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Article

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The package redelivery problem, convenience store solution, and the delivery desert: Case study in Aoba Ward, Yokohama

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ABSTRACT

The redelivery problem occurs when a delivery service cannot deliver an item to the recipient on the first attempt, requiring one or more additional attempts. There are impacts on profit, efficiency, convenience, traffic, and the environment. In recent years, the redelivery problem in Japan has been aggravated by the growth of e-commerce, which increases delivery volumes. As a solution, many convenience stores offer courier package pickup services, but the actual net benefits are uncertain. In this industry, store locations are chosen based on profitability and subject to laws and regulations. This study developed a model to assess the accessibility of convenience stores and their possible contribution to solve the redelivery problem. We defined a “delivery desert” as area where a resident cannot access the nearest convenience store package pickup service within walking distance, and developed a model that considers physical load relative to customer age and topographic slope. We then conducted a case study in a suburban neighborhood in the Tokyo Metropolitan Area and showed that (1) about 65% of residents in the study area live in a delivery desert, (2) regulations that restrict the location of convenience stores have a very small impact on our results, and (3) the percentage of people living in a delivery desert is low for the age groups targeted by convenience stores. These findings could serve as a reference in policy discussions for solving the redelivery problem.

1. Introduction

In recent years, smartphones, the Internet and social media have helped e-commerce grow rapidly (Lin, 2018). Japan is no exception, and it has been reported that e-commerce is spreading nationally (METI, 2018).

Along with the increase of e-commerce is growth in the delivery of goods (METI & MLIT, 2018). This has been viewed as a problem worldwide, in particular for the “last mile” of delivery (Morganti, Seidel, Blanquart, Dablanc, & Lenz, 2014). In Japan, it is reported that about 20% of courier items have to be redelivered (Cabinet Office Public Relations Office, 2017). Originally, e-commerce was expected to have a positive effect on greenhouse gas emission reductions (Siikavirta, Punakivi, Kärkkäinen, & Linnanen, 2008). However, later studies revealed that redelivery causes annual social costs in Japan of about 420,000 tons of CO₂ emissions and consumes about 180 million hours of driver's time (MLIT, 2015a).

In response, the government has promoted three policies: (1) strengthening communication between consumers and delivery companies, (2) improving the environment for active consumer participation in deliveries, and (3) improving delivery receiving methods to achieve greater convenience (MLIT, 2015b). Accordingly, the industry is working to enable consumers to designate the

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Table 1
Sample surveys of courier redelivery rates (MLIT).

	October 2017			April 2018			October 2018		
	A	B	C	A	B	C	A	B	C
Urban	844,935	139,486	16.50%	812,984	132,979	16.40%	883,584	151,386	17.10%
Suburban	1,436,175	209,040	14.60%	1,346,059	192,796	14.30%	1,354,016	198,572	14.70%
Rural	126,629	16,372	12.90%	116,576	14,721	12.60%	118,947	16,009	13.50%
All	2,407,739	364,898	15.20%	2,275,619	340,496	15.00%	2,356,547	365,967	15.50%

A = Courier deliveries B = Redeliveries C = Redelivery rate.

delivery date and time using websites and apps provided by courier and mail-order companies. Active participation encourages consumer cooperation through credits for feedback. The government is also encouraging condominiums and convenience stores to install delivery boxes to receive packages from couriers. One survey found that among all these efforts, enabling convenience stores to take deliveries was the most popular option for residents (MLIT, 2015b). However, courier services offered at convenience stores may not provide all the anticipated benefits.

The scale of the redelivery problem is evident from the results of government sample surveys of the courier redelivery rate, as shown in Table 1. The redelivery rate generally falls between 10% and 20%; hence on average, one of five packages must be redelivered because the recipient is not home the first time.

Due to location-related restrictions and biases, the ratio of the population that can go on foot to a convenience store may be limited. In this study, we define a “delivery desert” as an area where a resident cannot access the nearest convenience store package pickup service within walking distance. This is an analog to the “food desert,” a term that describes areas where people have difficulty accessing grocery shops (Suzuki, Kimura, Hino, & Kaneko, 2014; Walker, Keane, & Burke, 2010). To date no published study has geographically visualized the areas that have difficulty receiving shipments in the context of e-commerce. In this study, we evaluate the population in the delivery desert in our study area and analyze the potential contribution convenience stores can make to solve the redelivery problem.

2. Features and roles of convenience stores in Japan

The retail market share of convenience stores is rising every year around the world (Gahinet & Cliquet, 2018). In Japan, convenience stores are known as essential facilities to support daily life. Since the first convenience store, 7-Eleven, landed on the Japanese islands in 1975 the brand's growth has been conspicuous. Every store was carefully sited and services were strategically designed to reduce costs (Yuasa & Ikegame, 2001). Doing business 24 h a day, 7 days a week, increased business opportunities, and the franchise business model allowed the stores to spread rapidly across the country. Despite being designed to have limited store space, the functions of convenience stores in Japan are extremely diverse, including copying and printing, banking, ticketing, posting mail, and delivering official documents, in addition to selling the regular commodities of food, beverages, and stationery, etc. Many of the services are an extension of the Internet. Consequently, convenience stores have become an integral part of daily life, with the advantage of providing good accessibility to products and services (Gahinet & Cliquet, 2018; Nogimura, 2015). Some of the services now being provided were a response to social need, while some arose because of fierce competition in the industry, though they may have increased running costs and staff workloads. Beyond the needs of consumers for convenience stores, the development of greater assortment and functions convenient for daily life brought new opportunities and advantages to convenience stores, as shown in Table 2 (Sudo & Masuda, 2014). When it comes to introducing new concepts, 7-Eleven has typically been the market leader.

One of the functions added in this process was the service of receiving courier packages for customers to pick up in person, based on agreements between delivery companies and convenience store chains. To some extent, the convenience store chains try to

Table 2
Year of introduction of major convenience store functions.

Function	Start Year		
	7-Eleven	Lawson	FamilyMart
Open 24 h	1975	1977	1978
Copiers	1996	1983	1998
Ability to pay utility bills	1987	1989	1990
Receive courier deliveries	Yamato	1982 (~ 2004)	1985
	Sagawa	2015	–
	Japan Post	2004	2002
Ticketing services	2000	1981	1988
Food delivery	2000	2014	
ATM (banking services)	2000	2001	1999
Issuance of official resident's card	2010	2016	2016

differentiate themselves by signing contracts with different delivery companies (MLIT, 2015b; Yamato Transport Co., 2004).

The main target market of convenience stores was originally the younger generation. However, as store functions have diversified, the customer base has been changing. In the 2000s, the proportion of customers aged over 50 has rapidly increased, reaching 30% of total convenience store customers in 2013 (Kato, 2016). In recent years, convenience stores have also enhanced their support systems to provide services for seniors. This is another factor driving the increase in senior customers (Nakamura, Matsumoto, Yamamoto-Mitani, Suzuki, & Igarashi, 2018).

With the expansion of the customer base in addition to their inherent advantages of time, distance and opportunity, convenience stores are also beginning to serve as a kind of social infrastructure provided by the private sector. During the Tohoku earthquake and tsunami disaster that struck on March 11, 2011, convenience stores responded in a timely way and demonstrated resilience by providing convenient access to food, water, and many emergency needs with their own distributed logistics networks. In fact, in 2009, the Japan Franchise Association had already issued the “Convenience Store Declaration as Social Infrastructure,” supported by major convenience store chains (Japan Franchise Association, 2009).

This was also a reason for the government to look to convenience stores as a solution to the redelivery problem. Generally speaking, the delivery system in Japan is already very well done. For example, a customer can go online to specify the delivery time and location, and can also track packages being delivered in real time. These options provide convenience and increase the likelihood that a customer can receive the package at home. Meanwhile, one government survey reported that 90% of respondents would prefer to have courier deliveries go straight to a convenience store on the first attempt, in order to eliminate the need for redeliveries (MLIT, 2015b).

On the other hand, we must not forget that convenience store chains target specific customer segments to maximize profits, and operate under laws and regulations that constrain their location choices. The real potential for convenience stores to eliminate the redelivery problem is still an open question in Japan.

Therefore, in this study, we use geographical information systems (GIS) to estimate the number people living in the delivery desert in the study area, and define and measure the area where courier services cannot be practically provided via convenience stores. Our study recognizes the fact that picking up a package at a convenience store requires physical mobility within the delivery desert, and this could be a source of resistance for vulnerable persons.

3. Delivery desert: definition and quantitative evaluation

3.1. Definition

Before considering the delivery desert, let's look back on the definition of “food desert.” There is no clear definition of this term despite many studies on the topic. Food desert originally meant an area where people cannot access a grocery store near where they live. However, studies of food deserts more commonly assess differential access to healthy and affordable food between socio-economically advantaged and disadvantaged areas (Beaulac, Kristjansson, & Cummins, 2009). (Walker et al., 2010) proposed five indicators to identify a food desert: (1) distance to the nearest grocery store, (2) number of supermarkets in the area, (3) economic costs, (4) types of food provided, and (5) nutritional value of the food provided.

In contrast to the concept of food desert, when using e-commerce, the delivery company typically delivers an order to the front door of the consumer, meaning the consumer hardly moves physically. However, in the context of convenience stores being considered as a solution for the redelivery problem, the “last mile” requires the physical movement of the consumer. Thus, just as with the food desert, in our examination of using convenience stores for package pickup, it is possible for areas to exist where it is difficult to gain access to shipments. In the simplest terms, a delivery desert could be assessed simply by using a distance indicator, i.e., the distance from home to the nearest convenience store that provides a courier package pickup service.

Previous research targeting Tokyo shows that about 65% of the population has access to a convenience store by walking, and less than 80% by walking or cycling (Hwang & Takada, 1995). The use of bicycles decreases as access by walking increases in areas with slopes though the coverage is assumed to become smaller. For this reason, we adopted walkable distance as an indicator for access in this study. Some studies define a convenience store's walkable radius as 400 m or 500 m (Takemoto, 2015), equivalent to a 5-min walk. Thus, the accessible zone is set as a 5-min walking distance for this study. To summarize the above points, the definition of delivery desert in this study is “an area where a resident cannot access the nearest convenience store package pickup service within walking distance” (a 5-min walk, adjusted for metabolic equivalent).

3.2. Quantitative evaluation

As a method of evaluating walking access while also considering physical load, many studies have focused on energy expenditure (Hall, Figueroa, Fernhall, Kanaley, & Kanaley, 2004; van der Walt & Wyndham, 1973). Thus, in order to consider physical load, we used the metabolic conversion distance instead of actual distance to calculate the area of a delivery desert, with reference to previous studies (Hara, Ishizaka, & Ohashi, 2009; Satoh, Yoshikawa, & Yamada, 2006). The metabolic conversion distance is the actual distance calibrated with consideration of the physical load when walking. Parameters to calculate physical load include, walking speed, body weight, and basal metabolic rate by age as the attributes of pedestrians, and road slope as an attribute of roads. This is based on the assumption that the walking speed differs based on the pedestrian's age, basal metabolic rate, and the amount of energy required per day per unit of body weight. The population accessible to convenience stores was obtained by conducting a service area analysis using metabolic conversion distance and estimating the population size living in the reachable area (a 5-min walkable area,

Table 3
Symbol legend.

Variable	Description	Units
R	Walking load	–
E	Energy consumption	kcal
L	Metabolic conversion distance	m
RMR	Relative metabolic rate	–
BMR	Basal metabolic rate	kcal
W	Weight	kg
T	Walking time	min
a	Estimated energy requirement of day per weight	kcal/kg/day
L	Length	m
v	Walking speed	m/min
S	Slope	%

as mentioned above). The calculation of the metabolic conversion distance is shown below. The variables used in the following formulas are summarized in Table 3.

The metabolic conversion distance (L) is obtained by multiplying the actual distance (l) by the walking load (R) which takes into account elements such as the slope, then divided by walking load when the road is horizontal (R₀) (Satoh et al., 2006).

$$L = l \times R / R_0$$

Next, walking load (R) is “the energy consumption when walking from a certain point to a destination point divided by the energy necessary for one day” (Hara et al., 2009). Energy consumption by walking (E) is expressed by the following equation:

$$E = (RMR + 1.2) \times BMR \times W \times T$$

Relative metabolic rate (RMR) represents the influence of topography such as road slope. Relative loads are indicated by the value of (RMR + 1.2), where the constant 1.2 is the resting metabolic rate during daytime life. Basal metabolic rate (BMR) x body weight (W) is basal metabolism and represents the minimum amount of energy required to maintain human life for one day. Because these differ depending on age and body weight, the equation is as shown above (Kanamori & Yan, 2018). In addition, the influence of age is reflected in the movement time (T) as a decrease in walking speed (v).

$$\begin{aligned} R &= E / (a \times W) \\ &= (RMR + 1.2) \times BMR \times W \times T \times \{1 / (a \times W)\} \\ &= (RMR + 1.2) \times BMR \times (l/v) \times (1/a) \end{aligned}$$

The rate of relative metabolic rate (RMR) varies with the slope (s) and the walking speed (v). Research in the past used the walking speed for each age group to substitute for the above moving speed (T), while in the calculation of the energy metabolic rate, many studies substituted 80 m/min, indicating that the accuracy was not necessarily high. Therefore, based on previous studies that fully consider the continuity of the function, this study calculates using the following formula (Hara et al., 2009; Satoh et al., 2006):

when v = 80m

$$RMR(s,80) = 10.0 (s \leq -0.25)$$

$$RMR(s,80) = -58.07s - 4.52 (0.25 \leq s \leq -0.11)$$

$$RMR(s,80) = 3.113e^{4.614s} (-0.11 \leq s \leq 0.25)$$

$$RMR(s,80) = 10.0 (0.25 \leq s)$$

when s = 0

$$RMR(0,v) = 0.4366e^{0.0246v}$$

This is assigned to the following equation:

$$RMR = RMR(s, 80) + RMR(0, v) - RMR(0, 80)$$

The metabolic conversion distance can be calculated from the above equation.

4. Case study

4.1. Features of study area

The Japanese population made a significant transformation from rural areas to large cities in the 1960s and 1970s due to labor demand in urban areas. To meet the enormous demand for housing, a policy of ownership with a focus on own-construction was

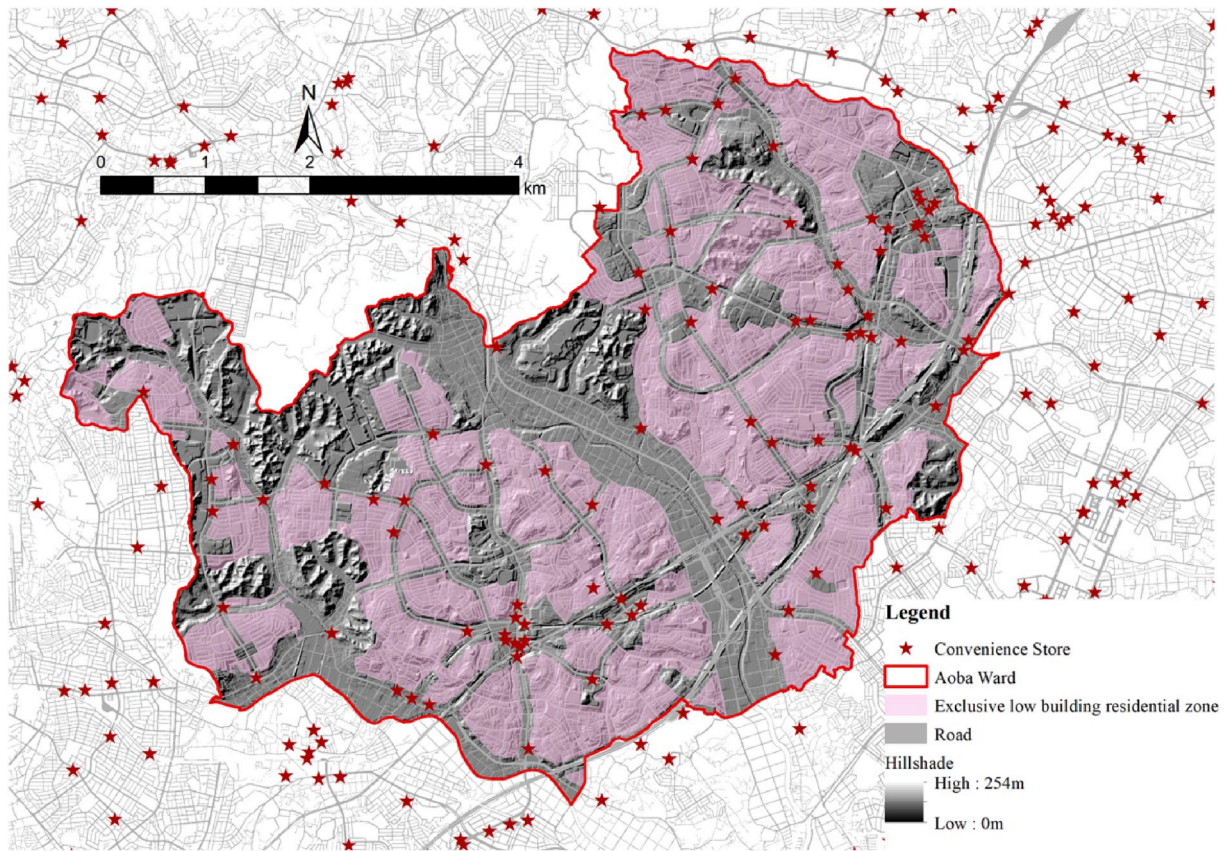


Fig. 1. Convenience store locations in Aoba ward.

promoted so that suburban areas were rapidly converted to residential areas by the private sector (Ishibashi & Taniguchi, 2005). Examples in Tokyo include Tama New Town and Tama Garden City, but for this study, we focused on Aoba Ward, Yokohama City, which is one of these housing complexes. Our targeted area corresponds to the second phase of Tama Garden City. The Radburn street structure with a view to the car society was adopted at the center of the area (Abe, Koshizawa, & Sakai, 2007). Thus, it is known as a popular residential area in the metropolitan area. The development has received high reviews, having been awarded the 1987 Architectural Institute of Japan Award, the 1989 Green City Award (Prime Minister's Prize), and the 2002 Japan City Planning Society Award (Ishikawa Prize).

On the other hand, problems in car-centered urban development and residential land formation remote from the city center in anticipation of land price escalation are becoming apparent with the aging of the town (Matsubara, 1982; Toura, 2018). The Aoba Ward is located on the Tama Hills, with steep slopes as shown in Fig. 1. The slopes are a challenge for elderly persons to walk if they have to surrender their driving licenses. In response to this, Tokyu Corporation, the developer of this area, and the municipality of Yokohama initiated a citizen participatory project, entitled Community Development for Next Generation of Suburban Town.

4.2. Convenience stores in study area

There are 86 convenience stores in Aoba Ward, basically concentrated in front of train stations but sparse in residential areas along main roads. As shaded pink in Fig. 1, about 47% of the area is zoned under Japan's City Planning Act as a "Category 1 low-rise exclusive residential district," where convenience stores are not permitted.

4.3. Managing data

In calculating the metabolic conversion distance, we used the coordinate data of the stores, the population data apportioned for each house, and road data for considering the physical load.

To estimate population for each house, we used 2015 census data and a 2013 City Planning Basic Survey by Yokohama City. First, buildings for housing were extracted from the City Planning Basic Survey, and population data from the census was distributed according to the total floor area of each building.

Finally, road section data considering physical load was created from three types of data: section length, slope, and physical load

Table 4
Parameters for metabolic conversion calculations.

Age	v (m/min)	BMR (kcal/kg/min)	a (kcal/day)
20~29	80.24	0.01601	41.93
30~39	80.76	0.01528	38.69
40~49	79.12		
50~59	70.19	0.01465	37.52
60~69	63.18		
70~	56.22		36.67

by walking. The road section data originates to the road center line data of the digital National Base Map. In addition, in order to calculate the slope of each road section, first, the 5 m grid Digital Terrain Model by the Geographical Survey Institute was set to the end points of each section of the road center line. Then the slope was calculated for each section. In order to reflect the average Japanese physical ability, the parameters shown in Table 4 were adopted from the report updated by the Ministry of Health, Labor and Welfare every five years (MHLW, 2015).

Based on these, we calculated the metabolic conversion distance for each road section and estimated the area of the delivery desert by using “Service Area Analysis,” an ArcMap tool for network analysis.

4.4. Results of analysis

Below we calculate the “delivery desert occupancy rate,” which we define as the ratio of adult residents in Aoba Ward who live in a delivery desert. We used the service area analysis function of ArcMap to estimate, by age group, the population living in a delivery desert. We found that the overall delivery desert occupancy rate was 64.82% for all adults in the study area. This is ratio of all adults without walkable access to any convenience store.

Using the same methodology, we also calculated delivery deserts for adults relying specifically on any one of the three major delivery companies, which together boast a 94.4% market share for package deliveries in Japan: Yamato Transport Co., Ltd., Sagawa Express, and Japan Post (MLIT, 2018). The results are shown in Fig. 2. Our study revealed that the company-specific delivery desert

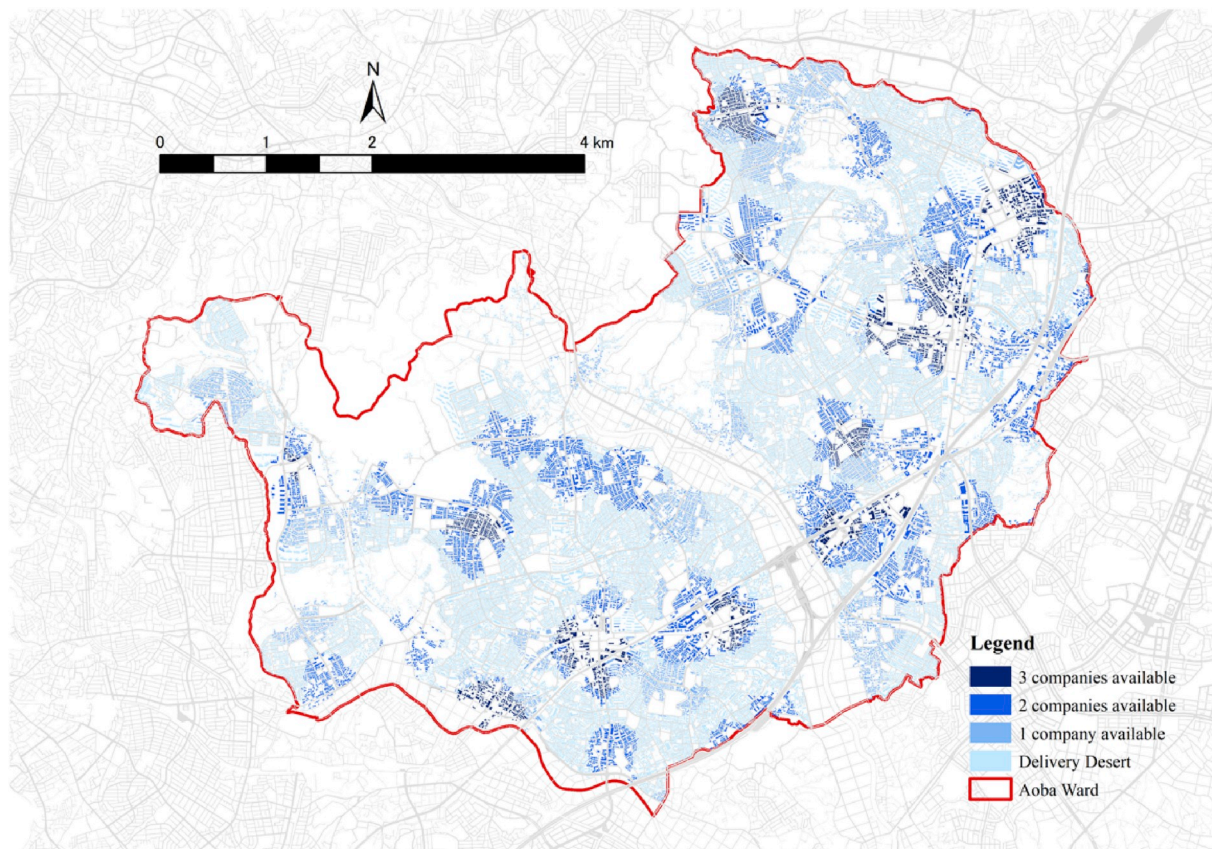


Fig. 2. Map of delivery deserts in Aoba Ward.

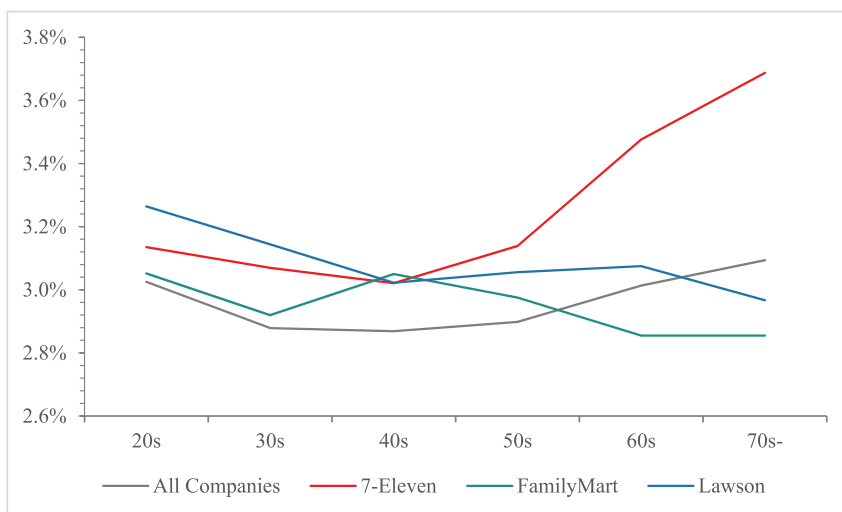


Fig. 3. Average percent of population per square kilometer living within walking distance of a convenience store (adjusted by age group and convenience store chain).

occupancy rates were 73.46% for Yamato Transport, 83.63% for Sagawa Express, and 74.72% for Japan Post.

The area not classified as delivery desert in the Category 1 low-rise exclusive residential districts was 26.11%, and 27.23% for Aoba Ward as a whole.

Our study also clarified the average percent of population per square kilometer living within walking distance of a convenience store. Fig. 3 shows that convenience stores have lowest coverage for residents in their thirties and forties. This figure also reveals differences in the apparent target segment of each company: Relatively speaking, it appears Lawson tends to attract customers in their twenties, 7-Eleven senior customers, and FamilyMart the middle age range.

5. Discussion

5.1. Discrepancies between delivery desert in study area and actual situation

Our study showed that 64.82% of the population in the study area lived in a delivery desert. In addition, we found that the delivery desert occupancy rate ranged from 73% to 84% depending on the delivery company, as shown in Table 5. However, in apparent contradiction, the aforementioned survey of home delivery service users found that about 90% of respondents answered that they preferred a convenience store as a method of receiving package delivery services without the need for redelivery (MLIT, 2015b). In other words, respondents have the perception that they can easily access convenience stores. Why does this gap occur?

A visual interpretation of satellite images revealed that more than half of the convenience stores in Aoba Ward had parking lots. Perhaps customers hesitate to pick up courier items by walking to the store if the items are heavy. This observation suggests that when discussing convenience stores in suburban areas it is also important to consider the means of transportation and the environmental costs that accompany them. This study underestimated the potential contribution of convenience stores to eliminate the delivery desert in suburban areas where driving a vehicle for errands is common practice. Although it has been suggested that e-commerce would help reduce greenhouse gases emissions (Siikavirta et al., 2008), at least in our study area, the last mile still largely depends on the customer driving a vehicle.

Table 5
Delivery desert occupancy rates for adults in study area.

Delivery company	Yamato	Sagawa	Japan Post
Contracting convenience store chain	7-Eleven FamilyMart	Lawson	FamilyMart Lawson
Service area (residents in 20s)	18.08 km ²	10.17 km ²	16.16 km ²
Delivery desert rate (residents in 20s)	48.60%	71.10%	54.06%
Service area (residents in 70s)	9.60 km ²	5.04 km ²	8.56 km ²
Delivery desert rate (residents in 70s)	72.71%	85.67%	75.66%
Delivery desert occupancy rate	73.46%	83.46%	74.72%

5.2. Delivery deserts and regulations affecting store locations

Laws and regulations have been important factors restricting the location and service areas of convenience stores in Japan (Ishikawa & Asami, 2013). In suburban areas, the location of convenience stores is strictly regulated in land use planning for the purpose of maintaining the living environment (Mikado & Nakade, 1995). Such regulations have affected the distribution of the stores in the study area and influenced the results of our assessment of the delivery desert. The ratio of land area not classified as a delivery desert was 26.11% in the Category 1 low-rise exclusive residential districts and 27.23% in the zoning district. Certainly, the coverage of convenience stores tends to be somewhat low within Category 1 low-rise exclusive residential districts. However, the map in Fig. 1 shows that convenience stores are mostly located not within but between the Category 1 low-rise exclusive residential districts. This reflects the urban planning zoning system. Roadsides and intersections are normally excluded from Category 1 low-rise exclusive residential districts in order to protect a good living environment. Interviews conducted by the author confirmed that this perception is present among residents in community, based on concerns that a good living environment will be damaged by noise and disruptions from living close to a convenience store. This perception appears to be stronger in areas that have a community environmental code. At the core of the debate about locations of convenience stores is a kind of tradeoff in convenience versus quality of living conditions.

5.3. Private sector constraints in solving the delivery desert problem

The delivery desert and a convenience store's pursuit of profits are inseparable issues. Convenience store chains use area marketing techniques to open shops in areas with many potential customers. However, as shown in Fig. 3, in this study area, cohorts in their thirties and forties tend not to live in areas where it is easy to access convenience stores, although these age ranges are mostly double-income households, and they are increasing in number in recent years. Those households are presumably in the busy years of raising families and would have higher needs for convenient courier delivery services, compared seniors who might tend to stay longer at home during the day. As a business strategy, while convenience stores certainly provide many social infrastructure functions, they also need to consider the changing population trends and consumer needs in the areas they serve.

6. Conclusion

Using a study area in Aoba Ward, Yokohama City, part of the Tokyo Metropolitan Area, this study examined the potential for courier package reception services at convenience stores to be a solution to the redelivery problem. The results showed that the delivery desert by our definition covers up to about 65% of the total land area in the study area. On the other hand, a survey showed that 90% of convenience store users preferred to use a convenience store to pick up their courier deliveries and avoid the need for redelivery (MLIT, 2015b). This gap arises in suburban areas where there are limited options to get to a convenience store only by walking.

Meanwhile, the percentage of land area not classified as a delivery desert was about 26% for Category 1 low-rise exclusive residential districts (where in principle, convenience stores are not permitted), and 27% for Aoba Ward as a whole. There is certainly a tendency for coverage to be rather low in the Category 1 low-rise exclusive residential districts, but our study showed that regulations on the location of convenience stores are a very minor factor in the delivery desert.

Generally, convenience stores, which are privately owned, are deployed in Japan to maximize profits by targeting a particular customer segment (Kato, 2016). For example, in the past, convenience stores were most popular for customers under age 30, but the target market has shifted to higher age segments (Kato, 2016). Fig. 3 shows that 7-Eleven has an advantage in popularity among seniors, Lawson among young customers, and FamilyMart among customers in their middle years. Our study described differences between the target segments for each convenience store chain. Furthermore, the accessibility of convenience stores for people in their thirties and forties was low in the study area, indicating a bias in the age structure of the beneficiaries. Our study has described the delivery desert in the study area and suggests that there are limits to the contributions convenience stores can make to solve the redelivery problem.

However, some limitations should be noted regarding this study. First, this method does not accurately estimate how many people are having trouble in receiving packages. For example, elderly persons who cannot drive a car tend to be at home and able to receive a delivery, or a family member may be at home and receive a package on behalf of the official addressee. Such cases were not considered in this paper, so our calculations may overestimate the number of people who live in the delivery desert. Moreover, our study area this time was a hilly neighborhood which is heavily car-dependent. Although such conditions are quite common in Japan, the results may vary in neighborhoods with different urban designs, densities, and topographies. Such variations remain for future study.

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