

# Research on Spatial Integration Design of Unmanned Aerial Vehicle Facilities in Future Communities under the Background of Low-Altitude Economy

## -- Taking Hangzhou Cloud City as an Example

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### ABSTRACT

The rapid development of the low-altitude economy and the construction of future communities have created an urgent need for the spatial integration of drone facilities and residential buildings. Existing research mainly focuses on airspace management, industrial economics, and technical engineering, while research on the spatial integration of drone landing facilities from the perspective of architecture and urban planning is still lacking. This study proposes the concept of "vertical logistics interface" and constructs a typological framework of "building-drone" interface types such as rooftop, facade, and balcony. Based on the four-dimensional coupling analysis of "drone type-facility-population-policy", it establishes six design principles: technology adaptability, population friendliness, structural safety, spatial embedding, dual-use (normal and emergency), and intelligent interconnection. It proposes a "2+N" distributed network strategy to address the pain points of existing public take-off and landing fields, such as end-point gaps, land occupation, and functional isolation. Taking Hangzhou Yuncheng Hangteng Future Community as an example, the spatial integration design of two rooftop integrated hubs and N building micro-platforms was completed. The pioneering use of balcony retractable landing panels to achieve direct drone delivery indoors was achieved, constructing a three-dimensional integrated logistics network of "underground-ground-low altitude", providing a reference design idea for the construction of future communities in pilot cities of the low-altitude economy.

### KEYWORDS

Low-altitude Economy; Future Community; Drone Infrastructure; Spatial Integration; Vertical Logistics Interface.

## 1. INTRODUCTION

### 1.1. Research Background

As drone technology drives the transformation of urban space from "two-dimensional" to "three-dimensional," the low-altitude economy has become an important component of national strategy[1]. Relevant policies in Hangzhou explicitly include future communities as key nodes in the low-altitude delivery network, providing a practical field for the interface design of drone facilities and residential buildings. However, while future communities emphasize "human-centeredness, digitalization, and ecology," their ground logistics and emergency response systems still have shortcomings, and three-

dimensional space resources are not fully utilized. Furthermore, existing research largely focuses on airspace management, industrial economics, and technical engineering, with a lack of research on the spatial integration of drone landing facilities from an architectural and urban planning perspective, lacking systematic design guidance on structural reservations, vertical connections, and noise control. This study aims to address this dual theoretical and practical need by exploring the spatial integration mechanism of drone facilities in future communities from an architectural perspective.

## **1.2. Significance of the Research**

The theoretical value of this research lies in expanding the boundaries of architectural research, proposing the concept tool of "vertical logistics interface," constructing a typological framework of "architecture-drone" interfaces such as rooftop, facade, and balcony types, and promoting the interdisciplinary translation of external logics such as airspace management and industrial policy into architectural spatial issues. Its applied value is reflected in three levels: directly serving the planning management and design guidance of the high-intensity development of Hangzhou Cloud City TOD; providing technical reference for the acceptance of "smart logistics" scenarios in future communities in Zhejiang Province and the updating of industry standards; and using the experience of Cloud City's "pilot zone" to provide replicable and adaptable design paradigms for low-altitude economy pilot cities in the Yangtze River Delta and even nationwide, helping to transform policy objectives from "indicator planning" to "spatial implementation." The theoretical framework for drone facilities in future communities.

## **2. THEORETICAL BASIS**

### **2.1. The Connotation and Characteristics of Future Communities**

The Future Community is an urban development concept proposed by Zhejiang Province in 2019. Its core lies in centering on people's pursuit of a better life, creating new urban functional units with a sense of belonging, comfort, and a futuristic feel through the three-dimensional integration of "space, scenario, and governance." Spatially, the planning units break through the boundaries of traditional residential communities, integrating residential, industrial, service, and ecological functions. In terms of scenarios, it constructs nine major living and governance scenarios, including smart logistics, education, health, transportation, and low-carbon initiatives. In terms of governance, it advocates a "platform + steward" model led by Party building and characterized by multi-party collaboration, achieving integrated construction, operation, and maintenance, as well as sustainability[2].

The future community is closely coupled with the low-altitude economy: high-density mixed development provides diverse drone access points such as rooftops, facades, and terraces; digital twins and all-domain perception support aircraft navigation and safety monitoring; smart logistics, low-carbon travel, and emergency inspection scenarios clearly define the application needs of drones; policy support and empowerment of "first-fly zones" form institutional dividends, providing a forward-looking empirical field for the design of building-drone interfaces.

### **2.2. Research on Technology and Facility Types**

With the continuous iteration of aerospace propulsion technology, intelligent control algorithms, and mission payload systems, unmanned aerial vehicle (UAV) platforms are showing a significant trend of differentiation, with their design shifting from a single-function orientation to a more refined division of labor adapted to multiple scenarios. Their scope has far exceeded the traditional understanding of small rotorcraft, represented by consumer-grade aerial photography drones, but rather encompasses a full spectrum of aircraft, from micro racing drones to large cargo drones.

The current core classification framework for unmanned aerial vehicles (UAVs) still fundamentally distinguishes between military and civilian applications; this study focuses on the latter. Civilian UAVs are deeply embedded in socio-economic operations, and their technological iterations and scenario expansions are reshaping the spatiotemporal structure of urban daily life, directly and profoundly impacting the spatial organization and functional configuration of future communities. Based on mission attributes and operational characteristics, existing civilian UAVs can be further subdivided into the following categories, and accordingly, a model series adapted to future community scenarios can be identified.

**Table 1.** Core Classification of Unmanned Aerial Vehicles

type	Features	Application scenarios
Military drones	High performance requirements, strong concealment, and high level of intelligence	Battlefield reconnaissance, target engagement, electronic jamming, communications relay, etc.
Consumer drones	Easy to operate, reasonably priced, and with a focus on shooting functions.	Personal aerial photography, recreational flying, and creative photography
Industrial drones	Long battery life, large payload, high reliability, and customizable	Agricultural plant protection, power line inspection, surveying and mapping, logistics and transportation, emergency rescue

Based on a systematic review of the current mainstream models in the market, civilian drones can be divided into six categories according to their core functions: agricultural plant protection, inspection and endurance, surveying and mapping, emergency rescue, logistics and transportation, and aerial photography. This forms the basis of the model spectrum for the needs analysis in this study[3].

**Table 2.** drone functions

Functional type	Core payload	Major customers	Market size and position
Agricultural plant protection	Spraying system, multispectral camera	Agricultural cooperatives and plant protection service companies	Largest market
Inspection and patrol	Infrared cameras, lidar	Power, oil, and transportation companies	Second largest market
Surveying and mapping	Orthophoto camera, LiDAR	Surveying and mapping institutes, construction companies, and land and resources departments	Stable growth
Emergency Rescue	Thermal imaging and communication equipment	Emergency management departments, fire departments, and public security departments	High-speed growth
Logistics and Transportation	Cargo hold, launcher	Logistics companies, e-commerce platforms	Greatest potential
Aerial photography	Gimbal camera	Individual consumers, film and television production	Consumer-driven

Among them, agricultural plant protection drones are concentrated in suburban farmland, with limited spatial overlap with urban residential communities; surveying and mapping drones mainly serve spatial data collection during the planning and construction phase, with weak relevance to daily community operations; aerial photography drones are geared towards individual image consumption

and lack functionality; while inspection and long-endurance drones can adapt to the future needs of community public facility operation and maintenance and building safety management; emergency rescue drones can serve as aerial support units for emergency management systems; and logistics and transportation drones, typically last-mile delivery drones, are characterized by high frequency, point-to-point, and immediate response, directly corresponding to the "last mile" logistics scenarios of future communities. The above classification indicates that logistics and transportation drones and inspection and long-endurance drones have the highest compatibility with the functional needs of future community daily operations. The former directly drives the necessity of configuring drone docking facilities in residential buildings, while the latter provides a technical basis for the multi-faceted design of facilities and the reservation of dual-use for both normal and emergency situations.

### **2.3. Community Scenarios and Needs Research**

The demand for drones in future communities is rooted in the three-dimensional operational logic of "space-scenario-governance," exhibiting dual characteristics of functional differentiation and system integration. In logistics and delivery, drones transform buildings from "passive logistics terminals" to "active nodes of an integrated air-ground network," requiring pre-installed interfaces on rooftops, balconies, and equipment platforms. In health and elderly care, drones construct a low-altitude medical logistics and emergency monitoring network, necessitating building transformation from "service consumption venues" to "distributed medical-elderly care nodes" with rooftop and medical unit interfaces. In emergency services, drones provide vertical redundancy independent of ground transportation, enabling communication relay, material delivery, and reconnaissance; buildings must evolve from "passive protection objects" to "active emergency support nodes" with pre-set dispatch interfaces on rooftops and refuge floors. In security patrols, drones build programmable aerial monitoring networks, driving community security from "passive monitoring" to "proactive risk perception," requiring rooftop and podium interfaces for take-off, landing, and data transmission.

These four scenarios converge on a core proposition: buildings must transform from "end-consumption venues" or "passive protection objects" into "active nodes" of integrated air-ground networks, achieving technological integration with logistics, health, emergency, and security systems through pre-set drone interfaces. The heterogeneous community structure-differentiated by age, income, and building type-determines significant demand stratification. Younger residents prefer high-frequency instant delivery; middle-aged groups prioritize family health and emergency preparedness; elderly users demand ease-of-use and rapid response with low tolerance for noise and privacy intrusion. High-income groups seek customized exclusive services; middle-income groups rely on shared standardized supply; low-income groups focus on public welfare accessibility. High-rise buildings emphasize rooftop hub connections and vertical rescue; multi-story and villa communities suit distributed micro-hubs and in-home direct access; mixed-use buildings require multi-functional hubs and time-sharing airspace management. This stratification necessitates demand-oriented, differentiated configuration standards to avoid structural mismatch between technological supply and population needs.

## **3. DESIGN PRINCIPLES FOR DRONE FACILITIES IN FUTURE COMMUNITIES**

The design of future community drone facilities needs to take into account four types of external constraints: policy compliance, technical parameters, user needs, and building conditions, forming a multi-dimensional coupled decision-making framework.

At the policy level, the national "Interim Regulations on the Management of Unmanned Aerial Vehicle Flights" and CCAR-92 have established basic systems such as airspace approval and operational qualifications. At the local level, the technical guidelines of Guangzhou and Shenzhen

serve as leading references, covering regulations on design classification, size loads and supporting facilities, providing a basis for the legality and compliance of facility construction.

From a technical perspective, it is necessary to establish a "model-facility" matching logic. Taking the operational practices in Shenzhen and Guangzhou as examples, the technical parameters of mainstream models such as Meituan FP400 V4 for logistics and Fengyi ARK80 for passenger transport, and EHang EH216-S for passenger transport, directly determine the scale threshold, load standards and supporting requirements of the take-off and landing field, constituting a rigid constraint on the spatial configuration of the building.

At the user and building level, the core stakeholders of the community include property management and residents. It is necessary to understand their functional needs and management concerns through field surveys. At the same time, we should return to the building itself and conduct multi-dimensional assessments of potential take-off and landing points such as roof, facade, and balcony, including structural bearing capacity, airspace accessibility, and noise sensitivity distance. We should compare the technical and economic characteristics of different models, select the best construction plan, and achieve a balance between technical feasibility and social acceptability.

The above four conditions are not linearly superimposed, but rather form a dynamically coupled design decision network through a multi-directional feedback mechanism of "policy defining the legal boundaries - technology specifying physical thresholds - users adjusting the quality of experience - building feedback on spatial feasibility".

Based on a multi-dimensional coupled analysis of aircraft parameters, airspace rules, building codes, community governance, and regional policies, this study establishes six core design principles.

The principle of technical adaptation emphasizes both rigid constraints and flexible reserves: the structural load is designed to be no less than  $3.5\text{kN/m}^2$ , the clearance height is controlled to be more than 1.3 times the rotor diameter, the power system is equipped with dual circuits, and a modular take-off and landing platform is adopted to adapt to model iteration.

The principle of being people-friendly seeks a balance between efficiency and perceived safety: low-noise blades, sound-absorbing barriers and physical isolation reduce safety anxiety and noise interference; cameras are shielded downwards and data is processed locally; information signs are set up in public areas to ensure the right to know; and indoor pickup points are located near transportation hubs and equipped with real-time tracking systems.

The structural safety principle achieves a balance between local reinforcement and overall protection: existing buildings adopt cantilevered elevated platforms to minimize intervention, new projects pre-load the roof with a  $5.0\text{kN/m}^2$  load and pre-embed pipeline interfaces, and rubber vibration isolation pads are installed in the landing zone to reduce vibration transmission.

The principle of spatial embedding promotes functional integration and visual dissolution: the roof zoning strategy separates take-off and landing functions from landscape functions, the facade receiving and sending platform is integrated with the curtain wall, the independent logistics core is physically separated from the passenger elevator, and the take-off and landing area is used as an equipment maintenance and photovoltaic energy storage carrier.

The principle of dual-use for both normal and emergency operations takes into account both daily operations and emergency conversion: the roof is reserved with mooring seats and quick loading and unloading interfaces, the charging facilities are linked to the emergency power supply, the logistics core can be converted into an evacuation channel in an emergency, and the flight data is synchronized to the city's emergency management platform.

The principle of intelligent interconnection enables facilities as nodes and digital twins: it reserves the conditions for 5G-A base station installation, configures edge computing servers to reduce cloud

latency, supports emergency autonomous landing decisions, and makes drone facilities a key interface between building intelligent systems and the city's digital foundation[4].

## 4. FUTURE COMMUNITY DRONE FACILITY DESIGN STRATEGY

### 4.1. Case Analysis of Existing UAV Take-off and Landing Sites

#### 4.1.1. Drone Take-off and Landing Field on the Rooftop of Hangzhou Wulin Hospital

After the airport staff loads the delivery items from the riders into the drone's cargo container, the drone takes off smoothly and arrives at the Shenhua airport, about 8 kilometers away in a straight line, in about 10 minutes. Then, the last-mile delivery riders complete the "last mile" delivery, delivering the items to the user.

#### 4.1.2. Dream Town Hub-type Public Drone Take-off and Landing Field in Yuhang District

The take-off and landing site is located on the second floor of the multi-story parking garage in the north of the Entrepreneurship Market, covering an area of approximately 1,500 square meters. It has 12 standard take-off and landing units and one emergency landing point. Currently, several drone operating companies, including Xunyi Technology, Yunyuan Technology, and Fengyi Technology, have set up operations at the Dream Town take-off and landing site and have opened multiple logistics and distribution routes for their daily transportation needs.



**Figure 1.** Hub-type public drone take-off and landing field in Dream Town, Yuhang District(Image source:tidenews.com)

#### 4.1.3. Xiaoshan Qianjiang Century City Public Take-off and Landing Site

The take-off and landing point is located at one end of Hangzhou's first drone delivery route, and the other end is at the SF Express sorting point in the Sanbao Internet Building. This route covers a distance of 7.5 kilometers and takes approximately 11 minutes. Operated by SF Express's subsidiary, Fengyi Technology, it primarily transports SF Express's same-city, cross-river urgent and express parcels. After drone delivery was launched, once the courier in Sanbao completes loading and takes off the drone, staff at the Qianjiang Century City public take-off and landing area immediately receive the notification. After the drone lands, staff at the take-off and landing area unload the goods and hand them over to the SF Express courier, who then delivers them directly to the recipient.

Based on the above case analysis, the existing take-off and landing fields still have some shortcomings.

The "last mile" gap in last-mile delivery is a significant challenge. Public drone landing pads typically have a service radius of 1.5-3 kilometers, meaning goods still require manual transfer to residents after arrival. Taking the Wulin Hospital route as an example, drone delivery is only available to users within a 1.5-kilometer radius of the landing pad; deliveries outside this range are unavailable. This

lengthens the "30-minute instant delivery" promise at the last mile, weakening the time-sensitive advantage of high-frequency orders. Furthermore, existing community drone services are not yet widely available to meet individual needs[5].

Land resource constraints and site selection . Based on existing experience with drone take-off and landing, a single hub-type take-off and landing site requires 1,000-1,500 square meters of land. In the context of high-density development in the main urban area, the cost of acquiring independent land is extremely high. The rooftop and facade spaces of individual communities are fragmented and numerous. If these spaces can be utilized, they will bring a new pattern to the layout of existing drone take-off and landing sites.

Physically separated from residential functions , public take-off and landing sites deliberately avoid residential areas to reduce the risk of noise complaints, but this also means losing deep integration with daily community services. However, if the existing spaces such as rooftops, facades, and parking lots of high-density communities can be utilized, it will not only greatly improve land utilization but also bring a qualitative leap to the drone service experience.

## **4.2. Design Strategy for Integrated Take-Off and Landing Fields in Communities**

### **4.2.1. Preliminary Preparations**

Deploying drones that are adapted to community functions requires completing three core tasks: "demand research, compliance approval, and equipment selection".

First, at the demand research level, core parameters are clarified through on-site surveys and stakeholder interviews. Taking logistics functions as an example, it is necessary to define the service coverage radius, peak daily order volume, and single delivery time (15-30 minutes), based on which the number of stops and route density are calculated[6].

Second, compliance approvals cover three dimensions: airspace, buildings, and communications. Regarding airspace, applications must be submitted through the UOM platform, specifying the docking point coordinates, flight altitude (below 120 meters true altitude), and flight path. Regular delivery requires a long-term permit. Regarding buildings, the use of rooftops, facades, and other common areas requires approval by a "double 3/4" vote of the owners' assembly, in accordance with Article 278 of the Civil Code. Structural modifications or power capacity increases require construction registration, and the load must meet the standard of  $\geq 3.0\text{kN}/\text{m}^2$  . Regarding communications, public network transmission requires a dedicated data card, and community private networks must comply with the regulations of the Communications Administration Bureau.

Third, equipment selection is divided into two categories: core equipment and supporting equipment. Core equipment prioritizes multi-rotor aircraft with noise levels  $\leq 60\text{dB}$  and payloads of 3-10kg, equipped with automated docking mechanisms, intelligent cargo holds, and robotic arm loading/unloading devices; the management platform supports order aggregation, dynamic route planning, and integration with the community's digital twin system. Supporting equipment utilizes a dual-circuit power supply of both mains power and photovoltaic energy storage, is equipped with 5G-A signal boosters to ensure coverage of high-rise buildings, and deploys infrared monitoring and audible/visual alarm devices. Furthermore, safety redundancy must be reserved for structural load testing, lightning protection grounding, fall protection nets, and emergency landing buffers to ensure long-term coordinated operation of the facilities and the building itself.

### **4.2.2. Equipment and Construction**

Drone take-off and landing pad facilities:

A take-off and landing platform that meets aviation operation standards must be built on the rooftop or in a designated area; it must be equipped with anti-slip ground, dynamic guide lights, millimeter-wave radar and other intelligent sensing equipment to ensure the safe take-off and landing of drones.



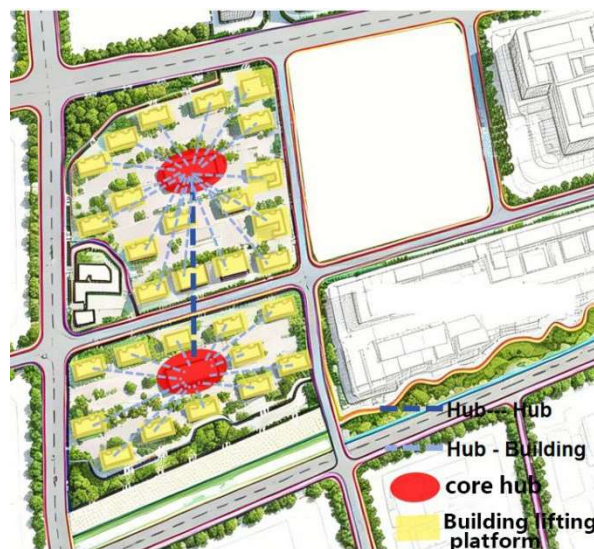
Zhejiang Province and the first future community practice area in Cloud City. The project is built above Longzhou North Road Station of Metro Line 3, providing direct access to Hangzhou West Railway Station. The plan aims to achieve an efficient living system of "five minutes to the metro station, five minutes to West Railway Station, five minutes to the expressway, five minutes to the complex, and five minutes to the school," forming a "mini-city" style TOD (Transit-Oriented Development) above-ground development pattern.

The surrounding architectural environment exhibits a high-intensity and highly complex spatial characteristic. To the north, it is adjacent to the core area of Hangzhou West Railway Station, a complex with a total area of approximately 1.3 million square meters, comprising two major complexes (north and south) and a planned 399.8-meter landmark skyscraper, dubbed the "Golden Finger ." To the west lies the East-West Avenue urban expressway, to the east, the planned river channel of Luting Road forms a waterfront green corridor, and to the south , the Yuhangtang River constitutes an ecological boundary. The site is surrounded by rivers on all four sides, forming a relatively independent planning unit . Industrial resources are highly concentrated, with surrounding areas including the Zhejiang University Alumni Enterprise Headquarters Economic Park, Zhejiang Talent Building, Supergravity Laboratory, and other science and technology innovation platforms, as well as research bases such as Westlake University and Yung Valley Industrial Park.

From the perspective of spatial conditions for drone deployment, the Hangteng Future Community has three key characteristics: First, the buildings are concentrated in height, with 21-26 story high-rise residential buildings providing ample elevation resources and flight path visibility for the rooftop helipad, but the airspace restrictions of the West Railway Station hub's airspace must be avoided; second, the TOD (Transit-Oriented Development) model allows for vertical integration of underground space with the subway system, reserving structural interfaces for the integration of vertical logistics channels; third, the ecological pattern of being surrounded by rivers on all sides and a 35% green space ratio provides natural conditions for noise buffering and visual concealment of facilities, but the waterfront wind environment places additional demands on the stability of drone take-off and landing. The surrounding 200-meter-class super high-rise building clusters (such as the West Railway Station complex and the Zhejiang Talent Building) pose significant electromagnetic environment and airspace coordination challenges, requiring careful avoidance in flight path planning.

## 5.2. Spatial Integration Design Scheme

### 5.2.1. Overall Layout



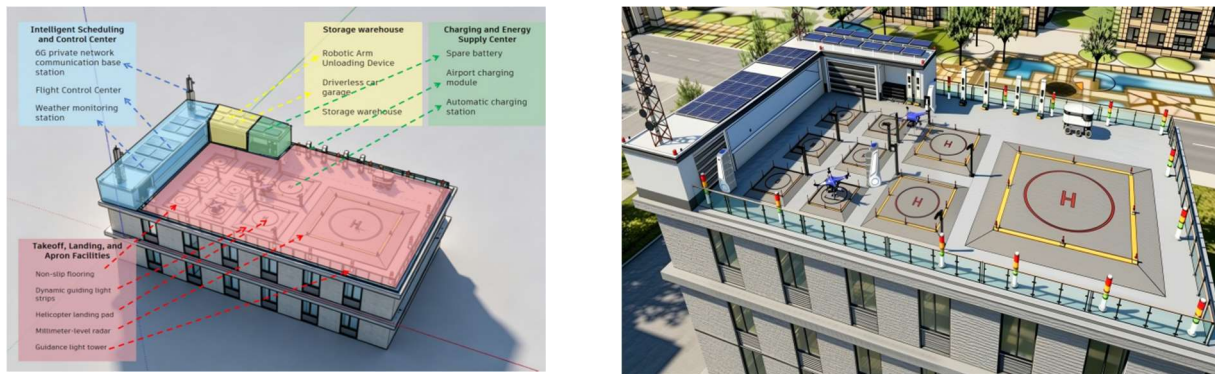
**Figure 3.** Community drone network(Image source: Author's own drawin)

Based on the spatial characteristics of the Hangteng Future Community, namely "high-intensity TOD development + ecological pattern of being surrounded by rivers on all four sides", this plan proposes a "2+N" distributed network architecture: namely, 2 comprehensive hubs + N building micro platforms, forming a three-level vertical logistics system of "hub distribution - building connection - direct access within the household".

In terms of airspace organization, the integrated hub undertakes the trunk logistics transfer function across communities and urban areas, connecting with Hangzhou West Railway Station hub and city-level drone routes; the building micro-platform is responsible for branch line delivery and last-mile delivery within the community. The route design follows a grid layout of "east-west main channel + north-south branch line". The main channel is set up along the east-west avenue, and the branch lines cut in perpendicular to the direction of the river, making full use of the open airspace above the river and avoiding electromagnetic interference and wind shear risks in densely built-up areas.

The core concept of this solution is the three-dimensional separation of ground-level and low-altitude logistics lines. By reserving vertical logistics cores in the underground space of TOD (Transit-Oriented Development), seamless connection between subway freight, unmanned vehicle delivery, and drone take-off and landing can be achieved, constructing a three-dimensional integrated logistics network of "underground-ground-low-altitude".

### 5.2.2. Integrated Hub Design



**Figure 4.** Core Hub Diagram(Image source: Author's own drawin)

The rooftop integrated hub, positioned as the geometric center and visual focal point of the community, offers 360° airspace accessibility and maintains an equidistant service radius to surrounding buildings. Vertically stacking four functional modules-take-off and landing apron, intelligent dispatch center, storage warehouse, and charging facility-on a single roof, the hub achieves spatial consolidation of aerial operations.

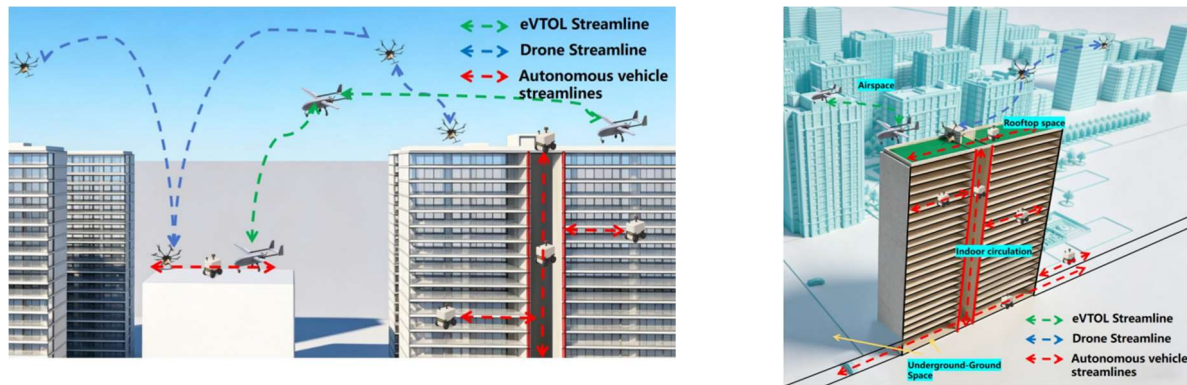
The rooftop is partitioned into four zones: take-off and landing area (60%), intelligent dispatch center (15%), unmanned vehicle garage and sorting system (15%), and charging center (10%). The apron employs anti-slip paving with a surface friction coefficient  $\geq 0.6$ , perimeter dynamic guidance lights with low-illuminance red-light mode for nighttime operation, and core berths equipped with millimeter-wave radar and all-weather beacons. Parking positions are scaled in three tiers: 10m×10m for eVTOL models (e.g., EHang EH216-S), 5m×5m for logistics drones, and 3m×3m for inspection and emergency aircraft.

The intelligent dispatch center deploys a 6G private network base station with 20° elevation coverage, supporting dual-mode "manual + automatic" operation for route planning, multi-aircraft dispatching, anomaly intervention, and data feedback. Its meteorological monitoring station triggers no-fly warnings when wind speed exceeds 12m/s or visibility falls below 500m.

The storage zone integrates robotic arm unloading (30-second cargo handling) and an unmanned vehicle garage vertically connected to the apron via dedicated freight elevator, enabling seamless air-to-ground transfer. Climate-controlled design accommodates cold-chain logistics for pharmaceuticals and fresh produce.

The charging center features automatic docking stations (30-second connection initiation), backup battery depot for peak-hour demand, and dual-circuit power supply combining grid access and rooftop photovoltaic storage. Photovoltaic panels installed on warehouse and control center roofs achieve an energy self-sufficiency rate  $\geq 40\%$ .

### 5.2.3. Building Micro-Platform Design



**Figure 5.** Building circulation(Image source: Author's own drawin)

The rooftop micro-takeoff and landing platform serves as an extension of the integrated hub. Each high-rise residential building has a standard 3m x 3m platform on its roof, with a structural load capacity  $\geq 3.5\text{kN/m}^2$ , meeting the takeoff and landing requirements of lightweight logistics drones. Retractable safety nets are installed along the platform edges, retracting during non-operational periods to maintain the integrity of the rooftop landscape. The rooftop micro-hub is connected to the integrated hub via a dedicated low-altitude flight path, with the flight path altitude controlled between 80-120 meters above ground level, and the entire journey taking no more than 3 minutes.

The retractable landing platform on the balcony is a key innovation for realizing "drone direct delivery to homes." Each south-facing balcony has a pre-installed 1.2m x 1.2m folding landing platform, which unfolds electrically when in use and is stored attached to the railing when not in use, without affecting the aesthetics of the facade. The landing platform is compatible with last-mile delivery drones with noise levels  $\leq 60\text{dB}$ , primarily serving instant retail and pharmaceutical delivery. Users reserve a time slot via an app; upon drone arrival, an audio-visual alert is triggered, and a suitable voice interaction system confirms receipt, supporting remote authorization for delivery.

For units without balconies, a concealed aerial delivery platform is integrated into the building facade and curtain wall system. It closes during the day, flush with the facade, and automatically opens at night, housing a smart cargo compartment where users can retrieve their packages using a verification code, balancing security and privacy.

Each building has an independent logistics core that extends from the roof to the basement level, physically separated from the passenger elevator system. The rooftop level connects to the drone platform, the standard floors connect balconies to the facade delivery and collection points, and the basement level connects to the unmanned vehicle passageway and the subway freight system. The logistics core is  $\geq 1.8\text{m}$  wide and has a slope  $\leq 1:12$ , meeting the requirements for fire evacuation conversion and achieving "dual-use" for both daily logistics and emergency evacuation.



**Figure 6.** Building Micro Platform(Image source: Author's own drawin)



**Figure 7.** Facade platform schematic diagram(Image source:Image source: AI-assisted generation)

### 5.3. Spatial Hierarchy and Scene Adaptation

This solution establishes a three-tiered spatial system, corresponding to differentiated service scenarios and response times:

The integrated hub, as a primary node, serves cross-regional logistics, emergency dispatch, and passenger transportation, with a response time of 15-30 minutes; the building micro-platform, as a secondary node, covers community delivery, security patrols, and elderly care, with a response time of 5-10 minutes; and the in-home terminal, as a tertiary touchpoint, handles instant retail, direct delivery of medicines, and personal express parcels, achieving instant response.

In emergency scenarios, the three-tiered space can be rapidly transformed: the integrated hub is upgraded to a regional relief material delivery center, the building rooftop is converted into an aerial evacuation interface for refuge floors, the balcony parking panels support the emergency delivery of AEDs and first aid medicines, the logistics core is converted into an evacuation channel, and the charging system is linked to the building's emergency power supply, comprehensively enhancing the community's disaster resilience.

## 6. SUMMARY

This study situates itself at the intersection of low-altitude economy and future community construction, examining the spatial integration of drone facilities with residential buildings through theoretical construction, strategic formulation, and case-based practice. At the theoretical level, it introduces the conceptual tool of "vertical logistics interface," incorporating drone landing facilities into the building body and establishing spatial prototypes-rooftop, facade, and balcony types-thereby filling the architectural research gap on spatial transformation induced by low-altitude transportation. At the strategic level, drawing on four-dimensional coupling analysis of "drone type-facility-population-policy," it proposes six design principles: technological adaptability, demographic friendliness, structural safety, spatial embedding, dual-use flexibility, and smart interconnection. The "2+N" integrated take-off and landing strategy for community buildings is formulated to address critical limitations of existing public facilities, including last-mile delivery gaps, land resource consumption, and functional disconnection from residential life. At the practical level, taking Hangzhou Yuncheng Hangteng Future Community as an exemplar, the study completes spatial integration design comprising two rooftop integrated hubs and N building micro-platforms, pioneering balcony retractable landing panels for direct indoor drone delivery and thereby generating a differentiated solution for high-intensity TOD development.

Nevertheless, the research remains subject to four constraints: limited empirical data, technological iteration pressure, institutional uncertainty, and restricted applicability. User needs and building

condition analyses rely predominantly on literature review without large-scale field surveys or long-term operational data. Facility standards calibrated to current mainstream aircraft models face obsolescence risks given rapid technological advancement. Legal frameworks governing airspace approval and property rights remain in pilot phases. The proposed solutions, optimized for high-rise TOD communities, await verification for multi-story neighborhoods and older residential areas. Future research should undertake participatory observation and post-occupancy evaluation throughout Hangteng Future Community's construction process, continuously refining design guidelines as policies and technologies evolve, thereby furnishing iterative and scalable references for future community construction within the low-altitude economy paradigm.

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