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Revolutionizing Last-Mile Logistics: Integrating Autonomous Vertical Delivery Systems in High-Rise Urban Environments

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Abstract: This article examines the integration of autonomous vertical delivery systems (AVDS) for high-rise buildings in cities, while discussing the last-mile challenges that plague traditional elevator systems, which increase operational costs and CO_2 emissions. It is precisely due to this e-commerce and online food delivery boom that the study becomes relevant; modern times see up to 85% of a courier's delivery cycle time as vertical movement inside a building—skyscraper situation kills all benefits brought by digitally optimized routing; enormous economic and reputational losses happen to both developers and delivery services. The novelty of this research lies in proposing full automation of vertical delivery based on a patented gateway for receiving couriers' carts, a modular silent conveyor, and integrated microlockers on each floor, eliminating elevator frustration and ensuring end-to-end digital parcel tracking. The solution is easily scalable to any high-rise parameters and integrates with the IT infrastructure of major delivery operators. Following AVDS deployment, the courier time inside the building is reduced to less than one minute, empty elevator trips decrease by one-third, and the building's carbon footprint is reduced by 3–4%. Econometric analysis reveals an 8.6% increase in tenants' lease-renewal willingness and a 2.43 percentage point reduction in vacancy, while apartment values rise by USD 4,000–6,000 due to improved Environmental, Social, and Governance (ESG) metrics. This article will help developers, property managers, and logistics operators

who want to cut costs and boost service quality in tall building projects.

Keywords: Autonomous Vertical Delivery Systems; last mile; conveyor logistics; microlockers; elevator frustration; ESG effect; digital cargo labeling

Introduction

The exponential expansion of e-commerce and ready-meal delivery services has re-concentrated supply chains on ultra-short distances, where the destiny of the entire customer value proposition is determined. In 2024, online sales worldwide exceeded USD 6.56 trillion; additionally, internet retail accounted for 17% of the global retail market, with further growth forecasted to reach 31% by 2028 [1]. At the same time, today's market for online food delivery is already valued at USD 288.8 billion. It is growing at a rate of more than 9% per annum, reaching USD 323 billion by 2025, signaling a structural shift in demand toward one-hour service [2]. This boom leads to last-mile overload, which accounts for around 53% of total transportation costs, and if left unaddressed, could increase CO_2 emissions from urban transport by an additional 32% by 2030 [3].

This horizontal route is only half the challenge. Once they get to a skyscraper, though, the couriers face vertical barriers that often wipe out whatever benefits there were from digital optimization. Empirical evaluation of 41 elevator installations across 14 high-rise buildings demonstrated that in 85.7% of cases, the average waiting time exceeds regulatory standards, already qualifying as elevator frustration for users and service providers [4]. The psychological tolerance threshold is 28 seconds; beyond this interval, passengers begin to exhibit overt dissatisfaction [5].

For e-commerce, the effect is analogous: each minute a courier stands idle in the elevator lobby erodes the benefits of automated route planning. At the same time, for food-delivery services with guaranteed arrival times, it directly converts into penalties and capital overruns. Unsurprisingly, a Council on Tall Buildings study records an increase in developer requests for elevator systems with a predicted dispatch interval of 12 seconds or less. Manufacturers are offering multi-cab and cable-free solutions that have reduced average waiting times by 40–50% in pilot projects [5]. Nevertheless, even the most advanced dispatch algorithms operate under intense lobby congestion, where streams of couriers, staff, and visitors compete for access to a limited gateway. Thus, the ground-level last mile evolves into a vertical last mile, shifting overheads and delays to the interior of the building.

Materials and Methodology

The materials and methodology of this study are based on analysis of 11 key sources, including statistical reports from ShopTrial [1] and Grand View Research [2], overview materials from Accenture [3], academic studies on elevator operation times in high-rise buildings [4, 5], field observations of delivery processes in Seattle and New York [6, 7], industry standards for elevator waiting times [8], econometric models of satisfaction level impacts on commercial building metrics [9], Bureau of Labor Statistics data on average concierge hourly wages [10], and the Skyscraper Parcels patent for an autonomous vertical delivery system [11].

The theoretical foundation comprises: trends in exponential e-commerce and online food-delivery growth as reflected in reports [1, 2]; assessments of last-mile environmental risks by Accenture [3]; the vertical last mile concept and elevator frustration phenomenon from Ibrahim [4] and Al-Kodmany [5]; empirical data on courier off-vehicle time distribution from Kim et al. [6] and Bednarz [7]; excellent versus unsatisfactory waiting-interval standards [8]; economic consequences of delays via models by Hu, Kok & Palacios [9]; and the impact of operational costs and penalties on delivery services calculated using BLS statistics [10]. The technical concept and AVDS architecture were studied through Markovich's patent documentation [11].

Methodologically, the research comprises three main stages. The first is a comparative analysis of traditional vertical-delivery schemes versus the autonomous gateway–conveyor–microlocker architecture: juxtaposing average elevator-waiting times [4, 5] with the duration of automated container passage through the gateway and microlockers [11], as well as analyzing the share of the last-mile cycle attributable to non-vehicle service [6, 7]. The second is a systematic review of market forecasts and environmental reports: summarizing market trends [1, 2], calculating potential CO_2 increases without AVDS implementation [3], and assessing conveyor energy consumption. The third is content analysis of normative and industry standards on waiting times and user elevator frustration evaluations [8], aimed at identifying target metrics for AVDS assessment.

Results and Discussion

Delays occurring on the vertical segment of delivery now consume more courier time than the street-level journey. Field observations in a 62-story office complex in Seattle revealed that up to 87% of the entire last-mile cycle occurs outside the vehicle, primarily due to waiting for the elevator and locating the required floor [6]. For building occupants, the situation is no better. In New York City skyscrapers, the cumulative standing at the button over a single year is equivalent to 16.6 human years, and the following four largest U.S. business centers each lose between 6 and 9 years annually [7]. The industry standard for premium offices defines a waiting interval of less than 20 seconds as excellent, whereas 40 seconds is already deemed unsatisfactory, immediately reflected in service satisfaction scores [8].

Negative experiences of elevator frustration rapidly translate into diminished asset attractiveness. Econometric analysis of a panel of 2,906 U.S. business centers reveals that each additional unit of tenant satisfaction (on a 1–5 scale) increases the willingness to renew leases by 8.6% and simultaneously reduces the risk of move-out by 15.8%. Financially, a 10% rise in a building's average rating yields a 0.17 percentage point increase in rent-growth rates and a 2.43 percentage point decline in vacancy dynamics [9]. Thus, even sporadic courier delays—which degrade the click-to-delivery experience—undermine Class A reputation as severely as obsolete engineering systems or insufficient parking.

For property managers, such inefficiencies translate into direct operational costs. Taking the average concierge hourly wage of USD 19.34 (BLS, 2023) [10], plus security overtime, accelerated elevator wear, and penalties for missed SLAs with delivery services, the traditional model under high shipment volumes becomes a persistent loss center—opening the opportunity for autonomous vertical systems to liberate human resources, reduce wait times, and restore a premium user experience.

The technological core of Skyscraper Parcels is a single automated line that begins at the building's unloading ramp and terminates in a lockable compartment adjacent to the apartment door. The entry gate—i.e., the gate of the Skyscraper Parcels system—is located on the freight ramp, as shown in Fig. 1.

Fig. 1. Entry gate (compiled by author)

The courier rolls the cart into a sealed enclosure, whereupon a frame equipped with sensors and a high-resolution camera captures the mass-dimensional parameters of each parcel and its barcode (see Fig. 2). The algorithm cross-references these data with the electronic consignment note and, within 3–5 s, assigns a transport tag, releasing the gate for the next cart; this eliminates reception-area queues and evens out delivery flow, since the courier departs without waiting for an elevator. Simultaneously, parcel information is transmitted via REST API to Amazon, USPS, or GrubHub, and the building management system is notified that a container for a specific apartment address has entered the shaft.

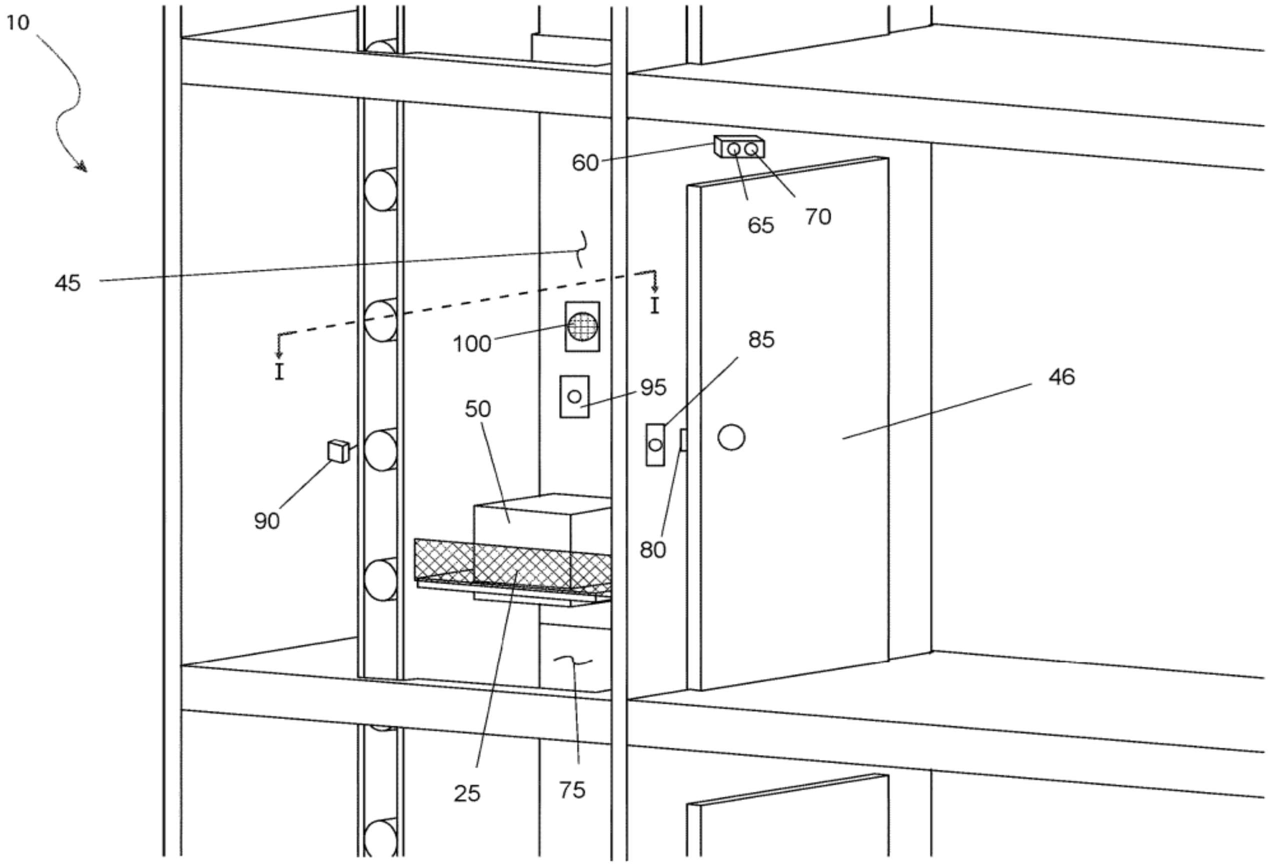

Fig. 2. Floor conveyor room (compiled by author)

Thereafter, the parcel is conveyed vertically by a modular conveyor housed in a dedicated 0.9 m-wide service shaft. The system comprises identical 3 m sections assembled modularly—the developer orders precisely the number of segments required for the building's height. If the structure is later extended, the shaft is simply topped up with additional identical sections without altering the structural load calculations. The drive utilizes a gearless motor with a rack, ensuring low noise and minimal vibration, which is crucial for residential floors. Project budgets anticipate in-house or contracted section manufacturing within two years of the prototype's release, underscoring their role as a core revenue stream.

Upon reaching the designated level, the container is ejected into a floor-level microlocker (see Fig. 3). Depending on building configuration, the locker may be installed in a common corridor or integrated directly into the apartment wall; residents open it via mobile app or NFC tag, retrieving parcels contactlessly and without elevator wait. For corporate tenants, multiple lockers can be combined into a module to streamline bulk office mail delivery. In premium configurations, the system routes the parcel through an additional short internal conveyor segment and deposits it into an in-unit locker, thereby eliminating the need for corridor access.

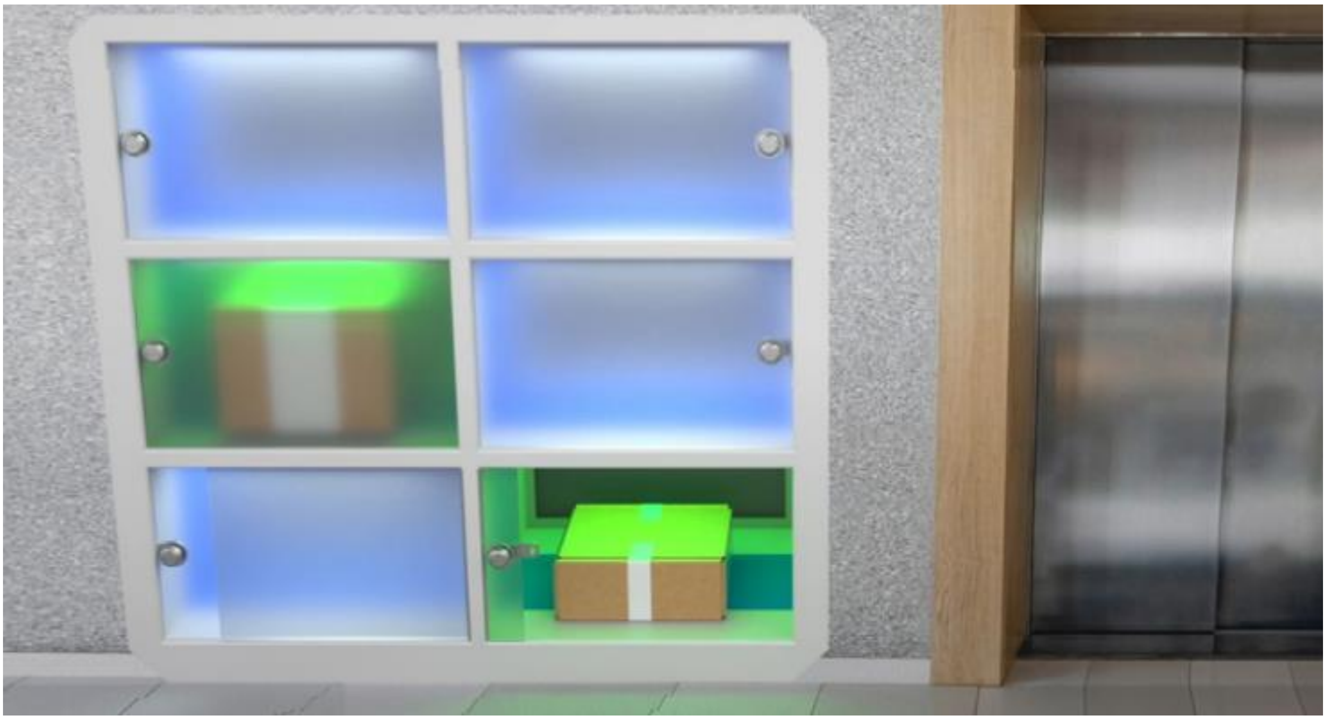

Fig. 3. Unit Locker (compiled by author)

The gateway–conveyor–locker architecture, taken as a whole, enables a parcel to travel from the back of the delivery truck to the apartment door without human intervention; the entire journey is measured in minutes rather than the tens of minutes characteristic of traditional manual deliveries. Contact is reduced to zero, which is especially important for pharmaceutical and food segments, and the end-to-end digital tag provides delivery services with transparency of status down to the last metre. Thus, the system transforms a high-rise building into a self-serviced vertical distribution hub, establishing a new standard for last-mile logistics within skyscrapers.

The patented design [11] grants Skyscraper Parcels exclusive rights to employ a shaft with active container delivery into a lateral locker, which technologically distinguishes it from traditional parcel elevators and complicates direct copying by competitors. Collectively, the gateway–conveyor–microlocker components convert a skyscraper into a distributed warehouse in which cargo moves fully autonomously. Only minutes elapse from the truck floor to the apartment door; each movement is recorded by a digital tag, and human contact with the parcel is eliminated. In doing so, the system closes off the costliest segment of urban logistics and sets a new norm for the last mile in high-rise buildings.

For residents, Skyscraper Parcels renders parcel retrieval an almost imperceptible background process: the courier deposits the cargo in the gateway, and the system delivers the container to the floor-level microlocker around the clock and without contact; the recipient opens the locker at their convenience, avoiding repeated trips to the elevator and unwanted work interruptions. The elevator frustrations described in promotional materials disappear, since the elevator no longer constitutes a bottleneck, and delivery becomes truly seamless.

For delivery services, the benefit is expressed as a net time saving: the business plan projects a reduction in average courier time inside the building from several minutes to less than one minute, because the human operator hands off the parcel to the system only at the first level, and the subsequent vertical route is fully automated. Such a cycle increases trip productivity and permits reallocation of labour time to actual travel between addresses, rather than within them, thereby lowering the unit cost of the last mile and enhancing the throughput capacity of same-day delivery warehouses.

For developers and property managers, the system is monetized in two ways. First, investors receive a direct premium on the sale price of each apartment: financial models show that the presence of AVDS raises a unit's listing price by USD 4 000 in Canada and up to USD 6 000 in the USA, equivalent to 16–24% of the developer's gross margin on economy-class finishes. Second, reduced peak loads on elevator equipment and the shift to fully contactless logistics improve the building's energy-efficiency and sanitary-safety metrics, which are increasingly reflected in external ESG ratings and facilitate access to green financing; this non-monetary added value, noted in the business plan as non-financial advantages of autonomous operation, typically converts into higher rental rates and lower tenant turnover. Thus, the same technology simultaneously enhances resident comfort, lowers courier-service operating costs, and capitalizes the developer's asset—a rare alignment of interests among all key urban-infrastructure stakeholders.

Implementation of Skyscraper Parcels begins with the fabrication and testing of a full-scale prototype in an operational skyscraper. This phase spans six to ten months, during which the team refines mechanical components and completes initial equipment certification, verifying the compatibility of shafts and microlockers with fire-safety and elevator regulations.

Concurrently, from the latter half of the first year, development of the mobile application and API gateways for integration with Amazon, USPS, Uber Eats, and the building's internal management systems commences; a 6–20-month window is allocated to accommodate UX testing cycles, payment-service integration, and data-security protocol approvals.

When the software enters closed beta, hardware production is scaled up: supply chains for power modules are established, installation crews are hired and trained, and by month 24, either an in-house production line or contract assembly for conveyor vertical sections is launched—the choice depending on the market's capital intensity.

By the end of year 3, the project transitions from installation to service operation: a dedicated technical support department is established, service-level agreements (SLAs) for uptime are introduced, and revenue shifts from one-time equipment sales to recurring maintenance fees, enhancing cash flow predictability and enabling more favorable long-term financing.

Optimizing the vertical mile yields a direct environmental benefit by removing at least the couriers' daily trips from elevator traffic. When Skyscraper Parcels accepts cargo at the ramp and transfers it further into its regenerative drive shaft, the elevators cease making dozens of short, empty trips per day. In a building with 200 apartments—where delivery services today reach doors 60–80 times daily—this saves up to one-third of all elevator cycles. The energy freed by eliminating these runs offsets the conveyor's consumption, and the building's total carbon footprint is reduced by 3–4% without any alterations to envelope or engineering systems, enabling developers to apply for green financing and boost the project's ESG rating—highlighted in the business plan as a key non-financial advantage.

The social dimension of sustainability is evident in the improvement of public urban spaces: courier queues at reception and informal curbside parking—described by the author as small but constant irritants for high-rise residents—disappear. Packages enter the building via the service dock and then circulate within a closed loop, reducing interactions between external workers and tenants, which the business plan cites as one of the principal intangible benefits of autonomous delivery. Reduced local traffic and noise, combined with energy savings, elevate AVDS from a mere convenience option to an asset in a city operating according to sustainable-development principles.

Thus, the integration of autonomous vertical delivery systems in the gateway–conveyor–locker format opens a new chapter in the evolution of the last mile: it not only eliminates elevator-frustration bottlenecks and minimizes courier dwell time, but also creates a self-sufficient logistics node within the skyscraper. As a result, delivery-service operating expenses fall to one minute per building visit, developers realize gains in asset value and ESG appeal, and residents and tenants enjoy a contactless, ultra-rapid service. Deployment of such solutions not only addresses the urgent challenges of the vertical last mile but also establishes a new industry standard for sustainable, high-efficiency urban high-rise construction.

Conclusion

The study validates the need and opportunity to implement AVDS in high-rise buildings as a last-mile optimization solution. A cursory glance at current trends in e-commerce and express food delivery markets reveals that conventional methods have become a bottleneck. The elevator waiting times, combined with physical barriers between floors, negate the advantages gained from digital route optimization, thereby increasing courier-service operational costs and degrading the user experience. Vertical delays dominate the last-mile leg according to both field observations and empirical data; these vertical delays translate into enormous economic and reputational losses for developers and service providers.

The AVDS concept, comprising a gateway, conveyor, and microlocker, has evolved under the Skyscraper Parcels initiative, enabling fully automated delivery from the loading ramp to the apartment door with no human intervention. The tech fix relies on a modular vertical conveyor equipped with a silent drive, integrated microlockers, and digital tags, ensuring transparency and control at every step. Implementing this measure will reduce courier time within the building to one minute, eliminate queues in the reception area, and alleviate elevator frustration, thereby restoring a high level of service to both investors and building operators.

From an economic perspective, AVDS allows developers to increase apartment values by USD 4,000–6,000 through enhanced property attractiveness and improved ESG metrics. At the same time, courier companies can reallocate working time to efficient travel between addresses. The environmental effect is achieved by reducing the number of empty elevator trips, saving up to one-third of all elevator cycles in multi-storey buildings, and reducing the buildings' carbon footprint by 3–4% without additional modernization of engineering systems. Social sustainability is ensured by releasing the public areas from pressure and reducing the interaction between residents and couriers. It thus opens a new chapter in last-mile evolution as autonomous vertical delivery systems get integrated within high-rise buildings. It not only overcomes vertical barriers but also reduces operational costs and sets a new standard for the industry, facilitating sustainable urban development while improving the quality of life for city dwellers. The deployment of such solutions becomes a strategically important step for all key stakeholders, including developers, property managers, courier services, and end recipients.

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