The Elevator-Integrated Delivery System for High-Rise Residential Buildings

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Abstract

With the growth of the online market, online commerce has facilitated the development of home delivery services. An economically active individual in a developed country receives an average of approximately 40 parcels per year, and this trend is expected to intensify in the future (Her, 2010). This study considers the transportation of parcels within high-rise residential buildings in terms of their movement and energy consumption and proposes the elevator-integrated delivery system, a new delivery system that modifies a passenger elevator to automatically move parcels to their designated floors. This paper examines the feasibility and benefits of the proposed system by considering various scenarios and assumptions. The results indicate that the proposed system is energy-efficient for large numbers of deliveries and can reduce the waiting time for passengers as well as for parcels.

Keywords: delivery; elevator; lift; passenger traffic; door-to-door service

1. Introduction

In many small countries, the limited land pushes cities toward high-density urban development. For example, approximately 60% of all Koreans live in high-rise residential buildings (about half of which have more than 15 floors). This type of residency has encouraged the development of home delivery services as well as online shopping malls and home shopping (Her, 2010). In the last decade, the home delivery industry has shown an average annual growth rate of 27%, resulting in a fivefold increase in the size of the market since 2000, and this trend is expected to intensify in the future.

This rapid growth of the delivery industry has given rise to some serious challenges. The transportation of parcels has considerable influence on urban congestion and air pollution. Also delivery trucks and motorcycles often park illegally, blocking roads during parcel delivery. In addition, random delivery schedules can waste time and energy during parcel delivery because the parcel carrier has to use the elevator to deliver parcels that generally weigh much less than the individual. On average, a building's elevator system accounts for 5-15% of the building's total energy consumption (Al Sharif, 2004).

This study focuses on the vertical transportation system for passengers and parcels in buildings. Some commercial and office buildings have separate freight elevators, but this system is not widely used in residential buildings. Authors propose a new delivery system called the elevator-integrated delivery system (EIDS) and examine it in terms of the pattern of real passenger traffic. In addition, two loading scenarios are considered through a simulation to verify its economic feasibility and benefits. This study is the first to consider an automated parcel delivery system for residential buildings.

2. Elevator-Integrated Delivery System

Most residential buildings in Korea are modular and consist of four to seven residential units connected through the central core, elevator shafts, and stairwells (Jo et al., 2009). The idea behind the EIDS is to make use of common areas for the delivery of packages. The EIDS uses a standard elevator, but it can also accommodate parcels and automatically dispatch them.

As shown in Fig.1., EIDS can be configured in the elevator space in various ways. The first image shows the case in which parcels are placed above the space for passengers, and the second image, below. The
third image shows parcels placed next to the passenger space. The idea behind the first two cases is to use the space between the floor slab and the ceiling, which generally exists in residential and office buildings (Fig.2.). This space typically measures 60-80 cm.

Fig.2. Typical Building Section Using the Elevator-Integrated Delivery System (Section)

In the first two cases, parcels can be moved using an automated system or a horizontal-rail system. These systems can detect destinations through sensors such as RFID tags that contain detailed destination information. Parcels can be transferred from the local post office to a specific building. Then an RFID reader attached to the elevator can process this information and direct the parcel to the appropriate floor. If parcels need to be collected first before being distributed, then a parcel pool can be located near the lift machine room on the first or basement floor depending on the physical structure of the building.

Fig.3. Plan View of a Building with the Elevator-Integrated Delivery System (General and Close-Up Plan)

Fig.3. shows the floor plan of a building using an EIDS with a parcel compartment above the elevator. For illustration purposes, a direct-access-type apartment layout is considered to demonstrate the use of the proposed system. For example, separate elevator doors can be located on both sides of the elevator, which allows parcels to exit independently of passengers. Once a parcel exits the elevator, it slides down from the ceiling to the floor.

3. Methodology

Using Elevate, a simulation tool, authors consider two existing systems and three new delivery options using the proposed system:

Case I) Existing delivery system (existing; Fig.4.a)
Case II) Immediate delivery system (new; Fig.4.b)
Case III) Interval delivery system (new; Fig.4.c)
Case IV) Overnight delivery system (new; Fig.4.d)
Case V) Delivery system using separate freight elevators (existing; Fig.4.e)

For the simulation, two scenarios are considered: In one scenario, the delivery demand is 3 times the current demand (scenario 1), and in the other, it is 10 times (scenario 2). In each scenario, the average destination time (the amount of time that a parcel takes to reach the destination) is calculated as well as vehicle energy consumption for a given parcel is measured.

Case I serves as the basis for a comparison of the proposed options. The existing delivery system is a manual delivery system in which the carrier has to take the same elevator as other passengers from the ground floor to the designated floor. After delivering the parcel, the carrier takes the elevator (with or without other passengers) to exit the building. The total amount of time the carrier spends outside the elevator on a given floor to deliver a parcel (including walking to a unit, ringing the doorbell, and walking back to the elevator) is set to five minutes. That is, the carrier spends a total of five minutes on a given floor before returning to wait for the elevator. In this regard, authors examine any increase in the amount of time that other passengers spend taking the elevator based on the existing system as well as the amount of time required for distributing parcels.

Cases II-IV are alternative delivery systems that can be operated using the EIDS. Case II, the immediate delivery system, follows exactly the same procedure as Case I with no manual interruption. This implies that there is no need for a carrier to walk to a unit and wait for someone to answer the door. Case II considers only the amount of time it takes to actually deliver a parcel (in this case, there is almost no waiting because of the immediate delivery). In addition, the increase in passengers' waiting time and transition time to their destinations is considered.

In Case III, the interval delivery system collects parcels up to a certain number on the first floor. This number is set to six by assumption that an elevator can accommodate up to six parcels at a time (see Section 3.2.5). Accordingly, the elevator releases parcels whenever it collects a total of six parcels.

In Case IV, the overnight delivery system implies that all parcels are collected at a reservoir and wait until there is no recurring passenger demand, which usually occurs at night in residential buildings. Authors consider the residential demand pattern in Strakosch (2010), in which the distribution of parcels starts at 10 p.m. This represents a case with a relatively long waiting time for parcels. Here the energy consumption is compared between EIDS and other systems to determine its efficiency in terms of energy use and passengers' waiting time.

Case V, a delivery system using separate freight elevators, requires a separate elevator reserved for parcels only. Freight elevators are often found in large commercial or office buildings but are rare in residential buildings, partly because freight elevators
consume substantial amounts of energy and their installation is costly. However, their installation facilitates faster deliveries (almost no waiting time for parcels), and they require no additional waiting time for passengers. For each case, the passenger's destination time and the parcel's total distribution time are examined. In addition, the elevator's energy consumption is considered. Fig. 4. visualizes these five cases for a better understanding.

3.1 Simulation Tool
To assess the five cases, Elevate 8.0, a simulation tool from Peters Research Ltd. which is the latest version (updated in 2007) is employed. This software package is widely recognized and used in more than 60 countries as an industry standard for simulations.

3.2 Research Data and Assumptions
3.2.1 Analysis Data
The group collective algorithm is employed as the dispatching algorithm. Among various dispatching algorithms, the group collective algorithm is chosen because it is the standard and simplest algorithm for elevators and is most suitable for this study. The group collective algorithm is widely employed in single-elevator residential buildings and can represent an elevator system that travels in one direction and responds to all registered calls. When there are no more requests in that direction, it turns around and answers calls in the opposite direction. When there are no calls from passengers, the elevator remains idle or moves to the home floor. The elevator stops only for up calls in the up direction and down calls in the down direction and remembers all calls until answered. The collective algorithm in Elevate 8.0 is programmed such that the elevator returns to the first floor (home floor) when there are no calls. In terms of the energy cost, the price of electricity is set to $0.11/kWh (KEPCO, 2011).

3.2.2 Building Data
Variations in the design and construction of Korean residential buildings are very small and limited relative to other building types (Kang & Rhee, 2012). In Korea, the required size and number of elevators for a given building are defined by the National Building Codes. Here, specifically for residential buildings, the floor area is not considered, but the type of residential unit and the number of households are. The lift installation regulations defined by the National Building Codes are summarized as follows (Korean Building Codes, 2009):

- Residential buildings with more than six floors must have an elevator that can accommodate more than six passengers.
- Residential buildings must install one or more elevators per access, and each elevator must transport the total number of households above the fourth floor multiplied by 0.3 (0.15 if each residential unit is designed for only one occupant).

This study assumes that a building has 15 floors and that the height of each floor is 2.6 m, which is typical in residential buildings. In the simulation, this height is used to calculate the travel time between floors by the elevator. For instance, if a 15-floor building has 60 units and each floor has 4 units (the maximum number of units for the direct access system), then it has 44 units above the fourth floor. Here, if this number is multiplied by 0.3, which is the value according to the codes, then 13.2 is obtained. It indicates that the elevator has to accommodate more than 13.2 passengers simultaneously. Therefore, one elevator is sufficient as a means of transportation for the building. For this reason, a standard 1,000 kg (15 passengers whose average weight is 65 kg) elevator is used (see Section 3.2.3). As discussed earlier, the number of elevators and their size depend on the demand. In addition, the entrance-level bias for the first floor is set to 100%. That is, all incoming traffic enters the building only from the first floor to reach the final destination. In addition, authors assume no inter-floor traffic because it is highly unlikely that a resident on a particular floor visits another resident on another floor. For this reason, the exit-level bias for the first floor is set to 100%. That is, all outgoing traffic leaves the building through the first floor. No absenteeism is assumed in the building.

3.2.3 Elevator Data
It is assumed that there is one single-deck elevator in the building that responds to the given passenger and
parcel demand. A single-deck elevator that has a weight capacity to 1,000 kg (15 passengers) stops on each floor with a request call. In addition, the most popular 1,000 kg elevator occupies 2.4 m$^2$ (1.5 m x 1.6 m). Its capacity factor is set to 80%, which means that when the elevator is 80% full in terms of weight (800 kg), passengers may refuse to ride it because they feel that it is full. This is a common phenomenon, and therefore an elevator’s non-occupied weight almost always reflects 20% of its full capacity. In the simulation, this gap is filled by using the mass of parcels (6 x 30 kg = 180 kg). It is assumed that it takes 1.8 and 2.9 seconds for the elevator to open and close, respectively. In addition, authors set the elevator’s speed, acceleration, jerk, and start delay to 2.5 m/s, 0.7 m/s$^2$, 1.4 m/s$^2$, and 0.5 s, respectively, which are standard values representing data measured on the field in Elevate. Table 2. summarizes the conditional assumptions for the elevator (here no leveling delay is assumed).

### 3.2.4 Passenger Data

The passenger pattern depends on the type of building. In office buildings, there are clear up- and down-peak periods during morning and afternoon hours. In certain cases, there is some inter-floor traffic, which represents traffic from one floor to another (excluding the first floor). However, up- and down-peak periods are rare in residential buildings. In fact, residential buildings tend to show a two-way traffic demand pattern. Two-way traffic refers to a type of traffic in which passengers enter the elevator from one entrance and exit through various floors during the up trip. By contrast, during the down trip, passengers enter the elevator from various floors and exist through one floor (the lobby). In this study, authors employ the data on daily patterns from a residential survey by Strakosch (2010), who collects the data from residents of various apartment buildings and represents them in terms of the percentage of the building population traveling up or down during a five-minute period. In residential buildings, peak traffic generally occurs in the late afternoon (15:00–) or early evening (18:30–) hours, when tenants and children return home while others leave for evening entertainment. Fig.5. shows some other forms of traffic. In the early morning hours, the clean downward demand pattern represents people leaving from home for work or school. However, based on the graph in Fig.6., it can be observed that this is not the highest peak in terms of total passenger activity. In addition, a zero stair factor is assumed. That is, residents have no choice but to take the elevator. In Asian countries, the standard weight of an individual is generally set to 65 kg. For this reason, 65 kg is considered as the standard weight of an individual within this study. The area occupancy of the elevator already provides a smaller constraint than when the elevator is full based on its weight (80%). When the elevator is 100% full in terms of its area, there can be 11.4 passengers (0.21m$^2$/passenger), and when the elevator is 80% full in terms of its weight, there can be 12.3 passengers (65kg/pers.). In this regard, authors can conclude that no more than 11 passengers can occupy the elevator simultaneously.

### 3.2.5 Parcel Data

If there are 4-residential units per floor and if each unit receives three parcels per month, then there are 720 parcels per month (an average of 24 parcels per day). The number of parcels addressed to the first floor

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**Table 2. Elevator Data Assumptions**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>1000 kg (15 person)</td>
</tr>
<tr>
<td>Car Area</td>
<td>2.4 $m^2$ (1.5 m x 1.6 m)</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>80%</td>
</tr>
<tr>
<td>Door Opening</td>
<td>1.8 second</td>
</tr>
<tr>
<td>Door Closing</td>
<td>2.9 second</td>
</tr>
<tr>
<td>Speed</td>
<td>2.5 m/s</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.7 m/s$^2$</td>
</tr>
<tr>
<td>Jerk</td>
<td>1.4 m/s$^2$</td>
</tr>
<tr>
<td>Start Delay</td>
<td>0.5 second</td>
</tr>
</tbody>
</table>

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Fig.5. Passenger Demand Based on Strakosch's (2010) Residential Survey

Fig.6. Total Passenger Activity Based on Strakosch's (2010) Residential Survey
is ignored because they require no use of elevators. Here four elevator trips with six parcels can easily be integrated into the daily use of elevators without interrupting the current use. This implies that the current number of deliveries requires no new elevator system. Given this, this study considers two scenarios: In one scenario, the delivery demand is 3 times the current demand (scenario 1), and in the other, it is 10 times (scenario 2).

4. Results
For the validity of the results obtained, authors have simulated each case 10 times with different passenger datasets. For each result, a similar tendency in terms of the passengers' destination time and parcels' distribution time, as well as their relativity to each other are verified. Accordingly, one random dataset is selected for the comparison (Table 3).

4.1 Case I: The Current Delivery System

In Case I, the data is modeled such that a carrier manually delivers parcels and exits the building. Therefore, it is necessarily assumed that the carrier returns to the home floor after five minutes. This five-minute period covers arriving at the unit, ringing the doorbell, and giving the parcel to the recipient. Based on a comparison of current and passenger-only data, up/down elevator calls increase by approximately 142 and 444 in scenarios 1 and 2 respectively. In addition, these increases are distributed evenly across operating hours. This clearly indicates that an increase in delivery traffic increases the destination time relative to the case in which only passengers make use of the elevator. Compared with the case of no parcel delivery, this leads to a 4.4-second increase in passengers' travel time for scenario 1 and an 18.9-second increase for scenario 2. The increase in the travel time is directly related to the number of parcels, but it is not necessarily proportional. In addition, an increase in the number of parcels increases the rate of increase in the destination time. The total distribution time for parcels is investigated. To calculate this, the following equation is used:

\[
\text{Total distribution time} = \sum_{i=1}^{n} Ri + Di, \quad (4.1)
\]

where \( n \) denotes the number of parcels/day, \( R \) is the reserve time, and \( D \) is the dispatch time.

In Case I, there is no reserve time, which is defined as the amount of time that a parcel spends in a reservoir from its arrival for the purpose of its collection and delivery. In this case, because the carrier delivers parcels immediately, authors consider this value to be zero. In addition, the total dispatch time represents the sum of the total waiting time and total transit time for a parcel. Further, the average distribution time for parcels is calculated by dividing the total distribution time by the total number of delivered parcels.

In both scenarios, the average distribution time decreases by 20 to 25 seconds relative to the passengers' destination time. In fact, a reduction in the waiting time for parcels leads to this decrease. There is little change in the transit time for parcels as well as for passengers because the former travel to the same number of floors as the latter and are distributed in the same way as the latter. In addition, authors assume that parcels take the same amount of time to be discharged from the elevator as passengers. However, the waiting time is shorter for parcels than for passengers. This may be due to the fact that parcels have no peak distribution hours because they arrive evenly throughout the day. For example, the number of passengers increases in the late afternoon in Strakosch's residential survey, whereas there is no change in the number of parcels. Therefore, the total waiting time during peak hours is shorter and helps to reduce the average destination time.

Proceeding to energy consumption, the data set has approximately 2,000 passenger calls. This number can vary across data sets. In this regard, authors consider 10 data sets to better understand the general tendency of elevator behavior. However, authors use one data set for the five cases for comparison purposes (Table 3). The last column of Table 3 shows daily energy consumption for parcels for Cases I–V.

Noteworthy is that in some cases, daily energy consumption is lower for scenario 2 than for scenario 1, which is inconsistent with the expectation. This may be because the average interval (the gap between when the elevator travels to other floors and when the elevator returns to the first floor) is approximately 3 minutes.

Table 3. The Destination Time, the Distribution Time, and Energy Consumption for Cases I-V

<table>
<thead>
<tr>
<th>Case</th>
<th>Mode</th>
<th>Average Destination Time for Passengers (Seconds)</th>
<th>Average Distribution Time for Parcels (Seconds)</th>
<th>Daily Energy Consumption (KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Scenario 1</td>
<td>84.2</td>
<td>59.1</td>
<td>70.1</td>
</tr>
<tr>
<td>I</td>
<td>Scenario 2</td>
<td>98.7</td>
<td>75.7</td>
<td>69.5</td>
</tr>
<tr>
<td>II</td>
<td>Scenario 1</td>
<td>82.7</td>
<td>60.4</td>
<td>69.7</td>
</tr>
<tr>
<td>II</td>
<td>Scenario 2</td>
<td>86.2</td>
<td>67.1</td>
<td>68.6</td>
</tr>
<tr>
<td>III</td>
<td>Scenario 1</td>
<td>83.3</td>
<td>1650.7</td>
<td>70.4</td>
</tr>
<tr>
<td>III</td>
<td>Scenario 2</td>
<td>91.1</td>
<td>604.6</td>
<td>70.7</td>
</tr>
<tr>
<td>IV</td>
<td>Scenario 1</td>
<td>79.8</td>
<td>29138.6</td>
<td>73.3</td>
</tr>
<tr>
<td>IV</td>
<td>Scenario 2</td>
<td>79.8</td>
<td>30226.8</td>
<td>76.5</td>
</tr>
<tr>
<td>V</td>
<td>Scenario 1</td>
<td>79.8</td>
<td>20.2</td>
<td>95.4</td>
</tr>
<tr>
<td>V</td>
<td>Scenario 2</td>
<td>79.8</td>
<td>20.5</td>
<td>104.9</td>
</tr>
</tbody>
</table>
This means that even when there is no parcel to be transported, the elevator comes back to the home floor every three minutes to load and unload passengers. Therefore, energy consumption depends only on whether a parcel arrives on time to be loaded onto the elevator with passengers immediately after its arrival or whether it arrives immediately after the elevator departs the first floor and thus has to wait for the elevator to return to the first floor. In addition, the weight of parcels has little effect on electricity consumption. There is no difference in electricity consumption between scenarios 1 and 2.

4.2 Case II: An Immediate Delivery System Using the EIDS

In Case II, when a parcel arrives, it is immediately sent to the designated floor. In other words, Case II is similar to Case I but needs no human to deliver the parcel. Therefore, there is no additional decrease in existing traffic. In Case II, as discussed earlier, parcels arrive uniformly over a given period, and only one parcel is loaded on the elevator for each trip. In this system, the operating hours are integrated into usual residential traffic. In this case, parcels and passengers are differentiated based on differences in their weight and occupied area. Parcels are always able to take the elevator even when it is full with passengers because the area reserved for parcels is separated from that for passengers. The demand for downward traffic is lower in Case II than in Case I. In particular, the average destination time is shorter in scenario 2 than in scenario 1 by 12.5 seconds. In addition, this is shorter than that in Case I. In terms of parcels, as in Case I, there is no reserve time because they are immediately delivered through the automated system. In scenario I, there is little difference between Cases I and II because one additional downward trip every 10 minutes does not produce a significant difference. In scenario 2, however, the distribution time is shorter in Case II than in Case I by 8.5 seconds because of an increase in the travel time caused by a series of downward trips by the carrier in Case I. With an increase in calls and the expansion of peak hours, the average destination time is necessarily longer in Case I than in Case II. In terms of energy consumption, there is little difference between Cases I and II.

4.3 Case III: An Interval Delivery System Using the EIDS

Case III considers a system that begins the delivery of parcels as soon as six are collected. Parcels wait on the first floor until they can fully occupy the elevator area reserved for them. Case III is different from Case II in that the elevator may not immediately deliver a parcel upon its arrival. That is, some reserve time is required for parcels until the elevator begins to deliver them. However, this waiting time (i.e., the reserve time) does not exceed one hour (20 minutes) in scenario 1 (2). Note that an increase in the number of packages to deliver reduces the waiting time before delivery because it takes less time for them to reach one dispatching set (six packages). In other words, the elevator travels to deliver collected packages every 20 minutes or one hour. Only the demand for upward trips is influenced by the parcels’ waiting time because the automated delivery system does not require a return trip to the home floor after the dispatch of the parcel. The results indicate that the interval delivery system under the specified conditions is less beneficial than the immediate delivery system. Unlike Case II, which requires a short travel time for each parcel, Case III combines short travel times into a long travel time, particularly during peak hours. A parcel may wait up to one hour depending on the situation in which the average distribution times are 1,650.7 and 604.6 seconds for 3 and 10 times the current demand. The distribution time is much longer in Case III than in Cases I and II, which can be explained by the fact that Case III includes the reserve time in the total distribution time. A comparison of the average distribution time without the reserve time still indicates that the immediate delivery system is much more efficient. This verifies the inefficiency of collecting parcels for delivery operations. In terms of energy consumption, there is little difference between Cases I and II. The amount of energy consumed is almost independent of the number of parcels.

4.4 Case IV: An Overnight Delivery System Using the EIDS

An overnight delivery system implies that parcels do not interfere with passengers’ elevator travel. All parcels are distributed after 10 p.m. in groups of six, which means that they wait in the reservoir until the late evening to be delivered. In this case, there is no additional destination time for passengers. On average, it takes about 20 minutes to deliver a parcel in scenario 1 and an hour in scenario 2 with no interruptions. Although it takes relatively little time to deliver parcels, this system entails the longest waiting time and thus the longest dispatch time (Table 3.). To calculate the total distribution time and the total reserve time, authors use Equations 4.1 and 4.2. In Equation 4.2, the first term 79,200 denotes the start of the delivery time (10 p.m.) in seconds.

\[
\text{Reserved Time} = \sum_{i=1}^{n} 79200 - A_l, \quad (4.2)
\]

where \( n \) denotes the number of parcels/day and \( A_l \) is the arrival time for parcels in seconds.

Accordingly, Case IV consumes more electricity because there are elevator trips exclusively for the delivery of parcels.

4.5 Case V: A Delivery System Using a Separate Freight Elevator

Finally, delivery systems using separate freight elevators are commonly found in high-density office or commercial buildings. Such systems are generally employed when the demand for freight transport is high or when parcels are too large to be delivered through
passenger elevators. In this sense, the advantage of having a separate freight elevator is that there are fewer limitations in delivering parcels and that there is no increase in the destination time for passengers. These conditions are similar to those in Case IV, but there is no additional waiting time for parcels as well as for passengers. By contrast, the disadvantage of using a freight elevator is that it requires more space and additional installation and operating expenses. Freight elevators remain rare in residential buildings because there is little need for the separate operation of freight elevators. Transporting only passengers entails no additional waiting time for parcels, and the average time to the passenger destination remains the same. Theoretically, there should be no difference in the average distribution time in Case V between scenarios 1 and 2 because this time represents only the average transit time. However, there may be some differences because of differences in the demand for various floors. On the other hand, unlike in the case of the distribution time, Case V shows the highest level of energy consumption for both parcels and passengers. That is, although the demand remains the same, having two elevators requires more energy. In addition, additional installation and maintenance expenses make this system a less economically efficient model.

5. Conclusion

This study proposes the EIDS, a new delivery system that uses existing elevators to load parcels and deliver them automatically to designated floors. Authors focus on various options using the EIDS by considering the pattern of residential traffic in Strakosch (2010). Five cases are considered under two scenarios (in one scenario, the delivery demand is 3 times the current demand, and in the other, it is 10 times). Here authors consider the destination time for passengers, the distribution time for parcels, and energy consumption as outcomes.

The results indicate the shortest destination times for Cases II, IV, and V but the shortest distribution times for Cases I, II, and V. Energy consumption was moderate in Cases I, II, and III. These results suggest that the effectiveness and efficiency of these systems depend on the given situation.

In sum, the results suggest that the immediate delivery system (Case II) is the most effective one because it consumes less electricity and entails shorter destination and distribution times than the other systems. In addition, this delivery system is more advantageous than the current system (Case I) when there is a sharp increase in the number of parcels. This study presents a new paradigm for addressing the increasing demand for home delivery by proposing a new delivery system as well as by verifying its advantages and feasibility relative to existing lift systems. However, this system is conceptual, and therefore its economic feasibility in terms of its installation and operation and its performance should be further examined using a mock-up. In addition, the results are derived based on a specific set of assumptions, which may vary across situations and needs. Another limitation of this study is that authors rely mainly on the data in Strakosch (2010), which may not necessarily reflect the typical pattern of elevator use in Asia. In this regard, future research should employ data on elevator use in Asia. This study is the first to suggest a new delivery system for parcels in residential buildings in response to the emergence of new lifestyles.

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