

Article

Case Study on the Efficiency of Recycling Companies' Waste Paper Collection Stations in Japan

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Abstract: Each year, a large amount of waste paper (WP) is generated in Japan, and due to the change in lifestyle with the COVID-19 pandemic, the WP collection and recycling system in Japan faces new challenges. Although the government of Japan has installed WP collection systems, the efficiency of these traditional WP collection systems is too low, and this causes inconvenience to the governments, residents, and other stakeholders. On the other hand, some recycling companies in Japan are trying to establish a nontraditional WP collection system by setting their own WP collection stations in cooperative supermarkets. Yet, the efficiency of this new system has not been clarified. This research aims to investigate the current status, operational characteristics, and the role of recycling companies' WP collection stations in the Japanese WP collection system. By performing trade area analysis and stepwise OLS regression, this research will evaluate WP collection stations' efficiency. Moreover, this research will also discuss how the new WP collection system improves WP collection efficiency and residents' convenience. The results show that WP collection stations efficiency is particularly high in large supermarkets with many parking spaces and long business hours, as well as in areas with many families with children. Recycling companies' WP collection system could create a system, which can satisfy resident, government, and recycling company interests at the same time.

Keywords: waste paper; collection station; efficiency; recycling company; Japan

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1. Introduction

Despite the rapid expansion of the electronic publication business, usage of paper is steadily increasing and has exceeded 400 million tons per year globally. More than half of the paper consumption occurs in China, the USA, and Japan [1]. This enormous consumption of paper could lead to various environmental problems such as forest degradation, contaminated gas and wastewater emission, and shortage in landfill capacity. Therefore, paper recycling is an important issue worldwide [2,3]. Moreover, due to the COVID-19 pandemic, more people tend to use in-home deliveries and spend more time staying indoors cleaning their homes. This change in lifestyle means more WP will be generated and will bring new challenges to the WP collection and recycling system [4,5].

In 1995, to improve the collection rate of household waste, the Japanese government published the "Packaging Waste Recycling Law", which mentioned the collection of WP. This law required residents, municipalities, and producers to participate in WP recycling, and suggested that the municipalities had the main responsibility for WP collection as a public service [6]. However, only 45% of WP is collected by municipalities currently, and most of these municipalities have felt an economic burden due to WP collection [7,8]. On the other hand, residents in Japan also think the traditional WP collection system is inconvenient since they have to separate and store WP at home first, and they then have to take

WP to a designated collection site on specified days. Residents in Japan consider the current WP collection system a time-consuming and unpleasant practice [9].

In addition, there is another traditional WP collection system, in which some residential groups (such as town councils and neighborhood community associations) cooperate with collection agencies to collect WP as well [10]. Unfortunately, this system is unstable since the price of WP changes constantly, and when the value of WP becomes too low, the collection agencies will stop collecting WP. Moreover, due to the COVID-19 pandemic, many residential groups have reduced or stopped collecting WP to prevent infection. Therefore, it is plain to see that these traditional WP collection systems are not sufficient.

On the other hand, some recycling companies in Japan started to establish their own WP collection system by establishing their own WP collection stations in cooperative supermarkets. However, the weight and quality of collected WP by these collection stations as compared to traditional WP collection systems has not yet been clarified.

Therefore, the first aim of this study is to investigate the current status, operational characteristics, and the role of recycling companies' WP collection stations in the Japanese WP collection system. This research also performs trade area analysis and stepwise OLS regression to evaluate WP collection stations' efficiency. Moreover, this research will also discuss how exactly the new WP collection system improves WP collection efficiency and residents' convenience. This research will clarify whether the WP collection stations established by the recycling companies improve WP collection in Japan. Since Japan is the third-largest country in terms of paper consumption, these research results can also be useful for other countries with large amounts of paper consumption and countries with less developed WP collection systems.

2. Literature Review

Tanaka surveyed the background and historical trend of Japanese waste management policies [6]. Tanaka suggested that, in Japan, local resident groups will play an important role in recycling activities, and only with close cooperation between the government, residents, and producers can an efficient recycling system be built. Sakata carried out a choice experiment and collected 500 samples from the north Kagoshima City to investigate residents' preference towards municipal service for waste collection [11]. The result shows that the rise in household waste recycling rate accompanied the rise in municipal service's cost. However, although the residents would spend time on separating the waste, they did not prefer to make higher direct monetary payments. Sakata also demonstrated that the municipal authorities and residents should keep communicating.

Videras et al. surveyed residents' environmental behaviors through interview research with 452 residents in the USA and tried to show the relationships between "green family profiles", altruistic behavior, and community-based behaviors [12]. The result showed that local residents play an important role in solving the waste recycling problem, and highlighted the need for uniting policy enactment, government service, and residents' participation in the process of waste recycling. These studies clarified that it is important for the residents to take part in waste separation, collection, and recycling activities.

On the other hand, the method of municipal waste collection services varies from country to country. For instance, in developed countries, most waste is collected from the curbside. Antoni and Marzetti surveyed the waste generation amount and recycling rates for 116 provincial capitals in Italy and showed that a municipal waste collection service from cities' curbside would greatly reduce the generation of waste and improve the waste collection rate [13]. However, the government will have to pay more to maintain such a service. In other words, in developed countries, the higher the waste collection rate is, the more collection costs the governments have to assume.

Other studies have analyzed the relationship between the average cost of municipal household waste collection and the collection rate of waste using econometric models. For instance, Bohm argues that although the cost for collecting waste will decrease as the

waste collection rate grows, when the waste collection rate reaches a certain point, chasing a higher recycling rate will cause higher economic cost; even so, many municipalities are trying to fulfill waste collection targets despite these economic rationalizations [14,15]. Similar to previously mentioned studies, Japan also has the same problems. Kinnaman, Shinkuma, and Yamamoto estimated the average social cost (such as municipal costs and revenues, household costs, and external disposal costs) to achieve different levels of recycling rates [16]. The result showed that the waste recycling goal in Japan is not economically efficient. Honma and Hu investigated 1809 municipalities' waste collection cost efficiency in Japan from 2011 to 2018 using stochastic cost frontier models [17] and found the current recycling rate was too high to minimize the recycling cost, and so, caused high economic pressure on the household waste recycling system. These studies suggest that the recycling rate set by the Japanese government was too high, and it is difficult for the government to minimize the waste treatment cost.

In other words, although waste paper collection and recycling technologies are well developed in Japan, from an economic point of view, the municipal household waste management system is still insufficient. Therefore, it is important to develop an efficient WP recycling system with less pressure on municipalities and residents. However, current research has not proposed an efficient solution.

López Alvarez et al. suggested that in Spain, GIS technology could be used to analyze the local population density and territory characteristics, and installed containers to collect WP from small businesses based on the analysis result. Such a method has improved local waste paper collection efficiency and quality [18]. However, the discussion about whether WP collection containers would decrease governments' and residents' burdens is missing from the previous studies.

3. Materials and Methods

3.1. Current Situation Analysis in Case Study Area

Recycling company A is one of the large recycling companies in Japan, and has established over 300 WP collection stations in Japan; the number of their WP collection stations is still increasing. Therefore, this research selected recycling company A as the research subject.

Miyagi prefecture has the most WP collection stations set by recycling company A. Furthermore, Miyagi prefecture has the largest population (approximately 2.28 million) in the Tohoku area of Japan [19], and so, this study selected Miyagi prefecture as the research area. The research result can be generalized to the status of WP collection in other cities in Japan as well.

Currently, recycling company A is cooperating with 94 local supermarkets to set WP collection stations (26% of all supermarkets in the Miyagi prefecture).

Figure 1 shows the distribution of the 94 WP collection stations in the Miyagi prefecture. The red symbols represent the location of WP collection stations, and the blue symbols represent the population density. Among all the WP collection stations, 45 of them are in Sendai city (the capital of Miyagi prefecture), and the other 49 of them are in other cities. These WP collections are mostly located in the area with high population density, and in areas with particularly high population density, multiple WP collection stations were installed.

To calculate the efficiency of these WP collection stations, this research collected the monthly WP collection data of these 94 WP collection stations from April 2019 to August 2020.

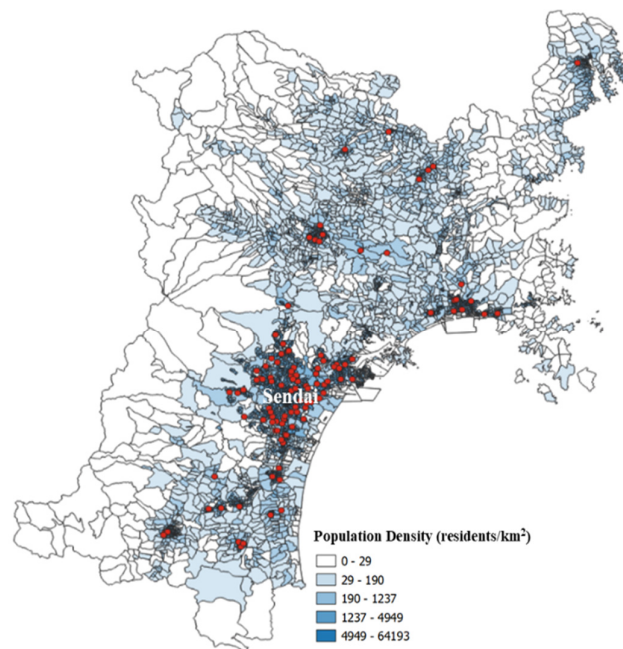


Figure 1. Distribution of WP collection stations in Miyagi Prefecture.

3.2. Field Surveys of WP Collection Stations

This research conducted field surveys on 40 WP collection stations in and around Sendai city to understand their operation state and WP collection situation (Figure 2). In order to obtain the actual use of WP collection stations and survey the change in WP collection stations' collection status, this research investigated the total and average WP collection results from April 2019 to August 2020.



Figure 2. WP collection status.

3.3. Approach of Trade Area Analysis

Since the WP collection stations are collecting WP from supermarket users, it is fair to presume that supermarkets' marketing activity will greatly affect WP collection stations' efficiency. For example, from the marketing perspective, the attractiveness of a commercial district can be quantified by the urban facility metrics (especially parking lots) and human metrics (such as population density) [20]. In other words, a supermarket's commercial scale, facility condition, business condition, and trade area population can represent its accessibility, which will not only affect its sales status but will also affect the efficiency of WP collection stations. Moreover, existing studies have shown the relationship between demographic parameters (such as population density and housewives) and WP collection status [21]. Therefore, in order to calculate demographic data, it is necessary to understand the studied supermarkets' trade area radius first.

According to a Japanese retail industry analysis, when the distance radius between the consumers and a supermarket is above two kilometers, consumers' usage frequency of the supermarket will decrease [22]. Since we consider WP disposal to be a daily behavior, we set the distance radius to be two kilometers in this study. Furthermore, since the population will greatly affect the amount of WP generation, this research also confirmed the population density and number of households with different types of families (such as couples, families with children, and extended families) in the researched area. To do so, we collected the population census data in every street (as in Chome in Japanese) from the Statistics Bureau of Japan [23]. The variables used in this research can be found in Table 1.

Table 1. Descriptive statistics of variables in WP collection station analysis.

Groups	Variables	Mean	Std. Dev.	Min.	Max.	Unit
Trade area characteristics	Business years (By 2019)	17	9	1	38	year
	Business hours	12	1	11	14	hour
	Parking spaces	295	205	10	1026	car
	Land price	74,278	59,966	12,400	390,000	JPY/m ²
Population	Population density	1204	882	62	5823	resident/km ²
	Couples	1144	864	72	5420	household
	Family with children	1666	1105	88	6565	household
	Extended family	573	345	16	1645	household

3.4. Stepwise Multiple Regression Analysis

To survey WP collection station efficiency, this research performed stepwise multiple regression analysis. We considered WP collection stations' monthly collection status (including usage frequency, new registers, amount of collected WP) as dependent variables. As there were COVID-19 infections in Miyagi prefecture from March 2020, only the data from April 2019 to February 2020 were used for the regression analysis.

Since there are large differences in the value range of variables, in order to ensure the reliability of analysis results, we rescaled the original variables. The normalized variables are shown in Table 2, the mean of rescaled variables was 0, and their standard deviation was 1.

Table 2. Descriptive statistics of variables in stepwise multiple regression analysis.

Dependent Variables	Min.	Max.	Median
Number of station usage (Dv1)	−2.102	2.960	−0.166
Number of new users (Dv2)	−0.777	2.792	−0.777
Total amount of WP (Dv3)	−2.446	3.464	−0.130
Amount of newspaper (Dv4)	−2.621	2.876	−0.003
Amount of magazine (Dv5)	−2.356	3.939	−0.054
Amount of cardboard (Dv6)	−1.390	2.548	−0.029
Independent variables			
Business years	−1.763	2.377	−0.029
Business hours	−2.197	2.809	0.306
Parking spaces	−1.380	3.544	−0.387
Land price	−1.026	5.237	−0.199
Population density	−1.288	5.208	−0.218
Couples	−1.233	4.921	−0.294
Family with children	−1.420	4.408	−0.190
Extended family	−1.606	3.088	−0.232

Meanwhile, to choose a relatively small number of significant explanatory variables from a vast array of possibilities, this research performed a backward stepwise regression. Such a method can not only guarantee the validity and importance of the chosen variables but also reduces additional errors introduced by the redundant variables [24]. The statistical analysis was conducted with R statistical package. We used the “lm” and “step” functions of R language to run the stepwise OLS regression, so the variable selection was based on AIC.

4. Result of Analysis

4.1. Management State of WP Collection Stations

Recycling company A signs contracts with supermarkets and pays them rent to install WP collection stations. The WP collection stations are mostly located near the parking lot or the entrance, and their business hours are the same as the supermarkets. Figure 3 is an image of WP collection stations.

Most WP collection stations divide the WP into two types, newspaper (including flyers) and magazine (including miscellaneous paper waste such as wrapping paper and envelopes). In total, 80% of the collection stations also have an individual cardboard collection box as well. The WP collection stations are equipped with cameras, and when the users deliver their WP to collection stations, the collection stations will add a certain number of points to their point cards, which can be used in the supermarkets. Generally, WP collection stations users will collect one point (which equals one Japanese Yen) for one kilogram of WP. Some users can also use the point they collect from the WP collection stations to exchange for store coupons.

Such a reward could nudge consumers' separating and recycling behavior; meanwhile, it is also easy for users to use the service since they do not need to wait for the specified municipal collection days, as they can dispose of WP anytime they go to the supermarket.



Figure 3. A WP collection station in Miyagi Prefecture.

4.2. Characteristics of WP Collection Stations

Based on the WP collection status from 2019 to 2020, the station usage and new users of WP collection stations increased (especially in 2020). As shown in Figure 4, the amount of collected waste cardboard also increased.

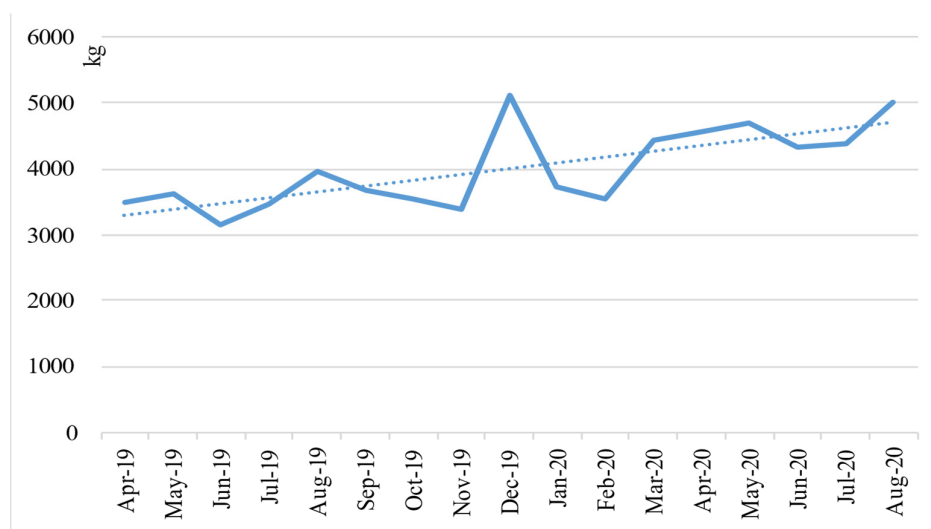


Figure 4. Average collection amount of cardboard by a WP collection station monthly.

From April 2019 to February 2020, 1695 tons of WP were collected through WP collection stations in Miyagi prefecture. The proportion for each type of collected WP is shown in Figure 5. Most WP was identified as newspapers, while a small part was cardboard. This could be because the Miyagi prefecture collects WP once every two weeks, while newspapers are usually delivered daily. Since the WP collection stations were installed, the local residents can dispose of waste newspaper easily and do not need to accumulate waste newspaper at home. On the other hand, since cardboard is comparatively heavy, it is necessary to have vehicles and physical strength to dump cardboard, and so, only a small amount of cardboard was collected.

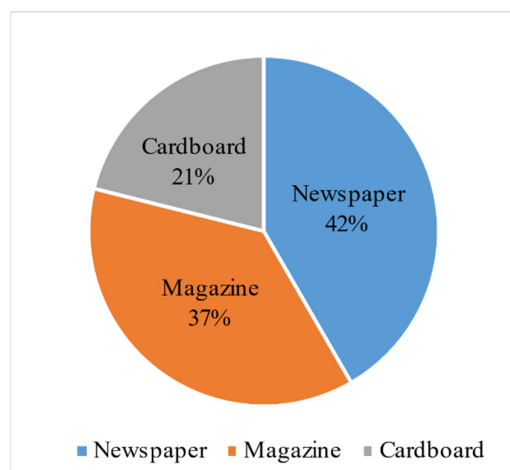


Figure 5. Ratio of three types of WP collected by WP collection stations in 2019.

WP collection status in different areas can also be different. In this research, based on the median land price, WP collection stations were classified into stations set in low land price areas and stations set in high land price areas, and the WP collection status in each area was investigated.

The usage status and new user number of WP collection stations in each area are shown in Figure 6. The usage frequency of WP collection stations in the downtown area reached 1620 per month, while the usage frequency of WP collections in the suburbs was

only 1450 per month. Furthermore, the number of new users in downtown and the suburbs was 36 and 27, respectively.

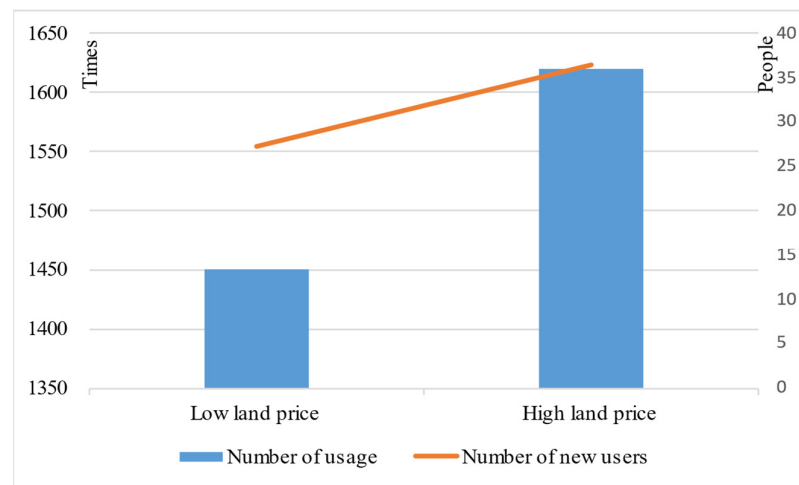


Figure 6. Average number of usage and new users of a WP collection station monthly according to different land prices.

Figure 7 shows the performance of WP collection stations in each area. According to Figure 7, WP collection stations set in downtown areas collect more WP than the stations set in suburban areas. This is because the floor space downtown is comparatively small, especially for the residents who live in an apartment, and there is no extra space to store WP.

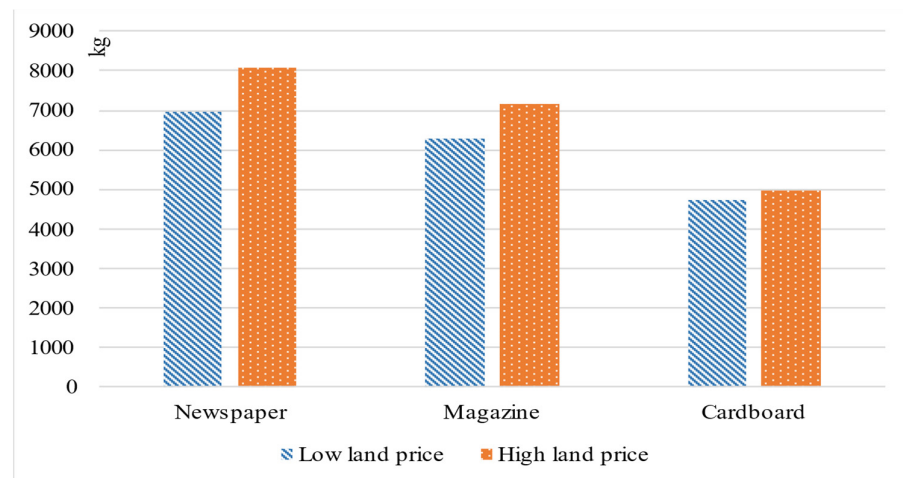


Figure 7. Average amount of three types of WP of a WP collection station monthly according to different land prices.

4.3. Pattern of WP Collection Station User Behavior

Compared to 2019, the amount of collected waste newspaper in 2020 decreased quickly (Figure 8). The reason could be that the digital media industry is growing fast, and so, traditional newspaper readership continues to decrease in Japan [25].

On the other hand, the amount of collected magazines in May and June in 2020 increased compared with that in 2019. This is because due to COVID-19, the government of Japan declared a nationwide state of emergency on 16 April 2020. Under such circumstances, many people started to work at home and were urged to declutter waste

magazines [26]. This led to the increment in waste magazine and books collection amounts in the next two months.

The amount of collected cardboard in 2020 also increased compared with that in 2019. Due to the COVID-19 pandemic, more users tended to use home delivery and online shopping services. This led to an increase in the amount of waste cardboard [27]. The amount of waste cardboard may keep increasing in the future.

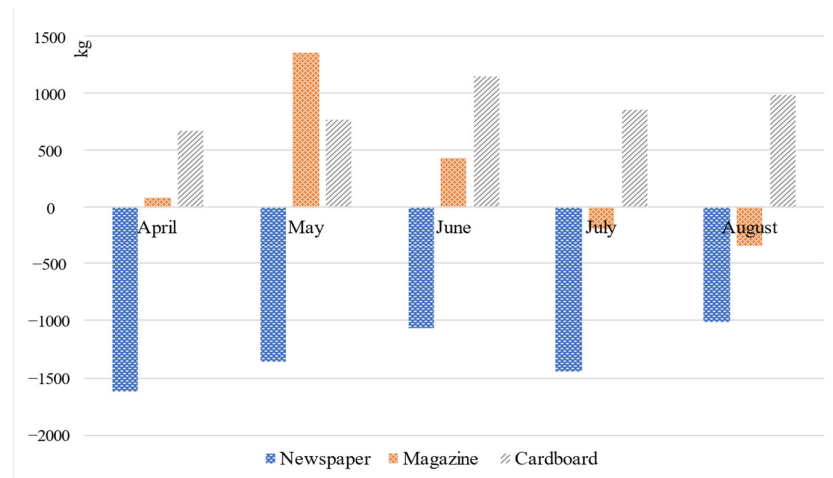


Figure 8. Increased amount of collected newspaper, magazine, and cardboard in 2020 compared to 2019.

Moreover, the proportion of waste newspaper, magazine, and cardboard in the total collected WP each reached 30% from April to August 2020 (Figure 9). Among these three types of items, the proportion of magazines was the highest. The ratio of newspaper decreased by 10%, while the proportion of cardboard increased by 9% compared to 2019 (as shown in Figure 5).

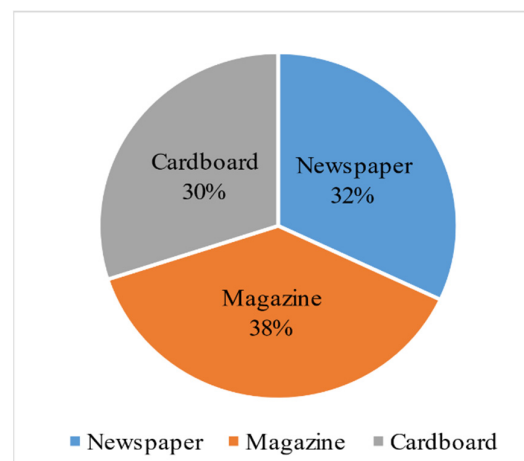


Figure 9. Ratio of three types of WP collected by WP collection stations in 2020.

4.4. Results of Stepwise OLS Regression Analysis

The results of the stepwise OLS regression analysis are shown in Tables 3 and 4. There was no systematic evidence that population density was associated with all dependent variables. In population-group variables, the population density was excluded, due to the high collinearity between households of different family patterns and dependent variables in the trade area.

The parking spaces had a positive and significant association with the amount of WP collection station usage, with the highest t stat among the independent variables. On the other hand, the business years coefficient value was negative. This could be because new WP collection stations usually cooperate with large supermarkets with equally large parking lots, and they use the opening campaign to promote WP recycling.

Moreover, business hours had a positive effect on the usage of WP collection stations, even if there was only three hours' difference between the studied supermarkets.

For WP collection stations' new users, there was a positive correlation between the business years, family type (couples), and the number of new users. On the other hand, the parking spaces and family type (extended family) showed a negative association with new users, indicating that more users (especially couples) started to use the WP collection stations set in old small supermarkets in the downtown area recently.

As for the total amount of collected WP, the coefficient of business hours and parking space were positively associated, though the coefficient of business history and land price were negatively associated. This means the recycling company could collect more WP by cooperating with newly built supermarkets in suburban areas. This kind of supermarket usually has large parking lots. Moreover, the population in the trade area showed different performances in using the WP collection station. The results showed that families with children had a positive and significant connection with a WP collection station, but the total amount of WP would decrease as the number of extended families increases in the trade area.

Table 3. Stepwise OLS regressions results of Dv1-Dv3.

Predictive var.	Number of Usage		Number of New Users		Total Amount of WP	
	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat
Intercept	3.707×10^{-16}	0	9.802×10^{-17}	0	2.225×10^{-16}	0
Business years	−0.415 ***	−4.753	0.276 ***	2.78	−0.356 ***	−3.862
Business hours	0.204 **	2.358			0.192 **	2.122
Parking spaces	0.414 ***	4.837	−0.312 ***	−3.179	0.338 ***	3.809
Land price					−0.193 *	−1.838
Population density						
Couples			0.268 *	1.954		
Family with children					0.443 ***	3.236
Extended family			−0.318 **	−2.297	−0.451 ***	−3.436
Multiple R-Sq	0.357		0.191		0.362	
Adjusted R-Sq	0.336		0.155		0.318	
MAX VIF	1.067		2.104		2.55	

*, ** and *** denote significance at 10%, 5%, and 1% levels.

Furthermore, the results in Table 4 show that business hours and parking spaces had a positive connection with newspaper and magazine collection, while the business history and land price had a negative connection with magazine collection.

As for population-group variables, the collected magazines will increase with an increase in families with children but decrease as extended families in the trade area increase.

Parking spaces had a positive and significant association with the amount of collected cardboard, and also had the highest t stat number among all the independent variables.

Families with children also had a positive connection with the amount of collected cardboard, but the amount of collected cardboard will decrease as the number of couples increases in the trade area.

Table 4. Stepwise OLS regressions results of Dv4-Dv6.

Predictive var.	Amount of Newspaper		Amount of Magazine		Amount of Cardboard	
	Coefficient	t-Stat	Coefficient	t-Stat	Coefficient	t-Stat
Intercept	2.347×10^{-16}	0	5.111×10^{-16}	0	7.968×10^{-17}	0
Business years	−0.154	−1.513	−0.283 ***	−3	−0.415 ***	−4.832
Business hours	0.198 *	1.985	0.22 **	2.375		
Parking spaces	0.195 *	1.968	0.22 **	2.426	0.437 ***	5.036
Land price			−0.215 **	−2.005		
Population density						
Couples					−0.942 ***	−2.864
Family with children	0.292	2.145	0.547 ***	3.907	0.951 ***	2.887
Extended family	−0.35	−2.584	−0.544 ***	−4.052		
Multiple R-Sq	0.19		0.333		0.364	
Adjusted R-Sq	0.144		0.286		0.335	
MAX VIF	2.007		2.552		5.17	

*, ** and *** denote significance at 10%, 5%, and 1% levels.

5. Discussion

In Miyagi prefecture, a WP collection station can collect approximately 39 tons of WP every month. Since the municipality collects WP once every two weeks, the residents have to store WP at home for a long time. Moreover, due to the COVID-19 pandemic, the WP collection activities arranged by the local resident organizations also decreased. Therefore, WP collection stations provide convenience for residents who have little storage space or want to dispose of WP at any time. In addition, the residents can collect supermarket points by using WP collection stations. From this point of view, the WP became valuable resources for the users and encouraged the users to cooperate in recycling WP [28,29].

Furthermore, since the utilization of WP collection stations can reduce local government costs for collecting, transporting, storing, and processing WP [8], although the WP collection station is independent from the traditional WP collection system, it can help reduce the burden of municipalities [30,31]. Moreover, recycling companies can collect a larger amount of high-quality WP by establishing collection stations, which could increase their profits and provide better WP collection services. In other words, the effective utilization of WP collection stations can create a win-win WP collection system and could achieve the interests of residents, governments, and recycling companies at the same time. Due to the lifestyle changes after the COVID-19 pandemic, collected waste cardboard has increased significantly, and so, the collection of cardboard could be the focus of WP collection stations in the future. Moreover, since the recycling companies are providing rewards for their users, more residents may participate in waste separation in the future [32].

The results of the OLS regression analysis show that the convenience of the supermarket, especially business hours and parking spaces, affects WP collection stations' status positively. Moreover, WP collection station efficiency is particularly high when many families with children live nearby. This is because most families with children use supermarkets regularly and own cars; they prefer to dispose of WP while using supermarkets rather than wait until the specified day of municipal collection. Therefore, it is possible to decrease both local government and resident burdens by establishing WP collection stations in large supermarkets with many families with children nearby. Such an effect could be higher in automobile-dependent areas. On the other hand, extended families do not share the same characteristic. The efficiency of WP collection stations can be quite low in areas with many extended families. Moreover, since most of the shopping centers were located in areas with high population density, under some scenarios, the recycling

company could have set multiple WP collection stations in shopping centers within a short distance. This could have a negative impact on recycling companies (higher rent and transportation costs).

In summary, the utilization of the WP collection stations can improve the efficiency of the local WP collection system and reduce the local governments' burden of collecting household waste as well. Therefore, municipalities should consider coordinating with recycling companies in operating a new and highly efficient WP collection system in the future.

6. Conclusions and Future Tasks

The current traditional WP collection systems in Japan are inefficient; it is necessary to reduce the municipal WP collection services' burden and improve convenience. Moreover, due to lifestyle changes with the COVID-19 pandemic, it is important to upgrade the WP collection system (especially for waste cardboard) in the future.

This study evaluated the current status, operational characteristics, and efficiency of recycling companies' WP collection stations. The research results found that WP collection stations' efficiency was particularly high in large supermarkets with an equally large parking area and long business hours. The same characteristics were found in areas with a large number of families with children. It is possible to improve the WP collection rate by installing recycling companies' WP collection system.

On the other hand, optimizing WP collection routes (how to transport collected WP to the WP recycling plant) should be discussed in the future. The reasons why consumers choose to use recycling companies' WP collection stations (such as economic incentives or convenience incentives) and different types of consumer attitudes toward WP collection stations (such as consumers of different ages and genders) remain unclear.

Finally, future studies could discern whether such a collection system could have a long-term impact on WP classification or consumers' usage habits [29]. It is also meaningful to investigate whether WP collection stations would prompt the environmental education awareness of families with children [33].

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