing, rescue work, and transport using six recurrent parameters: maximum take-off time, range, carrying capacity, speed, flight altitude, and weight [1]. These variables matter because urban missions differ sharply. A drone suited to static inspection is not automatically well suited to emergency response, and a platform capable of long-range logistics may not be ideal for dense urban maneuvering.

Table 1 summarizes the rapid-response objectives in the Czech smart-city framework that provide the institutional context for drone adoption. Tables 2 and 3 then consolidate selected technical parameters reported in the source review. These tables do not claim universal superiority of one platform over another; instead, they illustrate the practical variation that municipalities must account for when matching platforms to service needs.

Table 1: Rapid-response objectives in the Czech smart-city resilience framework

No.	Objective
1	Integrated security is developed at both vertical and horizontal levels.
2	Municipalities and regions are prepared for extreme weather events.
3	Cities, municipalities, and regions require technical equipment to cope with natural and anthropogenic disasters and other accidental events.
4	Data integration among municipalities, cities, regions, and their organizational units should be systematic and efficient, supported by innovative security technologies and approaches.
5	Systematic coordination is required when critical infrastructure elements are disrupted.

Adapted from the rapid-response framework discussed by Dubravova *et al.* [1].

Table 2: Selected technical parameters of drones used in security and rescue operations

Sector	**Drone type**	**Take-off (min)**	**Range**	**Payload (kg)**	**Speed (km/h)**	**Weight (kg)**
Police	Brinc Lemur S	31	13 km	0.45	80.5	1.1
Police	DJI Matrice 300 RTK	40	15 km	2.7	83	6.3
Police	DJI Mavic 2 Enterprise Advanced	30	10 km	n/a	72	0.909
Police	Autel Evo II Dual R	38	9 km	0.92	72	1.15
Police	DJI Matrice 200 V2	38	8 km	6.4	81	4.69
Police	BRUS	40	10 km	10.0	60	4.5
Rescue	Matrice 30 T	41	7 km	n/a	82	3.77
Rescue	Matrice 200	38	8 km	1.45	81	4.69
Rescue	Matrice 300	55	15 km	2.7	83	6.30
Rescue	Knight Hawk	180	120 km	n/a	150	n/a
Rescue	DOFEC	25	n/a	n/a	70	n/a

Condensed from the comparative tables reported by Dubravova *et al.* [1]. Values are presented as reported in the source review; “n/a” indicates that the source table did not specify a public value.

Table 3: Selected transport and urban air mobility platforms

Platform	**Take-off (min)**	**Range (km)**	**Capacity**	**Speed (km/h)**	**Weight (kg)**
CityAirbus NextGen	15	80	4 persons	120	n/a
Electricity VTOL	180	200	2 persons	80	4
SQA eVTOL	120	180	n/a	86.4	9.8
Wingcopter 198	75	94	4.7 kg	90	25

Adapted from the transport comparison presented by Dubravova *et al.* [1].

The comparative evidence suggests a basic urban-design principle. There is no single “best” drone category for all municipal purposes. Compact multi-rotor systems are valuable for precision observation, quick deployment, and hovering in dense built environments. Larger and longer-range systems are better suited to extended mapping, firefighting support, and logistics. Passenger-oriented eVTOL platforms belong to a different infrastructural category altogether because they implicate vertiports, airspace separation, passenger safety, and wider mobility planning.

A MUNICIPAL INTEGRATION PATHWAY FOR URBAN DEVELOPMENT

The literature reviewed by Dubravova *et al.* does not support indiscriminate deployment across all possible uses at once. A more credible urban strategy is phased integration. Figure 1 summarizes a practical sequencing logic that follows directly from the service domains and governance demands discussed above.

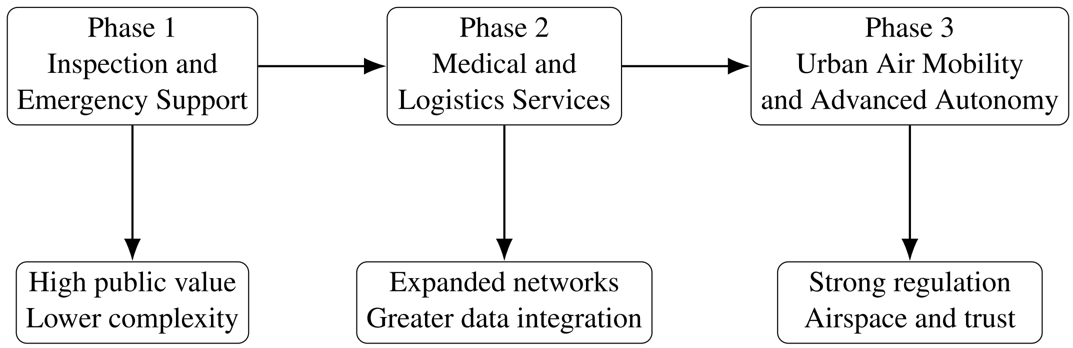

Figure 1: A phased pathway for integrating drones into urban service systems

Phase 1: inspection and emergency support. The most immediate candidates for municipal adoption are infrastructure inspection, environmental monitoring, fire-scene assessment, and tightly bounded public-safety missions. These applications have a clear public-interest rationale, produce fast operational gains, and can often be piloted within existing departmental structures [1].

Phase 2: medical and logistics services. Once cities establish operating protocols, data-sharing procedures, and airspace coordination, they can move into drone-enabled delivery of medical supplies, blood, AEDs, and selected parcel services. These uses require more mature routing, payload, and coordination capabilities than inspection tasks, but they remain directly aligned with urban service efficiency and resilience [1].

Phase 3: urban air mobility and advanced autonomy. Passenger eVTOL services, dense low-altitude traffic systems, and highly autonomous multi-agent operations should be treated as later-stage developments. They depend on stronger regulatory certainty, higher cybersecurity assurance, formalized traffic management, public acceptance, and a more advanced digital operating environment, including electronic conspicuity and digital twins [1].

This phased approach is particularly suitable for urban development policy because it ties technological adoption to service maturity, institutional capacity, and infrastructure readiness. It discourages symbolic innovation while supporting cumulative learning.

DISCUSSION

Three broader implications follow from the evidence.

First, drones should be understood as part of urban service infrastructure rather than as stand-alone gadgets. Their value emerges when they improve how cities inspect assets, manage emergencies, move critical goods, monitor environmental risk, and coordinate data-intensive operations [1]. This makes drones relevant not only to technology policy but also to planning, public administration, transport management, and resilience studies.

Second, the institutional bottleneck is often more important than the technical one. The reviewed literature repeatedly returns to training, regulatory compliance, cybersecurity, interoperability, and stakeholder communication. In practice, a city with weaker governance capacity may fail with an advanced drone platform, while a city with stronger coordination and clearer procedures may achieve substantial benefits using relatively conventional systems.

Third, the pace of adoption is shaped by political economy. The source review notes that the overall approach to expanding drones in the Czech Republic has been slower than in some larger foreign cities, partly because of financial costs, demographic scale, and competing budget priorities. At the same time, the review points to substantial scientific and institutional activity, including more than 600 implemented projects recorded in the Starfos database on related themes [1]. This combination of slower operational rollout and active research investment is instructive for other cities: strategic capacity can develop before full-scale deployment, but durable implementation still requires budget alignment and national support.

CONCLUSION

Drones are becoming an increasingly important component of urban development and smart-city practice because they improve the reach, responsiveness, and information quality of public and private services. The strongest evidence currently supports their use in policing and traffic governance, fire and rescue operations, emergency medical support, logistics, infrastructure inspection, and environmental monitoring. These domains connect directly to the core aims of contemporary smart cities: resilience, safety, efficiency, sustainability, and improved quality of life.

The evidence also makes clear that successful deployment depends on more than flight capability. Cities need coherent policy frameworks, regulatory compliance, secure digital integration, interoperable information systems, trained operators, and transparent communication with residents. Advanced tools such as electronic conspicuity, digital twins, teleoperation, and supervised autonomy are likely to become increasingly important as urban drone ecosystems become denser and more complex.

For urban policy and planning, the most credible path is staged integration. Municipalities should begin with high-value, lower-complexity uses such as inspection and emergency support, then expand into medical and logistics services, and only later consider passenger urban air mobility and more autonomous traffic systems. In that sequence, drones cease to be a novelty and become part of the working infrastructure of the smart city.

DATA AVAILABILITY

No new primary dataset was created for this article. The technical values, policy elements, and service examples synthesized here are drawn from the published review and cited sources discussed in the manuscript.

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