PRESS RELEASE

May 22, 2024
The University of Tokyo
Mitsui Fudosan Co., Ltd.

Using a Numerical Model to Elucidate the Efficacy of Drone-Based Delivery Inside Buildings

—Establishing a New Vertical Logistics System for High-Rise Residential Buildings—

Key Points

- Proposed a new delivery system using drones inside buildings such as high-rise residential buildings.
- Determined conditions under which drone-based delivery would be more advantageous than elevator-based delivery in terms of both power consumption and waiting times through a computer simulation using a numerical model.
- Explored the possibilities of new logistics systems inside buildings through cooperative use of drones and elevators.

Illustration of drone-based vertical delivery inside a building

Summary

Tokyo, Japan, May 22, 2024 – The University of Tokyo and Mitsui Fudosan Co., Ltd., a leading global real estate company headquartered in Tokyo, jointly announced today that a research group has designed a new drone-based delivery system featuring a dedicated space for vertical drone flight inside buildings such as high-rise residential buildings and has demonstrated the efficacy of such a delivery system through a numerical model-based analysis. The research group consists of three members affiliated with the Research Center for Advanced Science and Technology (RCAST) of The University of Tokyo, namely Project Lecturer Takahiro Ezaki, Project Researcher Naoto Imura and Professor Katsuhiro Nishinari; along with Kazuhiro Fujitsuka of Mitsui Fudosan Co., Ltd.

This study provides a solution not only to elevator-based delivery, which tends to have long waiting times, but also may offer promising options for logistics inside buildings, including delivering daily essentials while curtailing power consumption during natural disasters. In this study, the research group performed a theoretical verification using basic modeling techniques. The study lays the groundwork for further investigation using actual physical drones, elevators, and other equipment.

The results of this study were published in the online edition of Communications in Transportation Research on May 16, 2024.

—Researcher's Comments—

Although the use of drones in society is being considered in many different ways, projects are often stalled due to hurdles such as practical limitations and costs. In this study, we investigated in depth the specific advantages of drone-based delivery and how these advantages might arise. We hope that this type of research will provide a foothold for future studies of new drone-based logistics systems.

(Takahiro Ezaki, Project Lecturer, Research Center for Advanced Science and Technology, The University of Tokyo)

Main

In December 2022, Japan lifted its ban on drone flight over populated areas when the operator cannot see the vehicle (Level 4 Flight). Currently, drone delivery services are still mostly limited to Japan's mountainous and island areas. The University of Tokyo and Mitsui Fudosan believe that it is critical to implement drone delivery in densely populated areas such as city centers. Based on this view, the two partners are conducting collaborative research on vertical transportation systems that may serve as alternatives to elevators. High-rise residential buildings and office buildings present concerns about logistics infrastructure because elevators may become inoperable during natural disasters. Even during normal times, delivery methods that rely only on conventional elevators risk failing to meet expected delivery deadlines due to the growing delivery demand for food and beverage catering services and delivery-based shopping. In this study, the research group designed a system in which a dedicated space for vertical drone flight is built within buildings, and drones deliver cargo via drone ports set up on each floor where they can take off and land (patent pending). The successful implementation of such a system would enable drone-based deliveries to be made more quickly and energy efficiently than when using elevators.

Furthermore, in order to analyze the efficacy of the drone-based delivery system, the research group built a numerical model that simulates the actual situation. The numerical model is based on a hypothetical delivery process comprising steps such as cargo attachment and detachment, ascent and descent flight, and battery swapping (Diagram 1) as well as the specifications of an actual drone model (PF2-AE Delivery, ACSL Ltd.) Following that, the group investigated the delivery performance of various numbers of drones, assuming that each household in a hypothetical high-rise residential building generates demand for delivery based on the Poisson process[*1]. Parameters such as the required number of drones were determined using numerical analysis based on queuing theory[*2]. Furthermore, Monte Carlo simulations[*3] revealed that drone deliveries could be completed faster and with less power consumption than elevators up to a certain level of demand from households (Diagram 2). As a result, the study found that using drones has a clear advantage in certain situations, which is expected to pave the way for new business models.

Additionally, the study highlighted two transportation modes with distinct characteristics: elevator-based delivery, which excels at transporting large cargos, and drone-based delivery, which excels at providing case-by-case, immediate responses. The advantages of combining the two different transportation modes provide vital insights into other multi-modal logistics systems (systems that combine different transportation modes) that use drones.

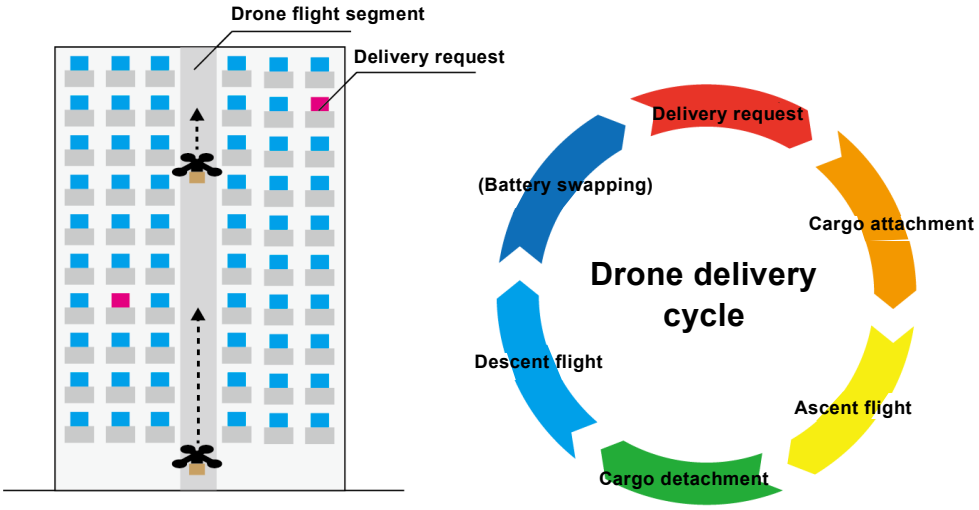

Diagram 1: Schematic of drone-based vertical delivery system

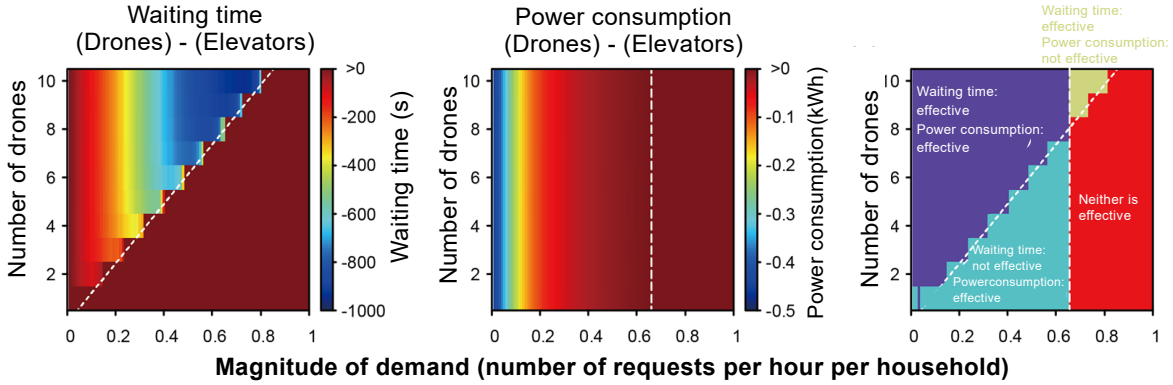

Diagram 2: Efficacy of drone-based delivery system in comparison with elevators

The diagrams (left and center) for waiting time and power consumption show that drones are more effective as the color in the diagram approaches blue. For example, if the number of requests per hour per household is 0.2 and deliveries are made using 5 drones, waiting time can be reduced by 280 seconds while power consumption per delivery can be lowered by 0.09 kWh. The diagram on the right summarizes these conditions in a map.

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Glossary of terms

*1: Poisson process
A probabilistic process used to model events that occur randomly over time or space

*2: Queuing theory
A mathematical framework for analyzing waiting times and waiting line (queue) lengths when services are provided in response to random occurrences of demand, such as server requests and customers arriving at a service desk.

*3: Monte Carlo simulation
A collective term for methodologies that simulate probabilistic phenomena by generating random values within a computer.

* The initiatives covered in this press release are contributing to three of the UN's SDGs.