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# Unwillingness toward PET Bottle Recycling Actions: A New Method of Contingent Valuation using Pairwise Comparison and Effect on Recycling Behaviors

Doctoral Dissertation

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# Chapter 1 Introduction

## 1.1 Worldwide trends in waste management

Along with the rapid expansion of urbanization, population growth, and economic development, waste and consequence air, land, and marine pollution have become a global problem. Especially with the continuous increase in urban population density, municipal solid waste (MSW) management is a major task for local governments (Lima and Silva, 2013). In other words, MSW treatment is turned into one of the biggest challenges in the urban area. According to the World Bank's prediction, in 2050, municipal solid waste (MSW) generation will increase by three times (Kaza et al., 2018). In addition, MSW also poses a great threat to public health. Hence, public health is concerned as one of the divers in the development of MSW management (Chen et al., 2010).

In recent years, government, local authorities, and researchers worldwide have approved various waste management strategies intending to reduce the volume of waste in landfills or direct incineration, reducing the subsequence impacts fills (Hotta and Aoki-Suzuki, 2014, Lima and Silva, 2013). As a result, waste classification and recycling have become an essential strategy in most countries, particularly developed countries. The positive impact of recycling is not only reflected in the reduction of environmental pollution but also in the effective reuse of

recyclable materials, thus significantly reducing the quality of waste generation (Al-Ansari, 2012; Aliu et al., 2014).

Japan is a country with a relatively developed waste classification and recycling system. However, this "stereotype" often makes people ignore some problems in the waste classification system. Thus, this study discussed the waste management system in Japan, mainly focused on PET bottles, one of the typical recyclables. The detail of solid waste management in Japan will be explained in the following section.

## 1.2 Waste management in Japan

### 1.2.1 Categories of waste in Japan

In Japan, generally, wastes are classified into "Municipal Waste" and "Industrial Waste." According to the existing state and treatment method, they both can be divided into several sub-categories (See Figure1-1) (Christine Yolin, 2015). In this context, the author mainly takes Municipal Solid Waste (MSW) as the object of discussion.

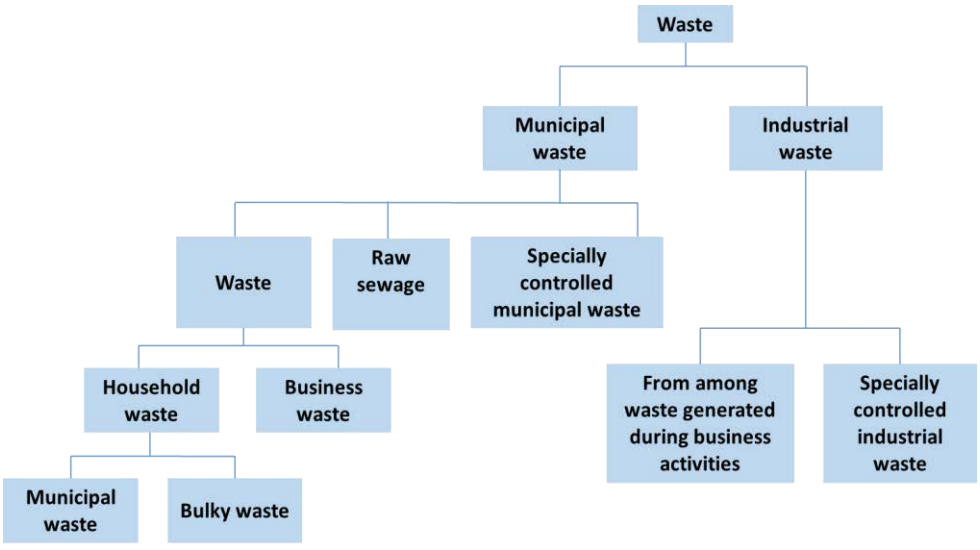



Figure 1-1 Categories of waste in Japan

### 1.2.2 History of municipal solid waste management

In Japan, the MSW management system has been implemented for over 40 years (Ministry of the Environment, 2014; Jiang et al., 2016). As a result of these four decades of effort, Japan has a developed management system of MSW. At the beginning of modernization, waste generators had been requested to manage their waste or entrusted with private waste treatment operators to collect and profit by selling valuables like metal, glass, etc. However, waste was discarded on the roadsides and rivers. As a result, it has led to an increase in flies, mosquitoes, and rats that carry infectious diseases.

Consequently, public health is seriously threatened. The first Waste Cleaning Act was enacted in 1990 to improve public health. The Act stated that waste should be incinerated, if possible, but because waste incineration facilities were not universal, waste was piled up in the open and burned. During the post-war period, a massive amount of waste and public health was still a crucial problem. To deal with that, the government and consumers collaborated, each entity responsible for the corresponding works. As a result, the public Cleansing Act was enacted in 1954 to improve the waste collection and transportation facilities, living environment as well as public health (Ministry of the Environment, 2014).

From the 1960s to the 1970s, Japan entered a rapid economic growth period. It was leading the changes in consumer behaviors. The waste generation rate also increased rapidly. During this period, the hazardous waste discharged from factories, such as organic mercury and

cadmium, have seriously affected residents' health. At the same time, the widespread utilization of plastic products caused a significant increase in plastic waste and the soot dust, acidic gases, and other hazardous substance during incineration. Ultimately, it caused severe water pollution. In 1970, to specify the standards for all kinds of waste, the Japanese government developed the primary waste management system. It established the Waste Management Act and revised the edition of the Public Cleansing Act (Ministry of the Environment, 2014).

During the "Bubble Economy" period, waste problems expanded not only its quality but also in quantity. The shortage of landfills, large-scale illegal dumping, and dioxins generated by incineration facilities have resulted in development. In 1991 the Act on the Promotion of Effective Utilization of Resources was enacted. It aims to practical use resources to reduce waste generation. Moreover, the Basic Act for Establishing a Sound Material-Cycle Society was established in 2000 to promote a sound material-cycle society from a mass consumption society. 3R (Reduce, Reuse, and Recycle) has become a social goal.

Along with the government initiatives on environmental awareness-raising and vigorous propaganda on the sorted collection of recyclable waste, the cooperation of residents, waste collectors, and local government has achieved remarkable progress. Sorted collection and proper treatment of different types of waste have improved the quality and quantity of waste. Meanwhile, recyclables have been reused, and Japan has become one of the countries with the

best waste management system in the world (Ministry of the Environment, 2014).

### 1.2.3 Municipal solid waste classification in Japan

Waste sorting is an essential step of waste management. It is also an environmental act, requiring the participation of both public and the government. Especially, the role of the public is not neglectable. It directly determines the quality and quantity of the collected waste, meanwhile, the workload of secondary classification. For effective waste management policies, understanding, attitude, and public participation are crucial factors. Previous studies have discussed the role of public environmental awareness and behavior in improving waste separation in households and public places (Zeng et al., 2016; Chung and Poon, 2001; Mukherji et al., 2016; Barr and Gilg, 2007).

Although waste classification is already becoming a worldwide topic, it is still an empty talk in most developing countries. Throwing garbage is an effortless thing, without any consideration. People can throw their garbage into any garbage can, even throw it anywhere and anytime. There is also no strict control over such behavior. Nevertheless, in Japan, waste classification is not such a simple thing. This is also one of Japan's "first impressions" of foreigners. They are surprised and confused by this systematic and elaborate activity in Japanese residents' daily life. Even for the Japanese who have moved to the new area, it is a top priority to figure out the local garbage classification rules.

In Japan, waste generators are required to cooperate with the government to participate in proper waste management, such as reducing waste generation, correct waste disposal, and recycling. Municipalities are had responsibilities for managing MSW within the jurisdiction. That means each city, town, or residential area has its own MSW collection and management system. In most cases, those systems are different. For example, they might have more specific classification rules, the differences in collection date for some types of waste, or the differences in collection bags. However, in general, the classifications by type are roughly the same. Here, take Setagaya City as an example to introduce each type in detail (Setagaya, 2019)

1) ***Combustible waste*** includes wastes that are neither recyclable nor unburnable. Such as kitchen scraps, cloth; paper scraps; small amounts of wood, branched and leaves, plastic items (except PET bottles); rubber or leather items, etc.

2) ***Incombustible waste,*** including items made of metal, glass, or ceramics; spray cans/lighters that are entirely empty; small household appliances smaller than 30 cm on each side, etc.

3) ***Recyclable resources,*** including used papers (newspapers, flyers, magazines, corrugated cardboard); glass bottles (empty food and drink bottles); cans (empty food and beverage cans), etc.

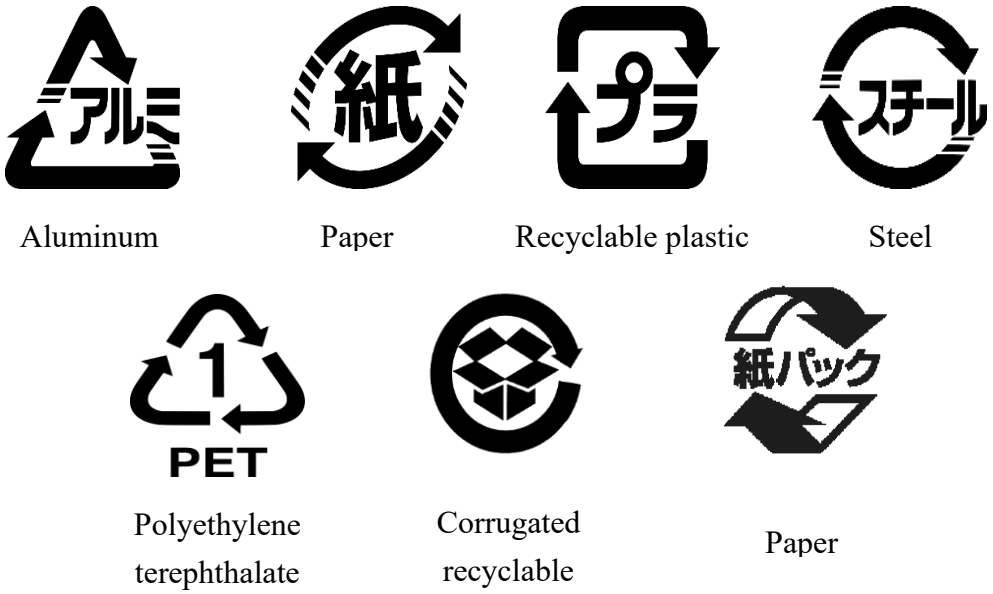
4) ***PET bottles*** are collected on the specified date, and the cooperating collection shops

also can be used to collect.

5) ***Large-size waste,*** including items with dimensions of 30 cm or more. Residents must apply in advance for collection, and a collection fee will be charged.

6) ***Home appliances*** including air conditioners, TVs, washing machines or dryers, refrigerators, etc. Residents must also apply for collection, and a collection fee will be charged.

In addition, in order to make it easier for residents to understand and distinguish recyclables, the Japanese government has prescribed specific recycling identification marks. For each type, different texts and shapes were used (see Figure1-2).




Aluminum　Paper　Recyclable plastic　Steel

Polyethylene terephthalate　Corrugated recyclable　Paper

Figure 1-2 Recycling symbols in Japan

### 1.2.4 Current situation of waste management in Japan

Japan is one of the top countries in the world with its developed waste management system. Whether waste collection, transportation, or treatment, Japan has a set of programs worthy of reference by many developing countries. Japan's achievements in waste management are not only due to top-down laws and regulations but also due to the active, spontaneous, conscious cooperation of residents with the local government.

According to the annual statistical data from the Ministry of Environment of Japan (2019), under the 3R (Reduce, Reuse, Recycle) initiative, annual waste generation has gradually decreased in recent years. The total amount of waste generation and per capita waste generation per day in the past decade were given in figure1- 3. In 2017, 42.89 million tons of waste were generated in Japan, 0.6% lower than in 2016. The amount of per capita waste generation per day was 938g, 0.4% lower than in 2016. Ten years of changes show that Japan's waste management system is undergoing a process of further improvement. Residents, one of the essential components, are also working to reduce waste emissions and thus contribute to environmental protection. However, compared with other developed countries in Europe, it is undeniably lower than others figure1- 4.

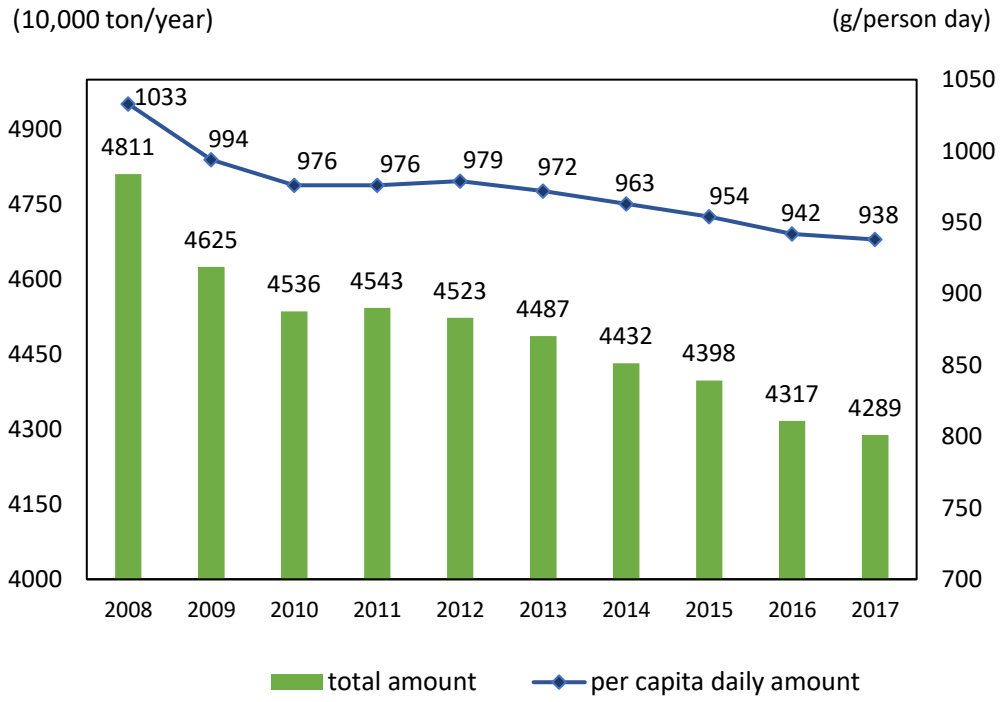



Figure 1-3 Total amount of waste generation and per capita daily waste generation

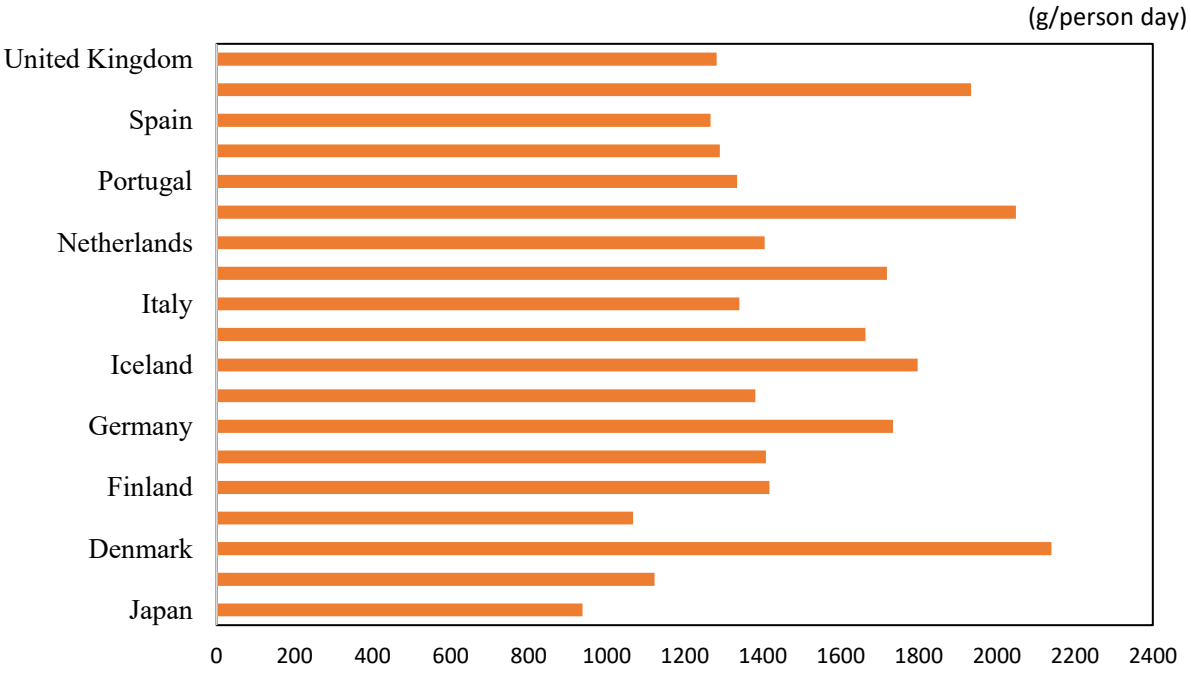



Figure 1-4 Per capita daily waste generation in different countries

Nevertheless, from the point of view of resource recycling, there is still a major problem. The trend of the total amount of resource recycling and recycling rate was shown in figure 1-5. Since 2008, the recycling rate has been almost decreasing yearly; by 2017, it has decreased to 20.2%. Compared with Germany, where the waste generation decreased by years while the resource recycling rate increased, Germany's resource recycling rate reached 67.7% in 2017.

Although waste sorting and recycling have become an essential part of Japanese daily life, everyone is familiar with the significance of resource recycling. However, the recycling efficiency is still at a low level. This may be due to the fact that the classification methods and accuracy have not met the requirements. In Japan, waste classification rules are decided by local governments. In some places, the classification rules are relatively simple; some recyclables, such as recyclable paper or plastics still considered combustible waste. In addition, in public places, even designated trash bins were set to the different types of trash; in most cases, waste is mixed, and it is difficult to ensure and supervise the correct disposal of trash by users. Therefore, it is necessary to guide users to develop unconscious and spontaneous waste classification behavior in a psychological stimulation way.

The resources recycled by municipalities (total amount of 6.51 million tons) and by residents (total amount of 2.17million tons) show in figure 1- 6 and figure1-7, respectively. Viewed from the type of resources, the paper-related resource was counted as a higher

proportion. In daily life, plastic products are used in large quantities, but the amount of recycled plastic-related resources is lower; many plastic resources may also be incinerated as combustible waste. Despite the utilization of the incineration reprocessing system, it could lead to air, water, and land pollution. it will significantly reduce the number of reusable resources.

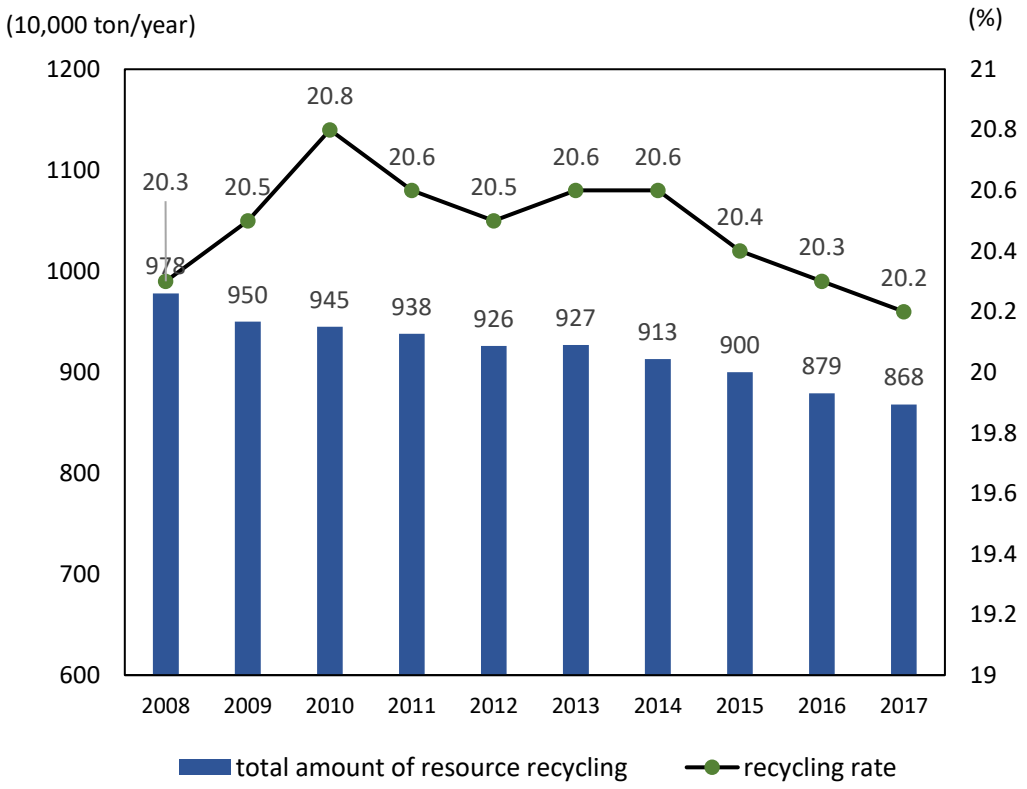



Figure 1-5 Total amount of resource recycling and recycling rate

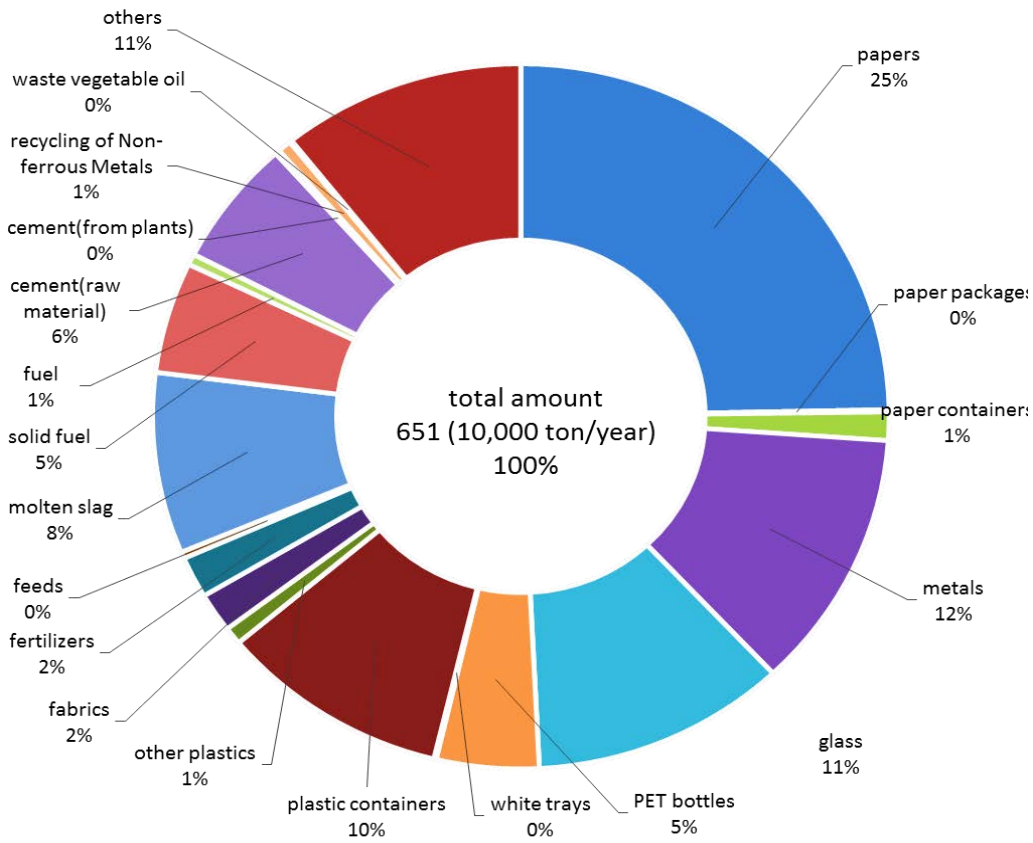



Figure 1-6 Types and proportion of resource recycled by municipalities

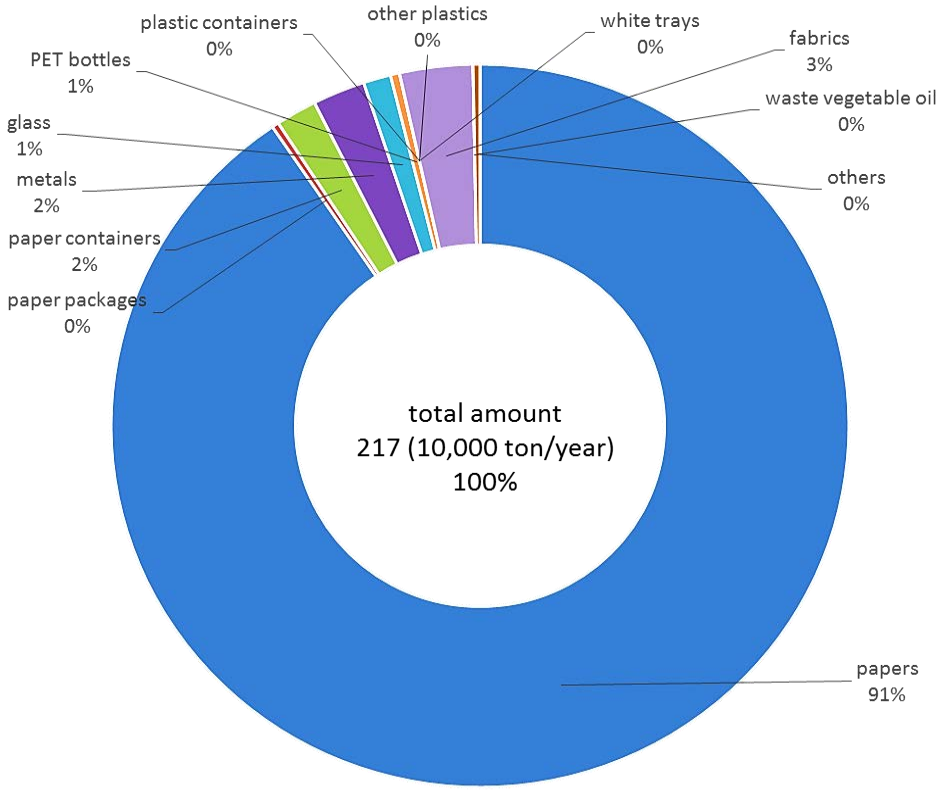



Figure 1-7 Types and proportion of resource recycled by residents

### 1.2.5 Current situation of PET bottle collection and recycling in Japan

Polyethylene terephthalate (PET) bottle is the beverage container with the highest utilization rate. On the one hand, it brings great convenience to people's lives; on the other hand, it brings a crisis to the environment if it is not processed adequately after use. PET bottles are separately collected and treated as recyclable waste worldwide, especially in developed countries (Frank, 2011; Plastic Waste Management Institute, 2016, The Council for PET bottle recycling Japan, 2020). In Japan, the Containers and Packaging Recycling Act enacted in 1995, and it was specified the responsibilities to the consumers, municipalities, and business operators such as manufacturers and packaged product sellers (Ministry of the Environment, 2014).

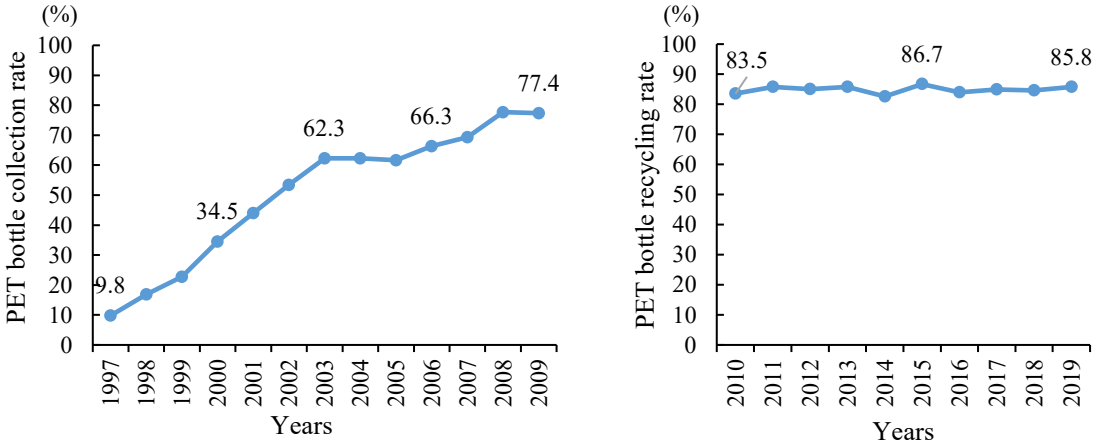



Figure 1-8 PET bottle collection and recycling rate from 1997-2019 in Japan

As the most typical example, PET bottles significantly improved their recycled quantity by the separated recycling initiatives figure 1-8 (The Council for PET bottle recycling Japan, 2020). It should be noted that, before 2010, the Japanese government focused on the PET bottle collection rate due to the initial stage of separated collection. From 2010, recycling and reusing

were the primary mission of the PET bottle collection system. Besides, when comparatively analyzed, both collection rate and recovery rate in Japan are significantly higher than other countries (see figure 1-9). However, the quality of the recycled PET bottles has great differences depending on the collection locations.

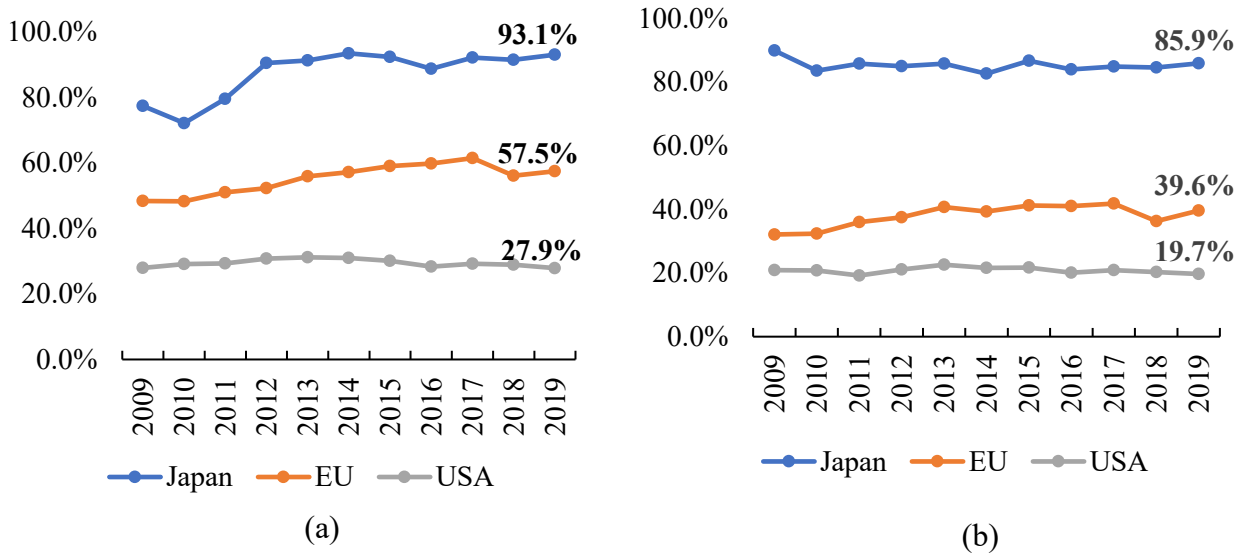



Figure 1-9 Comparison of PET bottle collection rate (a) and recycling rate (b) of Japan, EU and USA

Generally, the PET bottle recycling process in the Japanese recycling system includes eight sub-actions "Understanding disposal rule," "cap removal," "label removal," "bottle washing," "bottle crushing," "keeping bottles until disposal day," "bringing PET bottles to waste collection site near the house and dispose of them" (disposal at waste collection site), and "bringing PET bottles to a collection box in a supermarket and dispose of them" (disposal in the supermarket). These complex classification steps might bring a varying degree of

botheration to different participants in the recycling system. People's unwillingness toward the PET bottle sorting actions might lead to a difference in the performance of the recycling behaviors. Due to the typicality of plastic bottles in recyclable plastics, relatively straightforward recycling rules, and easy judgment of recycling effects, this study focused on the PET bottle classification and recycling.

## 1.3 Social Psychology

### 1.3.1 Definition of social psychology

Social psychology is the scientific study of how people's thoughts, feelings, and behaviors are influenced by the actual, imagined, or implied presence of others (Allport, G.W, 1985). Each of us is different, and our characteristics, including our personality traits, desires, motivations, and emotions, impact our social behavior. However, our behavior is also profoundly influenced by the social situation—the people we interact with daily. These people include our friends and family, our classmates, our religious groups, the people we see on TV or read about or interact with online, as well as people we think about, remember, or even imagine. Social psychologists typically explain human behavior due to the interaction of mental states and social situations. Our social situations create social influence—the process through which other people change our thoughts, feelings, and behaviors and through which we change theirs.

Kurt Lewin formalized the joint influence of person variables and situational variables, which is known as the person-situation interaction, in an integral equation:

Behavior = f (person, social situation)

Lewin's equation indicates that the behavior of a given person at any given time is a function of (depends on) both the characteristics of the person and the influence of the social situation (Kurt Lewin, 1936).

### 1.3.2 Affect, behavior and cognition

Social psychology is based on the ABCs of effect, behavior, and cognition. In order to effectively maintain and enhance our own lives through successful interaction with others, we rely on these three fundamentals and interrelated human capacities:

1) **A**ffect (feelings)

2) **B**ehavior (interactions)

3) **C**ognition (thought)

**Social Cognition**

*Social cognition* can be defined as thinking and learning about others. The human brain contains about 86 billion neurons, each of which can interact with tens of thousands of other neurons. The distinguishing brain feature in mammals, including humans, is the more recently evolved cerebral cortex—the part of the brain involved in thinking. Humans are highly intelligent, and they use cognition in every part of their social lives. Psychologists refer to cognition as the mental activity of processing information and using that information in

judgment. Social cognition is cognition that relates to social activities, and that helps us understand and predict the behavior of ourselves and others. Social cognition involves the active interpretation of events. As a result, people may draw different conclusions about the same events.

**Social affect**

*Social affect* is the feeling about ourselves and others. As our day progresses, we may find ourselves feeling happy or sad, jealous or grateful, proud or embarrassed. Although the effect can be harmful if it is unregulated or unchecked, our affective experiences usually help us to function efficiently and in a way that increases our chances of survival. Affect signals us that things are going all right or that things are not going so well. The effect can also lead us to engage in behaviors appropriate to our perceptions of a given situation. For example, when we are happy, we may seek out and socialize with others; when we are angry, we may attack; when we are fearful, we may run away.

**Social behavior**

*Social behavior* is the process of interacting with others. Because we interact with and influence each other daily, we have developed the ability to make these interactions proceed efficiently and effectively. We cooperate with other people to gain outcomes that we could not obtain on our own, and we exchange goods, services, and other benefits with other people. These behaviors are essential for survival in any society (Kameda et al., 2002; Kameda et al.,

2003).

As a member of a society or one's social circle, the daily behavior of everyone affects the group. Waste collection and classification behavior are also essential to daily behavior that may affect the living person, the public environment, and the same habits as others. Proper waste management is not negligible in maintaining and improving the behavior of others so that the whole can benefit from it. Therefore, it is essential to study and analyze human behaviors on waste separation and the factors affecting them from the perspective of social psychology.

## 1.4 Web questionnaire survey

A survey is a research process to collect information such as data, opinions, and comments on something or some phenomenon related to people (Delavar, 2006). Generally, surveys can be conducted through personal interviews, paper questionnaires, telephone, E-mail, and web questionnaires. To all types of surveys, the same principles can be applied. However, more detailed information can be easily obtained through a web survey. Respondents can check more references such as pop-up information, menus, videos, and photos just by relevant links (Angeliki et al., 2006). In addition, Web surveys are the ideal choice when researchers have no idea about the sensitivity of respondents or cannot determine whether the questions enter the private sphere of intimacy or not. Psychological researches show that a researcher present during a survey can lead to less honest and more socially desirable answers. When using online or e-mail questionnaires, because there is no time limitation and no one is waiting for an answer,

respondents can take their time to complete the questionnaires, and they will often answer more truthfully. Therefore, in order to exclude other social psychological factors, several web questionnaire surveys were conducted for data collection in this study. Moreover, to reduce the effect of fatigue and boredom of questionees on the accuracy of the result, the author separated the questionnaire into several parts.

## 1.5 Analysis tools

### 1.5.1 Psychological preference

Psychological preference is the people's psychological attitude towards the selected objects. It results from an individual's decision-making process (Kahneman and Tversky, 1982, Lichtenstein & Slovic, 2006). However, psychological preference has neither the correct answer nor will it remain the same. It will be influenced by subjective or objective factors (Zajonc et al., 1982). A questionnaire survey is a common approach to collecting psychological preferences in psychological analysis. These questionnaire surveys are usually in the form of selection from two or more options or in the form of scoring. In this research, the web questionnaire was designed using pairwise comparison, with only requested questionees selected from each pair (A or B). The preference scores were calculated by Thurstone's law of comparative judgment (Thurstone, 1927). The detail of the calculation method will be given in the following chapter.

### 1.5.2 Data collection

In this research, data were collected by web questionnaire and on-site data collection. In terms of web questionnaire surveys, they were conducted from July 2012 to December 2013 and 2017 by Quickmill®, Macromill Co. Japan. When the questionnaire respondents were collected randomly from different places in Japan (all respondents were Japanese), they were pre-screened to adjust for equal male/female balance and equal age distribution from 20 s to 60 s at a 10-year age interval. In addition, on-site data collections were conducted in 2012, 2013, 2017 and 2018 at major classified recycling centers of targeted cities.

### 1.5.3 Word selection and translation

Emotional adjectives help people to express feelings, emotions, and the tone of the words. For the same feeling or emotion, different adjectives may express different degrees. Yamaguchi has reported that, in the Japanese language, there are many adjectives expressing negative feelings than adjectives expressing positive feelings (Yamaguchi,1982:210). For this reason, in the language selection of the questionnaire, the choice of appropriate words, especially Japanese words expressing negative emotions, might have a certain impact on the results of the questionnaire.

A study on the three negative emotional adjectives 「鬱陶しい」、「煩わしい」、「面倒くさい」with similar meaning has been summarized that 「鬱陶しい」means feeling

uncomfortable when a subject exceeds the appropriate range and wanting to get rid of it. 「煩わしい」can be the expression of feeling uncomfortable or annoyed with one's own or others' behavior that is psychologically burdensome. In terms of「面倒くさい」means don't feel the urge to do (or continue) what someone is not interested in (Kato, 2011). Although these three words can express someone's annoyance about something. However, from the interpretation and examples of each word in the article, 「煩わしい」 is a more appropriate word for the psychological burden caused by an action. In the web questionnaire survey, 「煩わしさ」( nominalized 煩わしい) was used in the questions to ask about the annoyance or difficulty people feel when they are requested to finish some actions.

For an action such as PET bottle recycling, its implementation will be determined by people's ability to overcome the troubles, botherations, or difficulties caused by the action. Based on the subject areas of papers in scientific journals and books, in the field of social science, psychology, and environmental science, "Unwillingness" is the most frequently used word to express people's reluctance due to various factors. According to the Cambridge Dictionary, the definition of "Unwillingness" is the quality of not wanting to do something. Oxford Learner's Dictionaries, also define unwillingness (to do something) as the fact of not wanting to do something and refusing to do it, for example, "unwillingness to compromise". Thus, In the present context, the Japanese word 「煩わしさ」 in the web questionnaire was translated to "Unwillingness" to express a negative feeling.

### 1.5.4 Analysis method

The statistical analysis interprets the collected data to indicate the trend or regulation. In this study, Thurstone's model was used for unwillingness calculation. For the willingness to pay (WTP) method, double-bounded dichotomous choice contingent valuation (DBDCCV) was used as elicitation format, and, Weibull distribution was selected as a parametric model in survival analysis to calculate mean WTP. Besides the Multi-ways ANOVA, in particular, the Tukey method was used to identify the significance of the relationships of some factors.

### 1.5.5 Theorical framework

In behavioral research, the Theory of planned behavior (TPB) model is a commonly used analytical method. It is a psychological theory that differentiates the influencing factors on human behavior into attitude, subject norms, and perceived behavioral control and their impact on an individual's behavioral intention (Ajzen, 1991). The basic concept of TPB is shown in figure 1-10. TPB is commonly applied to studies of the relations among beliefs, attitudes, behavioral intentions, and behaviors in various human domains. These domains include but are not limited to advertising, public relations, advertising campaigns, healthcare, sports management, and sustainability.

The main components of TPB are defined as follow:

**Attitude**

According to TPB, the attitude of individuals toward a behavior is determined by their beliefs about the behavior. It refers to individuals' positive or negative opinions toward the behavior in question.

**Subjective norm**

Subjective norm is constraints by external factors such as laws, rules, and other people's judgments. It is crucial to shaping an individual's perception of specific behavior, such as waste recycling.

**Perceived behavioral control**

The perceived ease or difficulty of an individual is performing a behavior known as perceived behavioral control. It might be based on personal experience or influence by others.

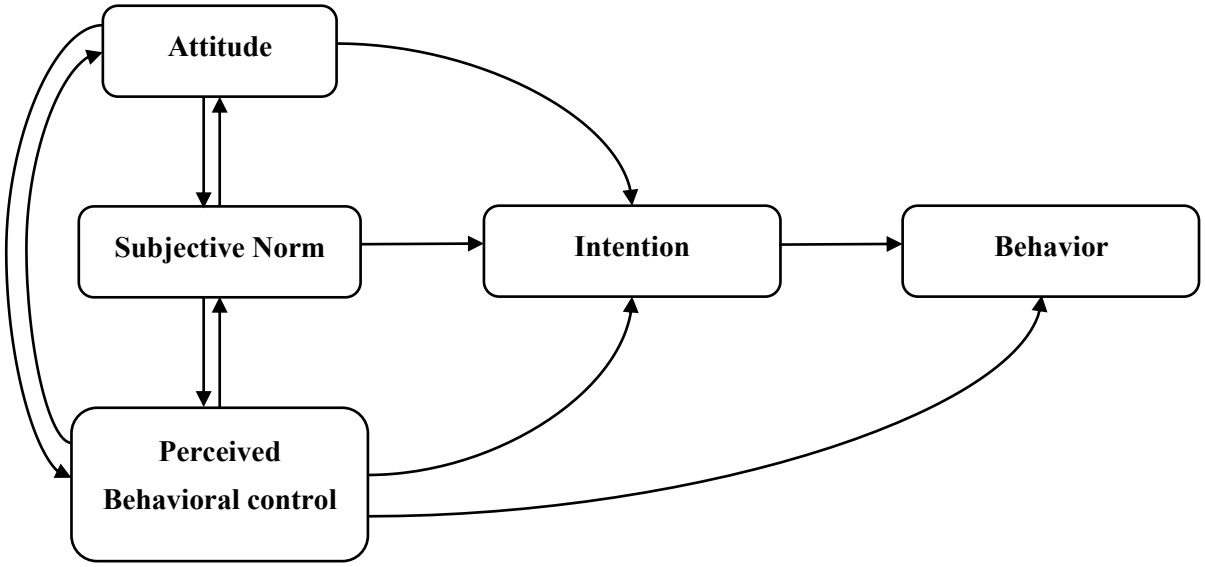



Figure 1-10 The model of the Theory of Planned Behavior (Ajzen, 1991)

If individuals believe that the more opportunities and minor difficulties, they have to complete a behavior, their perceived behavior control over the behavior will be more substantial.

**Intention**

An Individual's willingness to perform a given behavior can be indicated as intention. It can be seen as the possibility of behavior determined by the behavior, subjective norm, and perceived behavioral control.

The intention of TPB can be described as the following function (Eq. 1) (Ajzen, 1991):

$$BI = w_A A + w_{SN} SN + w_{PBC} PBC \quad (\text{Eq. } 1)$$

Where *BI* is Behavioral intention, *A* is Attitude toward behavior, *SN* is Subjective norm, *PBC* is Perceived Behavioral Control, and *w* is empirically derived weight/coefficient.

To sum up, according to the TPB model, behavior is affected by both behavioral intention and perceived behavior control, which could be expressed as follow (Eq. 2) (Ajzen, 1991).

$$B = w_{BI} BI + w_{PBC} PBC \quad (\text{Eq. } 2)$$

Where *B* is behavior, *BI* is Behavioral intention, *PBC* is Perceived Behavioral Control and, *w* is empirically derived weight/coefficient.

Environmental psychology is one of the main fields widely applying the TPB. Because

typical environmental protection behaviors such as waste classification and recycling are not only related to personal environmental protection awareness and willingness to complete environmental protection actions but are also constrained by external conditions such as legal and moral factors, it can comprehensively analyze the beneficial or unfavorable behaviors of participants in a recycling system, from subjective and objective aspects. That is to say, TPB could be one of the most valuable theories for designing and improving environmental policies. The application of TPB in past studies will be given in the following chapters.

## 1.6 Research objective and structure of this thesis

### 1.6.1 Quantification of unwillingness toward PET bottle recycling actions by a new contingent method

As mentioned in 1.2.5, in Japan, PET bottle disposal includes several steps such as "Understanding disposal rule," "cap removal," "label removal," "bottle washing," "bottle crushing," proper segregation and cleaning treatment of collected PET bottles are always required before recycling. In addition, there may be follow-up steps depending on the place of disposal, for instance, "keeping bottles until disposal day," "bringing PET bottles to waste collection site near the house and dispose of them" (disposal at waste collection site), and "bringing PET bottles to a collection box in a supermarket and dispose of them" (disposal in the supermarket). Complex waste classification steps might cause people to have different degrees of psychological botheration, in other words, unwillingness to complete the

classification actions. Thus, different classification effects will be obtained. Numbers of previous studies reported that the environmental awareness and attitude toward correct classification are the crucial factors in the implementation of a waste management system (Zeng et al., 2016; Chung and Poon, 2001; Mukherji et al., 2016; Barr and Gilg, 2007). Therefore, residents' environmental protection and waste recycling actions can also be regarded as a dynamic form of local environmental policy.

In the conventional method, Willingness-to-pay (WTP) method has been commonly used to analyze the public acceptability of non-marketing goods or services (Bai et al., 2019, Bernad-Beltran et al., 2014, Otoma et al., 2013). Some past studies on people's environmental protection and waste recycling behaviors also used the WTP method to quantify willingness toward some recycling activities such as E-waste recycling or improving the waste management system (Wang et al., 2011, Vasanadumrongee and Kittipngvises, 2000). However, some researchers indicated that there might be some biased results due to the difference in the monetary transformation of an environmental action into an exact amount price (Ryan and Spash, 2011). Furthermore, the bias might also cause by the lack of understanding of the questionees (Orset et al., 2017). Therefore, a valuation approach might be needed to obtain a low bias result. Thus, in this study, a new low-bias method is proposed to quantify the unwillingness toward waste recycling activities, and the feasibility of this method is verified by taking the recycling process of PET bottles as an example. Besides, the quantification result of

the new method and conventional method was also compared. Moreover, further discussion was conducted according to the Theory of Planned Behavior.

### 1.6.2 PET bottle sorting condition in target cities and its influencing factors

The quality of plastic bottles recycled on different occasions often varies greatly. This issue might be determined by various factors such as local policies under the general waste classification rules, classified recycling facilities, the distance between residents and classified recycling facilities, and residents' characteristics (Song et al., 2016; Han et al., 2019; Huang et al., 2011; De Young, 1986; Nyamwange, 1996). Many researches on the classification of household waste are conducted in the form of self-reported questionnaires. Nonetheless, some past studies have pointed out that in a self-reported survey, there is a gap between people's answers and their actual behavior (Timlett & Williams, 2008, Baumeister et al., 2007; Wilson & Gilbert, 2003; Corral-Verdugo,1997). Therefore, to avoid over or under estimation and obtain a more accurate result of residents' PET bottle sorting behaviors, the on-site survey was conducted in the main PET bottle collecting center of six targets citied in Japan. In this survey, the collected PET bottles in the centers were divided into 16 sub-categories, and the completion rate of each sub-category was calculated. In addition, influence factors on PET bottle sorting conditions were discussed from the perspectives of sociodemographic factors and local collection rules.

### 1.6.3 Correlation of monetary transformed unwillingness and completion rate of PET bottle sorting actions and “participants screening”

People’s environmental protection behaviors, such as proper waste recycling, depend on the willingness or unwillingness to complete requested actions (Wang et al., 2011; Song et al., 2016). In the investigation process, it is found that the recycling quality of plastic bottles varies greatly at different collection facilities; even at the same collection point, such as in public places, there are significant differences in the pre-treatment process of the PET bottles before disposal. The stronger unwillingness that people feel about some recycling actions seems negatively impact people's willingness to complete the recycling actions. The more the unwillingness, the lower the completion rate? Why do participants of a recycling system have obvious differences in overcoming such strong unwillingness?

In this part, first of all, based on the results of previous chapters, the investigation of the relationship between unwillingness of PET bottle disposal actions and the actual situation of PET bottle sorting conditions was conducted. Then, according to the correlation of monetary transformed unwillingness and completion rate of PET bottle sorting actions, the Participants of this survey were screened into recycle-conscious and non-recycle-conscious groups. As the Theory of Planned Behavior (TPB) describes, attitude, subjective norm, and perceived behavioral control will affect environmental intention and determine people's environmental behavior (Ajzen, I., 1991). What people think about recycling, how they do it in their daily life,

and external factors, such as distance to recycling facilities and local environmental policies, might have a joint effect on individuals' waste recycling behavior. Finally, in order to further understand both recycle-conscious and non-recycle-conscious groups from the three aspects mentioned above (what people think about the recycling, how they do in their daily life, and external factors), a web questionnaire survey was conducted, and a multi-way-ANOVA test is carried out for the further analysis of the answers.

### 1.6.4 Suggestions for improving the PET bottle collection system by "participants screening"

Based on the overall results of present research and the Japanese waste classification system, as well as the current classification situation, this study puts forward several initial suggestions that consider both recycle-conscious and non-recycle-conscious groups for the promotion of PET bottle sorting in Japan. Furthermore, it is assumed that, when improving a classification and recycling system, if the participants of the system are scientifically screened and analyzed and targeted implemented the improvement measures, it might improve classification quality more effectively.

## 1.7 Thesis structure

The contents of doctoral research have been divided into six chapters as follows (see figure 1-11):

**Chapter 1 Introduction**

**Chapter 2 Evaluation of unwillingness of PET bottle recycling actions**

**Chapter 3 PET bottle sorting condition in 6 target cities in Japan**

**Chapter 4 Correlation of monetary transformed unwillingness and the completion rate of PET bottle sorting actions**

**Chapter 5 Suggestions for improving the PET bottle collection system by "participants screening"**

**Chapter 6 Conclusion**

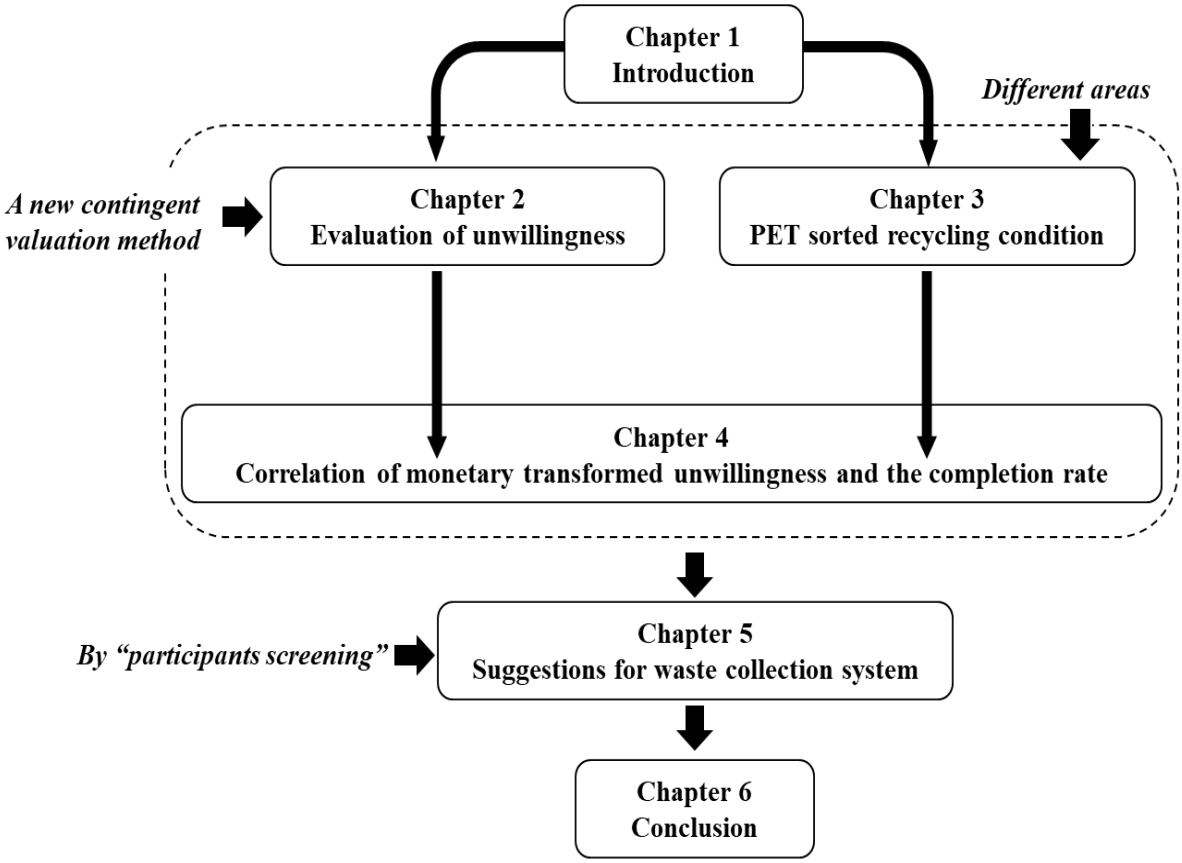



Figure 1-11 The thesis's content and its relationship

## 1.8 Publication

### 1.8.1 A new contingent valuation approach requesting only simple comparison of perceptive stimuli: A case study of unwillingness toward PET bottle recycling behaviors

**ABSTRACT**

This study developed a new contingent valuation approach which requested only simple comparison of perceptive stimuli by questionnaire respondents. This approach subsequently valuated the stimuli, like unwillingness toward waste sorting, based on outsourcing market prices. It was applied to answer why the quality of PET bottles collected from supermarkets and public waste drop-off stations waste were contrastingly high and poor, respectively. Unwillingness toward required actions for PET bottle recycling were evaluated by conventional Willingness-to-Pay (WTP) method and the new method. There was good agreement between two methods for weak and moderate unwillingness. The easiest and hardest actions are cap removal (1.77 JPN yen) and disposal in supermarkets (57.9 JPN yen), respectively. On the other hand, the unwillingness toward disposal in the supermarket was valuated three times larger than that of WTP method. The gap between the results of the new method and WTP method means this method valuated not only perceived unwillingness but also unconscious part. Large unwillingness toward bringing PET bottles from home to a supermarket might serve like a social filter to allow only recycle-conscious persons to participate in PET bottle recycle against

large unwillingness. It eventually results in PET bottle collection with constantly good quality. Social implementation of psychological barrier like strong unwillingness in waste collection system might be promising for efficient waste separation, called “separate recycling participants, not wastes” approach.

### 1.8.2 An efficient recycling of PET bottles: “participants screening” through the slightest unwillingness toward cap removal

**ABSTRACT**

This research continued our previous study and applied the same contingent valuation method proposed in the previous research to monetary transform people’s unwillingness toward multiple PET bottle recycling actions. Actions that included some situational factors such as distance and complexity showed stronger unwillingness. It is in line with the results of some previous researches focusing on the influencing factor on waste recycling behavior as well as our previous research. This research also investigated the actual PET bottle sorting condition of 6 target cities in Japan. There were no significant gaps among all the cities regarding the overall completion rate of sorting actions. However, in some specific actions, some differences are determined. The influence of sociodemographic factors and local waste recycling system was analyzed, and the consistency between insufficient information and relatively low completion rate of some actions were found. In addition, the correlation between the unwillingness toward PET bottle recycling actions and the actual sorting condition was

investigated. The exciting finding is that the respondents can be divided into recycle-conscious and non-recycle-conscious by the slightest unwillingness toward “Cap removal,” which is only 1.8 JPN yen. For recycle-conscious respondents, the completion rate increases with increasing unwillingness, while for non-recycle-conscious respondents, the completion rate decreases with increasing unwillingness. Moreover, a web questionnaire survey on the public environmental awareness and a multi-way-ANOVA analysis was conducted to the survey result. Finally, several improvement strategies for the PET bottle recycling system were put forward by a “participants screening” process. Joint implementation of psychological barriers, more comprehensive information, proper feedback, advanced recycling facilities, and economic incentives might be the approach to achieving an “everyone-correct-recycle” society.

# Chapter 2 Evaluation of unwillingness toward PET bottle recycling actions

## 2.1 Background

Polyethylene terephthalate (PET) bottle has become one of the most common beverage containers. The utilization ratio continues to rise worldwide and it is also a main component of recyclable plastic waste (Frank, 2011; Plastic Waste Management Institute, 2016). In Japan, the containers and Packaging Recycling Act was enacted in 1995 and applied to PET bottles in 1997 (Ministry of the Environment, 2014). PET bottles have been collected separately from public waste drop-off locations by local authorities and, through a post-processing process, the recycled PET bottles are turned into raw polyester materials and, finally, by a re-production process, turn into new PET bottles or other polyester goods, such as uniforms, carpets, plastic sheets, egg cartons, ball-point pens, etc. (The Japan Containers and Packaging Recycling Association, 2021). Compared with other countries, the time and efficiency of implementation own the leading position, which might be the most fundamental reason for the higher collection rate. The total volume of collected PET bottle was 552000 tones, which accounts for 93.1% of total volume of sold PET bottles. Compare to USA (27.9%) and Europe (57.5%), collection rate is favorable, but the quality of collected PET bottles is usually not satisfactory for recycle (The Council for PET bottle recycling Japan, 2020). PET bottle recycling process includes bottle

washing, removing the caps and labels since they are made from different materials from bottle and compacting. However, many PET bottles are usually not washed, caps and labels are not removed, and other wastes are mixed (see Figure 2-1A) (Frank, 2011; Jiang et al., 2019). Therefore, segregation and cleaning treatment of collected PET bottles are always required before recycling.


Figure 2-1 Collected PET bottles (A: Municipal waste collection sites, B: Supermarkets)

For effective waste management policies, understanding, attitude, and participation of the public are crucial factors. Previous studies have discussed about the role of public environmental awareness and behavior to the improvement of the waste separation in households (Zeng et al., 2016; Chung and Poon, 2001; Mukherji et al., 2016; Barr and Gilg, 2007). In addition, some previous studies have shed light on the influencing factors of waste recycling behaviors such as perception, attitude, and environmental awareness (Huang et al., 2011; De Young, 1986; Nyamwange, 1996; Sia et al., 1985; Vining and Ebreo, 1990). There

were also some contrary findings toward the same aspect. A positive attitude plays a significant role in acting pro-environmentally (Bradley et al., 1999; Schultz and Oskamp, 1996) while it is not the most decisive factor (Martine et al., 2006). Vencatasawmy et al have reported that people's utilization of recycling stations was directly related to their attitude towards recycling activities (Vencatasawmy et al., 2000). Using the Theory of Competition of Attention, Jiang et al. explained a non-negligible impact of setting condition of PET bottle collection facilities as an external influencing of factor. (Jiang et al., 2019). The distance between users and waste collection station as well as recycling bins, not only affecting the amount of waste but also its separation efficiency (Erfani et al., 2017; Struk, 2017; O'Connor et al., 2010, Nattapon et al., 2019).

In this context, the authors have focused on psychological factors to explain such poor quality of collected PET bottles, in particular, unwillingness or botheration people perceive when they remove a cap and a label, wash a bottle, and dispose of it according to bottle disposal rule. Such unwillingness seems to greatly discourage people from performing PET bottles recycling actions. However, it is still uncertain that what process people perceive strong unwillingness and how strong it is. In addition, as shown in Figure 2-1B, the quality of PET bottles collected in supermarkets are always high. Caps and labels are removed, bottles are washed, and not contaminated. It is also a large question of why supermarkets can collect only clean PET bottles.

Willingness to pay (WTP) and Willingness to accept (WTA), categorized in contingent valuation methods (CVM), are useful methods to evaluate the residents' affordability to pro-environmental activities such as waste separation or collection services (Song et al., 2016; Han et al., 2019). Using these methods, it is also possible to evaluate the degree of unwillingness on the monetary scale. However, questionees must be requested a difficult translation from the unwillingness to money (acceptable payment). The lack of understanding of the questionees to the activities or inadequate information about them might lead an inaccurate monetary valuation (Ana, 2019; Joaquin et al., 2009). Demographic characteristics of questionees such as income, age, gender, frequent users and direct users might cause a non-negligible bias in the valuations (Carson et al, 2001). In some cases, scope insensitivity (Desvousges et al., 1993) and/or moral satisfaction (Kahneman and Knetsch, 1992) might be critical. In addition, there might be a significant disparity between WTP and WTA (Flachaire et al., 2013; Georgantzis and Navarro-Martinez, 2010). In terms of valuation validity, it is reasonably motivated to use several valuation methods with different valuation concepts. Therefore, the authors developed a new method to evaluate unwillingness, which enables easier choices for questionees and valuation based on real market prices of services and goods. This method might be in line with the Travel-cost method, which uses indirect valuation of recreation loss or gain based on travel costs (Parsons G.R. 2003).

In this chapter, the concept and details of the new method (Indirect monetary-transform

method) would be proposed. As a case study, the unwillingness toward PET bottle disposal actions would be valuated by WTP and the new method. In addition, unwillingness toward multiple PET bottle disposal actions would be conducted. Furthermore, this study would discuss what causes poor quality of PET bottles collected from public waste drop-off locations and high quality of those collected in supermarkets as well as the stronger unwillingness of some disposal actions.

## 2.2 Methodology

### 2.2.1 Concept of the new method (Indirect monetary-transform method)

The new valuation method consists of two steps in which unwillingness toward PET bottle recycling actions are quantified at the first step and the quantified unwillingness are transformed on monetary scale (valuation) at the second step. PET bottle recycling actions tested in this study are “Understanding disposal rule”, “cap removal”, “label removal”, “bottle washing”, “bottle crushing”, “keeping bottles until disposal day”, “bringing PET bottles to waste collection site near the house and dispose of them” (disposal at waste collection site), and “bringing PET bottles to a collection box in a supermarket and dispose of them” (disposal in the supermarket). At the first step, each recycling action is compared with several reference actions in terms of unwillingness strength. In this binary comparison, the questionees select one action to which they perceive stronger unwillingness. By the regression analysis of the answer data (selection results), the unwillingness toward each recycling action is quantified. At the

second step, the quantified unwillingness are automatically transformed to monetary values using correlation curves between unwillingness degrees and market prices (see Figure 2-2).

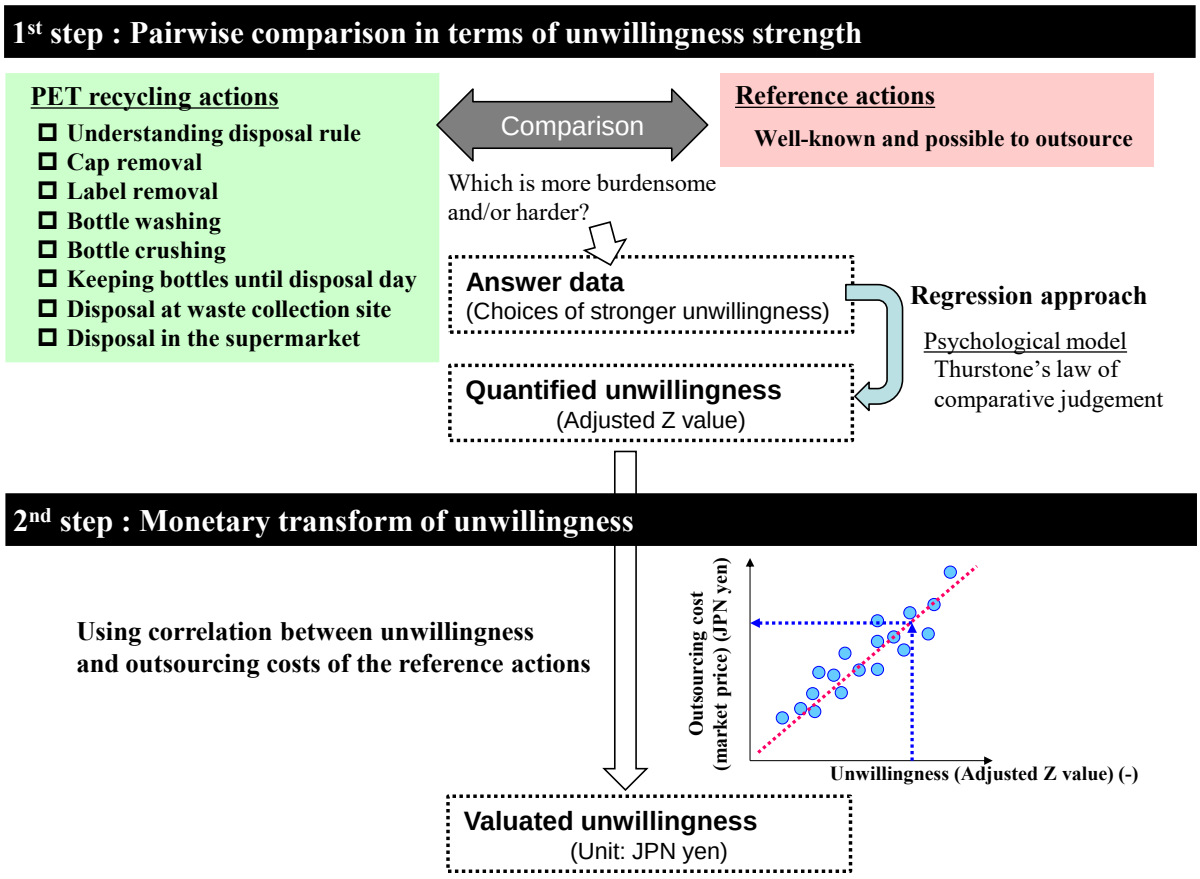



Figure 2-2 Concept and measurement flow of the new method

### 2.2.2 Reference actions

In this study, 32 actions, which were common for Japanese people and easy to outsource or purchase alternative goods/services, were selected as references for the monetary transform of the unwillingness (see Table 2-1). For example, when a person perceives moderate or strong unwillingness to grill two fishes (C6 in Table 2-1), outsourcing is possible (This person buys two grilled fishes in a supermarket or a convenience store). In some reference actions, volume, area or time was presented to help the respondents imagine performing reference actions. Market prices to outsource the reference actions were surveyed and the average prices were used for monetary transform of unwillingness. The averages of market prices, standard deviations, and sample sizes were listed in Table S1. Brief reason descriptions of reference action selections and survey methods of outsourcing prices are listed in Table S2. It should be noted that the reference actions of B8, C2, and D6 were used to quantify the unwillingness but not used for monetary transform of unwillingness owing to outlier market prices due to the diversity of market prices. It is discussed in the last section.

Table 2-1 32 reference actions tested in this study

| Item | Reference action | Alternative goods/services to outsource |
|---|---|---|
| A1 | Wash two set of chopsticks | Disposable chopsticks |
| A2 | Boil water using a kettle (1.5 L) | Boil water using an electric thermo pot |
| A3 | Cook four rice balls (onigiri) | Rice balls in supermarkets /convenience stores |
| A4 | Cook noodle sauce for two persons | Bottled noodle sauce |
| A5 | Boil two cups of rice using a rice cooker | Boil-in-the-bag rice |
| A6 | Fix a flat tire of a bicycle | Tire repairment service |
| A7 | Wash and iron two cuter shirts | Cloth cleaning service |
| A8 | Wash a car manually | Car washing machine |
| B1 | Wash two cups | Disposable cups |
| B2 | Clean up the floor using a broom (about 19 $m^2$) | Clean up the floor using a vacuum sweeper |
| B3 | Cook curry and rice for two persons | Boil-in-the-bag curry and rice |
| B4 | Boil pasta for two persons | Boil-in-the-bag pasta |
| B5 | Shred cabbage for two persons' salad | Shred cabbage in supermarkets /convenience stores |
| B6 | Sharpen a kitchen knife | Knife sharpening service |
| B7 | Walk to next train station (20 min) | Use a train |
| B8 | Clean filters inside an air conditioner | Filter cleaning service |
| C1 | Wash two dishes | Disposable dishes |
| C2 | Go up to the third floor by upstairs | Use an elevator |
| C3 | Refill shampoo into a container | A new shampoo |
| C4 | Cook roasted barley tea (1.5 L) | Bottled roasted barley tea |
| C5 | Sweep the floor with a dustcloth (about 19 $m^2$) | Sweep the floor using a disposable brush |
| C6 | Grill two fishes | Grilled fishes in supermarkets/convenience stores |
| C7 | Cook fried chickens for two persons | Fried chickens in supermarkets/convenience stores |
| C8 | Repair a hole in a sock | A new sock |
| D1 | Take a shopping bag | Disposal plastic bag |
| D2 | Call a friend using a land-line phone | Call a friend using a mobile phone |
| D3 | Drip a cup of coffee | Bottled coffee |
| D4 | Cook miso soup for two persons | Instant miso soup |
| D5 | Wash two cups of rice | Pre-washed rice |
| D6 | Cook a strawberry cake | A strawberry cake in a shop |
| D7 | Hang out ten T-shirts | Use a dryer built-in a washing machine |
| D8 | Weed a yard (30 min) | Weeding service |

### 2.2.3 Quantification of the unwillingness toward the reference actions and its correlation with outsourcing costs

#### *2.2.3.1 Binary pairwise comparison*

The unwillingness toward reference actions was quantified by binary pairwise comparison method. In the pairwise comparison method, each object was paired with one of the other objects. They were compared with respect to the strength of the psychological stimulus. In this study, the stimulus was unwillingness to which the questionees perceived when they performed each reference action. When 3 objects (A, B, and C) are tested by pairwise comparison, for example, the number of all comparisons is three (A vs B, A vs C, and B vs C). In general, pairwise comparison of N objects needs ${}_NC_2$ number of binary comparison and yields ${}_NC_2$ number of selection ratio data.

Selection ratio data were transformed to the degree of unwillingness (Z value) according to Thurstone law of comparative judgment (Thurstone, 1927). When two psychological stimuli are compared, the Thurstone's model assumes that each stimulus invokes a "discriminable process" and both stimuli are ranked by corresponding "discriminable process" (Cheng et al, 2013). In the model, the ratio of object selection corresponds to the difference of psychological stimuli between two objects presented to the questionees. If the questionees perceive stronger unwillingness to perform object A than the other (object B), for example, object A will be selected at higher probability when the questionees are requested to answer which is harder.

According to the case V initial condition in Thurstone's classification, cumulative Gaussian normal distribution with the mean of 0 and the variation of 1 was selected to describe the relation between selection ratio and the difference of psychological stimulus (unwillingness) (Thurstone, 1927) (see Figure 2-3). When pairwise comparison of N objects is conducted, each object has N-1 data of selection ratio. Selection ratio data are converted by the inverse transform of cumulative Gaussian normal distribution function (Eq. 3) and the average of N-1 converted data represents the degree of unwillingness (Z value) (Thurstone, 1959).

$$F(A) = \frac{1}{\sqrt{2\pi}\sigma} \int_{-\infty}^{Z_{AB}} \exp\left( -\frac{(Z_A - Z_B)^2}{2\sigma^2} \right) dZ_A \qquad \text{(Eq. 3)}$$

where F(A) is selection ratio of object A, σ is standard deviation (=1.0), $Z_A$ and $Z_B$ are the unwillingness toward object A and object B, respectively, $Z_{AB} = Z_A - Z_B$ is the difference of unwillingness between object A and object B.

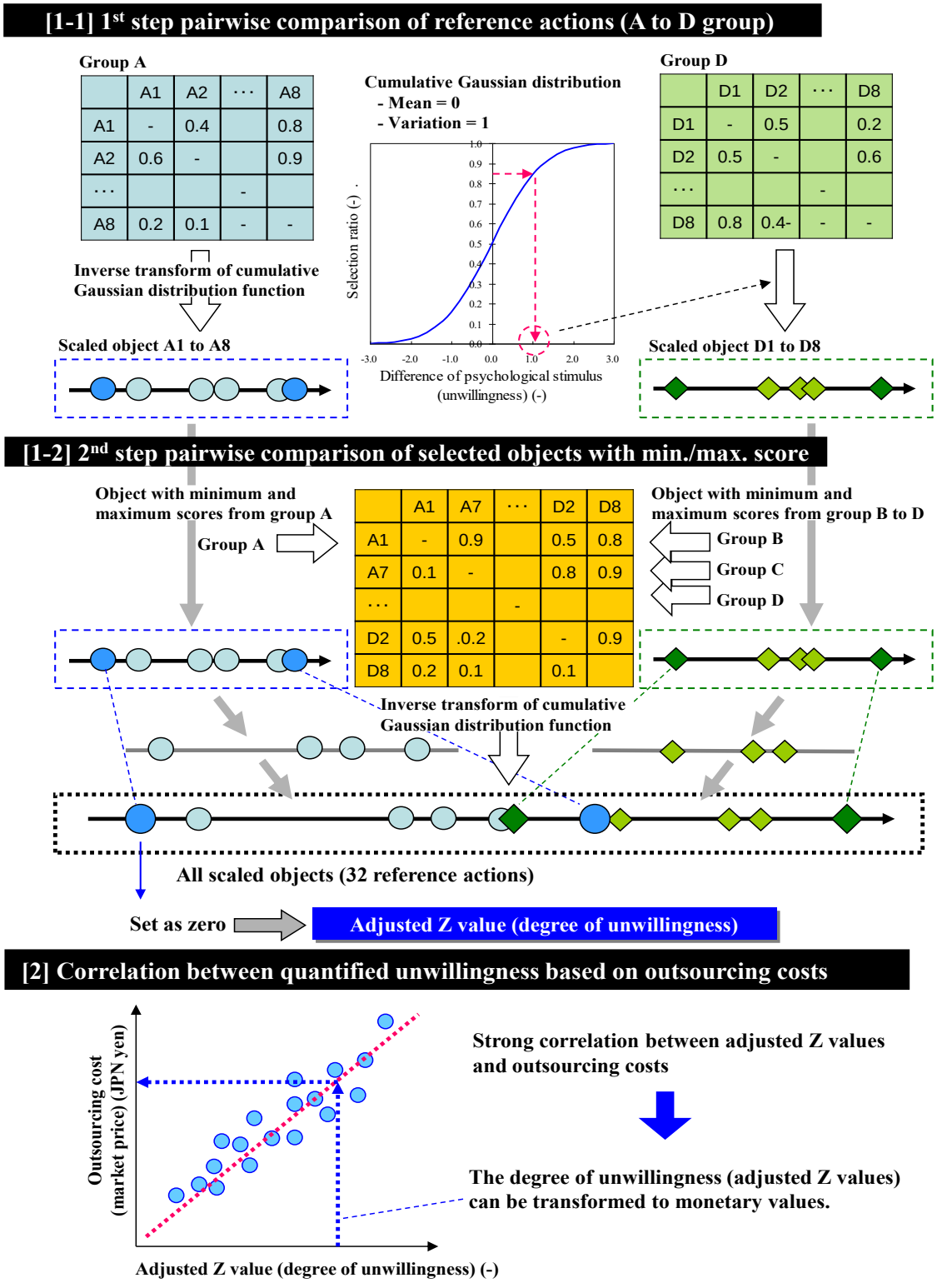



Figure 2-3 Unwillingness quantification of the reference actions and correlation with outsourcing costs

### *2.2.3.2 Two-step pairwise comparison to reduce the necessary number of comparisons*

Web questionnaires were conducted from July 2012 to December 2013 by Quickmill®, Macromill Co. Japan. When the questionnaire respondents were collected randomly from different places in Japan (all respondents were Japanese), they were pre-screened to adjust equal male/female balance and equal age distribution from 20 s to 60 s at 10-year age interval. The questionees were asked to select a "stronger unwillingness" object from each pair according to their perceptions. In general, the number of objects (N) should be small because the number of binary comparison (${}_{N}C_{2}$) increases exponentially with increase of N. This study needs the pairwise comparisons of 32 objects (32 reference actions) and it requests 496 comparisons to each questionee. Due to unrealistic workload, pairwise comparisons of 32 objects were decomposed to two steps in order to reduce the necessary number of binary pairwise comparison. At first, 32 objects were divided into 4 groups (group A, B, C, and D) and the pairwise comparison of each group was conducted. Unwillingness scores ($1^{st}$-step Z values) of 8 objects in each group were calculated. The easiest and hardest objects were selected from each group according to $1^{st}$-step Z values and made up one more group. Therefore, this group also has 8 objects. At the second step, the pairwise comparison of this re-established group was conducted and $2^{nd}$-step Z values were calculated. After the second step pairwise comparison, the unwillingness ranges of four initial groups (group A, B, C, and D) were defined as the

difference of 2nd-step Z values between the easiest and the hardest objects of each initial group. Moderate objects of each group were re-located internally within the unwillingness range of each group according to 1st-step Z values (see Figure 2-3). For example, the second step pairwise comparison calculates 2nd-step Z values to be 2.0 for object A1 (the easiest object of group A) and 8.0 for object A4 (the hardest object of group A). The unwillingness range of group A is 6.0. If the first step pairwise comparison of group A calculates 1st-step Z values to be -5.5 for A1, -2.5 for A2, 1.5 for A3, and 6.5 for A4 (the sum of all Z values must be zero), object A2 and A3 are located in the unwillingness range of group A proportionately to 1st-step Z value range obtained by the first step pairwise comparison. In this example case, A2 and A3 will be located at 3.5 and 4.0 in the unwillingness range of group A, respectively. Therefore, the two-step pairwise comparison can be summarized that 1st-step Z values were used only for the internal allocation of moderate objects in each group. The second step pairwise comparison was used to calculate the unwillingness range of each initial group (group A, B, C， and D). After all objects were ordered according to 2nd-step Z values, a certain value was added to each 2nd-step Z value to adjust the smallest 2nd-step Z values as zero (adjusted Z values). In this study, sample sizes (the number of the questionees) of the first-step pairwise comparison (four initial groups) and second-step pairwise comparison was 470 and 420, respectively.

#### *2.2.3.3 Building the calibration curves for monetary transform of unwillingness score*

According to quantified unwillingness of the reference actions, the authors investigated correlation between quantified unwillingness scores (adjusted Z values) and their outsourcing costs (market prices) for monetary transform of unwillingness scores of PET bottle recycling actions.

### 2.2.4 Valuation of unwillingness to PET bottle recycling actions

#### *2.2.4.1 Quantification of unwillingness to PET bottle recycling actions by non-linear regression (1st step)*

Because three good correlations were found between unwillingness (adjusted Z values) and outsourcing costs, 29 reference actions were summarized to three groups correspondingly. Eight PET bottle recycling actions were compared with each of the reference actions in three groups and then selection ratio data were obtained. As described in Eq. 3, selection ratios were controlled by the difference of unwillingness between a PET bottle recycling action (optimized variable) and a reference action (measured variable). Therefore, the unwillingness toward PET bottle recycling actions were optimized by non-linear regression method to fit predicted selection ratios with measured selection ratios. It should be noted that the variation ($\sigma^2$) in Eq. 3 is not equal to 1.0 here owing to 2nd-step Z value adjustment. Therefore, the variation was

also optimized along with the unwillingness.

#### *2.2.4.2 Valuation of unwillingness using the calibration curves (2nd step)*

Using three correlations between unwillingness and outsourcing costs for the reference actions, unwillingness toward the PET bottle recycling actions were transformed to monetary values.

### 2.2.5 Valuation of unwillingness to PET bottle recycling actions by Willingness-to-Pay method

Willingness-to-pay (WTP) method has been commonly used to analyze the public acceptability of non-marketing goods or services (Bai et al., 2019, Bernad-Beltran et al., 2014, Otoma et al., 2013), and the contingent valuation method (CVM) is the most frequently used valuation method for the WTP analysis (Oerlemans et al., 2016, Afroz et al., 2009). Wang et al., 2011 took Beijing, China as an example, conducted research on the individual's behavior towards E-waste recycling. Vasanadumrongee and Kittipngvises investigated the influencing factors on source separation intention and how much would Thai residents willing to pay for improving the urban waste management. However, some researchers indicated that there might be some significant differences are existed in the responses of participants to the economic model due to their difficulties to monetary transforming an environmental action into an exact amount (Ryan and Spash, 2011). In a study on PET bottle consumers' responses to

environmental policies, Orset et al. 2017 also mentioned that, as other researches using WTP approaches has shown, the result might include some bias, and it might cause by the lake of understanding of incorrect information. Therefore, an affirmation process is necessary to recognize the differences between the new method and the conventional method. In order to validate the consistency of the new method with WTP method, the unwillingness toward PET bottle recycling actions was also quantified by WTP method. There are several types of elicitation formats commonly used such as Open-ended questions, bidding games, payment cards, and dichotomous choice. In this study, the questionnaire survey with the double-bounded dichotomous choice contingent valuation (DBDCCV) method was employed due to its high statistical efficiency. Weibull distribution was selected as a parametric model in survival analysis to calculate mean WTP.

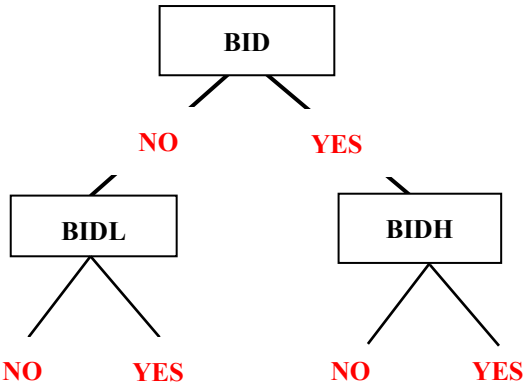



Figure 2-4 DBDCCV questionnaire sequence

Based on the DBDCCV method, there were two sequences of questions that had to be answered by questionees for each sub-process of PET disposal. The first sequence was called initial bid (BID). The second sequence were called lower bid (BIDL) and higher bid (BIDH).

The second sequence were based on the answer of first sequence. If ‘YES’ was given to the first sequence, then the higher bid was offered, if ‘NO’ was given to the first sequence, conversely, the lower bid was offered (see Figure 2-4) In this study, four initial amounts of price were given which are JPY 2, JPY 6, JPY 101, and JPY 201. The BIDL and BIDH of each range were determined by the initial amounts (see Table S3). In WTP method survey, its sample size was 400. The mean WTP truncated at the maximum bid was used for comparison with the new method.

### 2.2.6 Unwillingness toward multiple actions

In previous section, the quantitation of unwillingness toward the PET bottle disposal process was aimed to investigate the unwillingness of every single action of the PET bottle disposal process and justify the applicability of the new method. However, in a waste recycling system, generally, individuals are requested to complete several processes. Struk and Song et al. pointed out that the situational factors, such as distance and simplicity of the waste recycling process, are crucial in residents' participation (Struk, M., 2017; Song et al., 2019). Perrin and Barton concluded that less effort and a more convenient separated collection might be more perforable for users (Perrin and Barton, 2001).

To further validate the new unwillingness valuation method, the quantitation of unwillingness of multiple actions by the new method is necessary. Besides, the author assumed that some specific actions in the whole process would have a more significant influence on the

unwillingness; therefore, based on the eight single processes of PET bottle disposal, with the same quantitation method (Dilixiati et al., 2023), the unwillingness quantitation of two, three and, four actions were conducted, respectively. Moreover, the unwillingness of multiple actions is requested to do simultaneously and separately were compared for further analysis. Multiple actions are listed in Table 2-2.

Table 2-2 PET bottle recycling actions (multiple)

| **2 actions at the same time** | |
|---|---|
| Cap Removal, Label Removal | A-B |
| Cap Removal, Bottle Washing | A-C |
| Cap Removal, Bottle Crushing | A-D |
| Cap Removal, Disposal At Waste Collection Site | A-X |
| Cap Removal, Disposal In The Supermarket | A-Y |
| Label Removal, Bottle Washing | B-C |
| Label Removal, Bottle Crushing | B-D |
| Bottle Washing, Bottle Crushing | C-D |
| Bottle Washing, Keeping Bottles Until Disposal Day | C-S |
| Bottle Washing, Disposal At Waste Collection Site | C-X |
| Bottle Washing, Disposal In The Supermarket | C-Y |
| Keeping Bottles Until Disposal Day, Disposal At Waste Collection Site | S-X |
| **3 actions at the same time** | |
| Cap Removal, Label Removal, Bottle Washing | A-B-C |
| Cap Removal, Label Removal, Bottle Crushing | A-B-D |
| Cap Removal, Bottle Washing, Bottle Crushing | A-C-D |
| Cap Removal, Bottle Washing, Keeping Bottles Until Disposal Day | A-C-S |
| Cap Removal, Bottle Washing, Disposal In The Supermarket | A-C-Y |
| Label Removal, Bottle Washing, Bottle Crushing | B-C-D |
| Bottle Washing, Keeping Bottles Until Disposal Day, Disposal At Waste Collection Site | C-S-X |
| **4 actions at the same time** | |
| Cap Removal, Label Removal, Bottle Washing, Bottle Crushing | A-B-C-D |
| Cap Removal, Bottle Washing, Keeping Bottles Until Disposal Day, Disposal At Waste Collection Site | A-C-S-X |

A: Cap removal, B: Label removal, C: Bottle washing, D: Bottle crushing, S: Keeping bottles until disposal day, X: Disposal at waste collection site, Y: Disposal in the supermarket

## 2.3 Result and discussion

### 2.3.1 Calibration curves for monetary transform of unwillingness toward reference actions

The quantified unwillingness toward reference actions (adjusted Z values) and their outsourcing costs (the average of market prices) were compared as shown in Figure 2-5. Three single logarithmic regression curves were found. Market competition of alternative goods/services for outsourcing might contribute into these different single logarithmic linearities. Although market prices will be given by the balance between demand and supply in a completely competitive market (Lars Henriksson, P46), real markets are not completely-competitive and thus products/services providers can gain some profits in the market. It might cause different outsourcing costs (market prices) of reference actions even when they receive almost equal unwillingness. In addition, unwillingness might not be only a motivation to outsource reference actions. Further study is necessary to distinguish appropriate reference actions (see chapter 6). In this study, three single logarithmic linearities were used. Therefore, the unwillingness toward PET bottle recycling actions was quantified with a certain range.

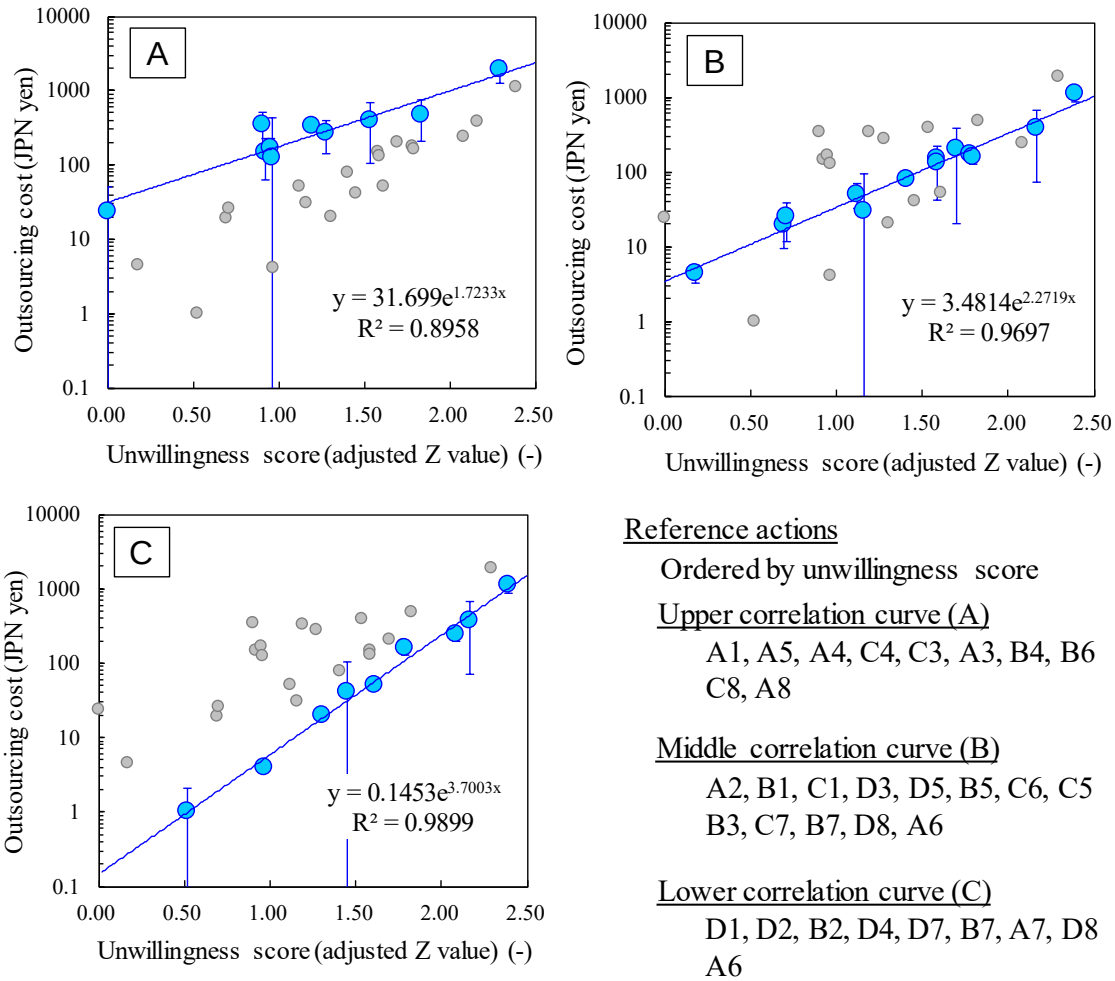



Figure 2-5 Single logarithmic linearity between quantified unwillingness toward reference actions and their outsourcing costs

(A: Upper correlation curve, B: Middle correlation curve, C: Lower correlation curve)

### 2.3.2 Validation of unwillingness toward PET bottle recycling actions

Based on the single logarithmic linearity, reference actions were summarized to three groups (see Table S1). Comparisons between measured and predicted selection ratios are shown in Figure 2-6. The predicted selection ratios have good agreement with measured ones. However, some reference actions like boiling water using a kettle and cleaning floor using a broom (B2) show large differences in selection ratio between prediction and questionnaire

measurement. These reference actions might have given the survey respondents larger difficulty to image the unwillingness to perform them.

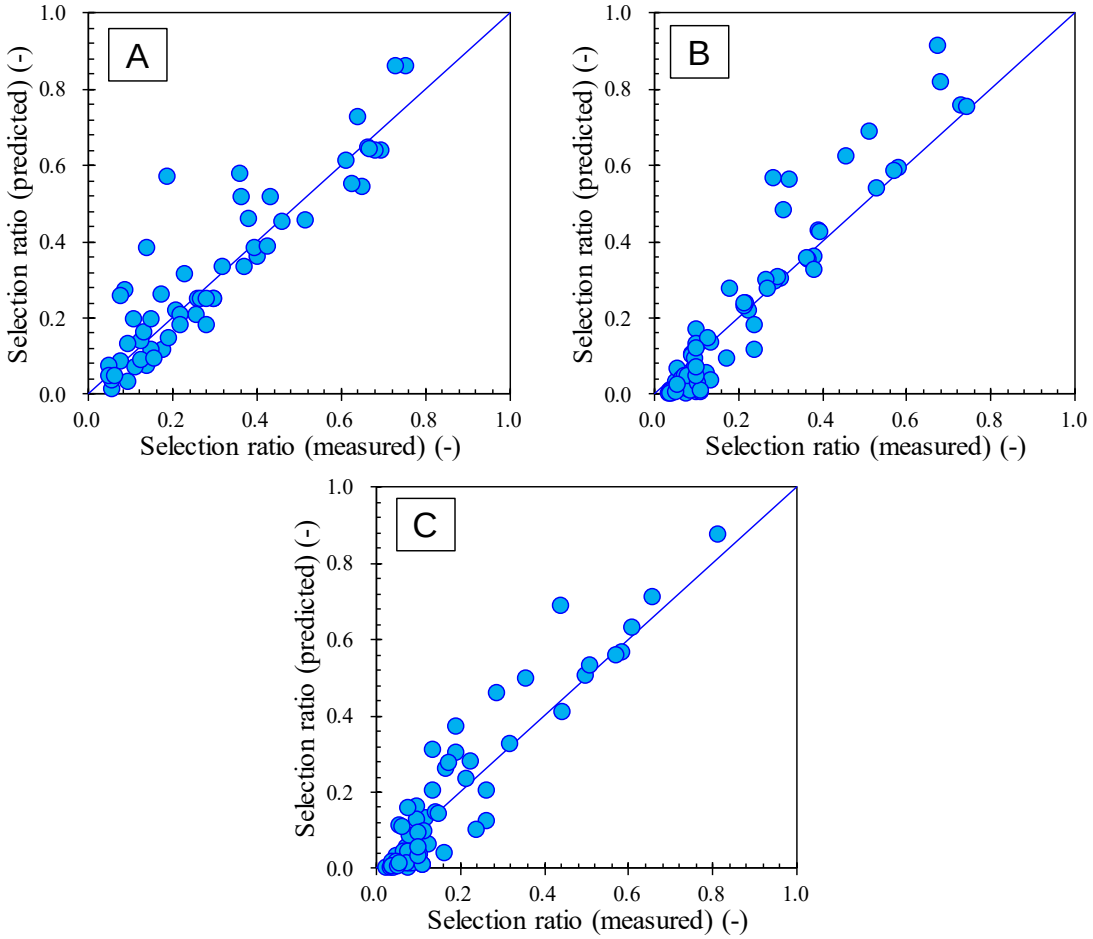



Figure 2-6 Comparisons of measured and calculated selection ratios for unwillingness validation (A: Upper correlation curve, B: Middle correlation curve, C: Lower correlation curve)

### 2.3.3 Valuated unwillingness toward eight actions for PET bottle recycling

The valuated unwillingness toward eight actions for PET bottle recycling are shown in Figure 2-7. In Figure 2-7, the bottom (minimum) and the top (maximum) of unwillingness were quantified using lower and upper single logarithmic linearity curves, respectively. The eight

actions for PET bottle recycling could be arranged in order of unwillingness strength as follows; “Disposal in the supermarket” > “Disposal at waste collection site” > “Understanding disposal rule” > “Bottle washing” > “Bottle crushing” = “Keeping bottles until disposal day” > “Label removal” > “Cap removal”. “Disposal in the supermarket or at waste collection site” causes the strongest unwillingness. They were measured 57.9 JPN yen (17.9 to 358 JPN yen) for “disposal in the supermarket” and 25.5 JPN yen (4.06 to 346 JPN yen) for “disposal at waste collection site”, respectively. The weakest unwillingness is given toward “cap removal” and measured 1.77 JPN yen (0.319 to 8.19 JPN yen). The unwillingness toward “understand disposal rule” is the third strongest among eight actions (12.2 JPN yen as the middle) and it can clearly explain why foreign materials are always mixed with PET bottles. Such strong unwillingness discourages people from understanding PET bottle disposal rule and causes unconsciousness of correct PET bottle disposal for recycling. It finally results in other waste contaminations into PET bottles. Some efforts for waste disposal rule publicity have been paid by local governments in Japan. For example, the illustrated disposal chart is usually distributed to each household (Ministry of the Environment, 2014). However, such efforts must overcome 12.2 JPN yen (or 2.30-

110 JPN yen) of unwillingness for effective publication.

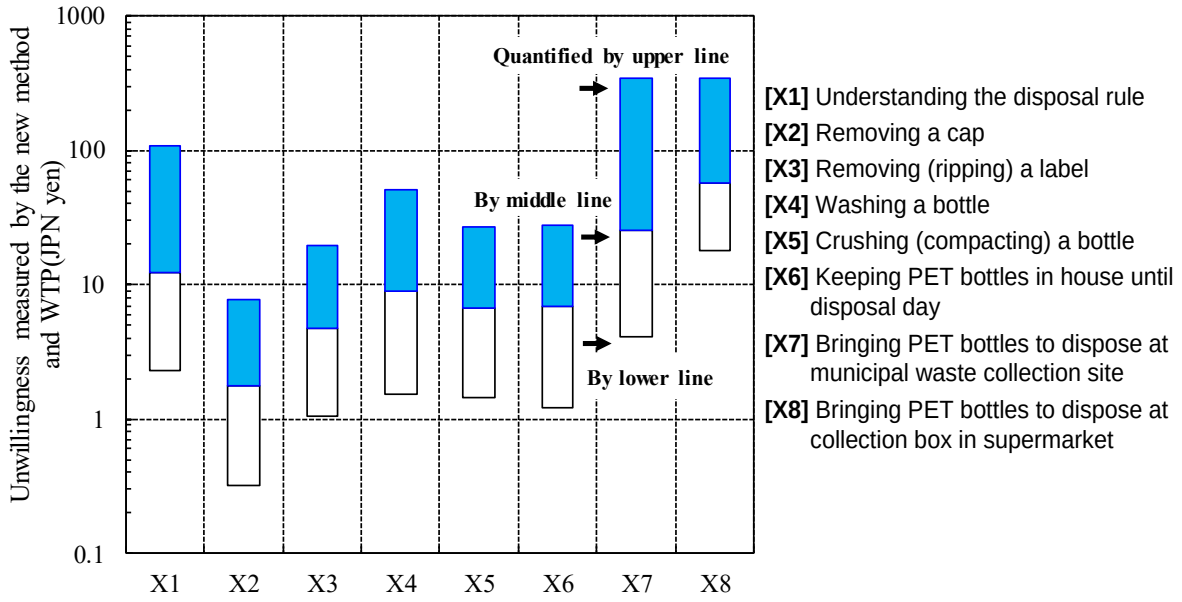



Figure 2-7 Unwillingness toward PET bottle recycling actions quantified by the new method

Previous researches indicated that situational factors such as distance between households and collection facilities, time consumption, convenience and ease of usage have a great effect on the recycling behavior (Klöckner and Oppedal, 2011; Saripah et al., 2012; Chen and Tung 2010; Vencatasawmy et al., 2000). Lange et al. suggested that perceived distance to the waste collection site was decisive for recycling behaviors (Lange et al., 2014). If negative effects of these factors on recycling behaviors are highly associated with unwillingness, strong unwillingness toward PET bottle disposal at waste collection site and in supermarket are reasonably consistent with previous works. In addition, the strong unwillingness toward "disposal in the supermarket" can explain the question of why the quality of PET bottles

collected in supermarkets is always high. Because only recycle-conscious people can overcome such strong unwillingness, they will bring PET bottles to supermarkets to contribute into PET bottle recycles. For such recycle-conscious people, it is easy to remove caps and labels, wash and compact bottles, and separate PET bottles from other wastes because of smaller unwillingness. Therefore, the quality of collected PET bottles is always very high. The findings of this work are clearly harmonized with Theory of Planned Behavior (TPB). For performing a pro-environmental behavior such as waste recycling, TPB proposes that personal intention is one of the crucial factors. The intensity of the intention directly determines the occurrence of the behavior (Ajzen, 1991). In addition, the subject norm is also identified as the social normative factor affecting an individual's intention (Oerleman et al., 2016; Fishbein and Ajzen, 2009). It is suggested that stronger unwillingness makes the intention shifted to "no recycling behavior" but the subject norm (recycle consciousness) mitigates negative effect of unwillingness. In addition, many researches indicate that improvement of environmental awareness of people to establish a positive attitude might be an essential step for shaping a good recycling behavior and solving environmental problems (Kollmuss and Agyeman, 2002; Armitage and Christian 2003; Huq and Toulmin, 2006; Lee and Moscardo, 2005; Moser 2006; Patchen, 2006). According to strong unwillingness toward understanding disposal rule, it might answer why the improvement of environmental awareness is difficult. A great psychological burden needs to be overcome.

### 2.3.4 Comparison between the new method and WTP method

The unwillingness toward eight actions for PET bottle recycling, valuated using the middle single logarithmic linearity curve and measured by WTP method, are compared in Figure 2-8. Good agreement between two methods is found for “label removal”, “bottle washing”, “bottle crushing”, “keeping bottles until disposal day”. On the other hand, the new method valuated unwillingness toward “understanding disposal rule correctly”, “disposal at waste collection site”, and “disposal in supermarket” higher than WTP method by 51.99%, 20.55%, 221.9%, respectively. WTP method might have underestimated these unwillingness. It is reported that under- or overestimation of WTP for non-marketing public goods or service are caused by lack of understanding and incomplete information (Delmas and Lessem, 2014; Bergstrom et al., 1990; Oerlemans et al., 2016; Zhou et al., 2018). Meanwhile, these gaps might suggest that the unwillingness to perform these actions are stronger than that people perceive consciously. In other words, the new method might be able to valuate the unwillingness including unrecognizable or unconscious part. If it is explained by TPB, behaviors are influenced by intentions, which are determined by three factors: attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). People perceived behavioral control to those actions (“understanding disposal rule correctly”, “disposal at waste collection site”, and “disposal in supermarket”) might be affected by other external factors such as distance or effort which might be difficult to imagine or directly translate to money (See Figure 2-9). Although it has been

demonstrated that unconscious information processing affected perceptions, decision making, and behaviors (Galdi et al., 2008; Messner and Wanke, 2011), its impact on pro-environmental activities like waste recycling is still uncertain. Coupled use of WTP and the new methods might be useful to quantitatively detect and analyze unconscious unwillingness toward other pro-environmental activities.

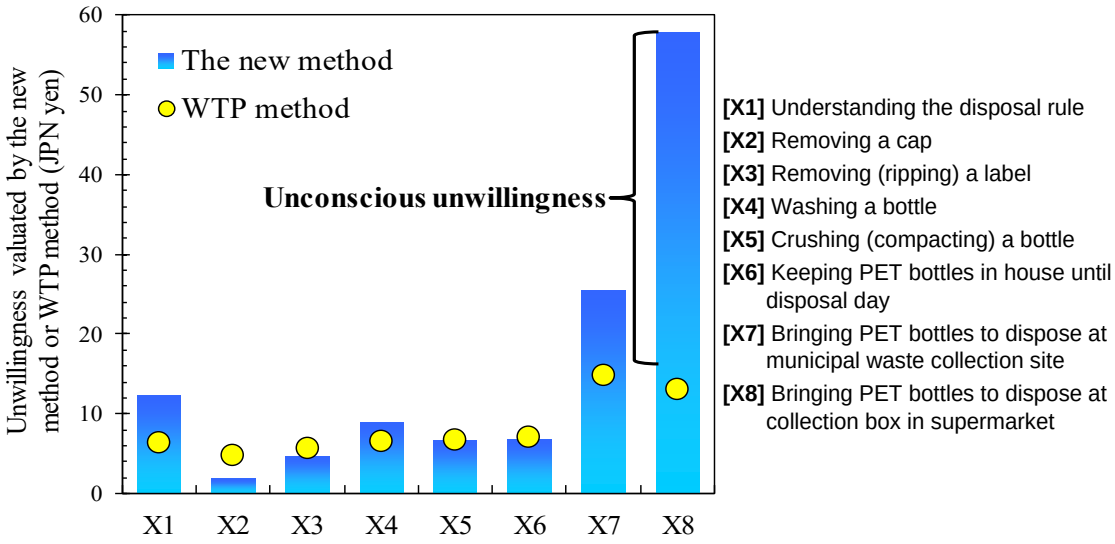



Figure 2-8 Unwillingness toward PET bottle recycling actions quantified by the new method (using the middle correlation curve) and WTP method

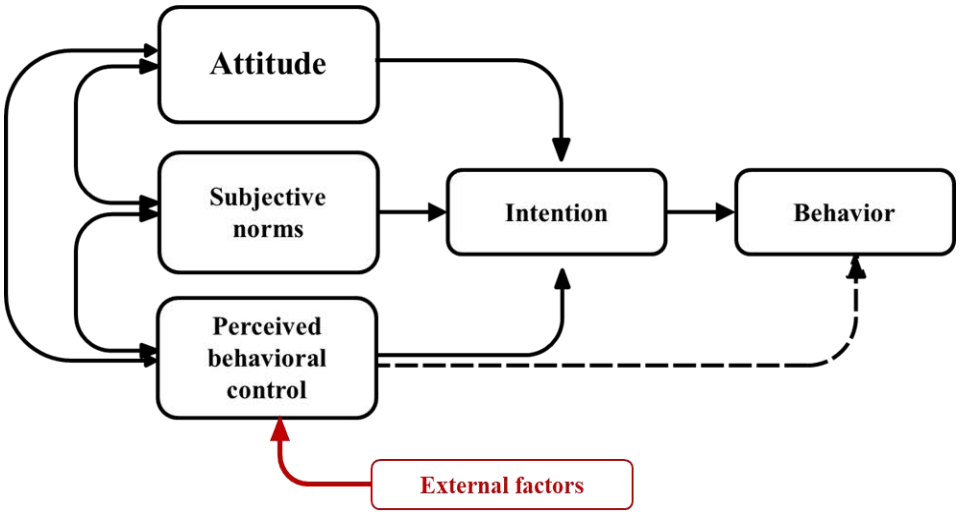



Figure 2-9 Explanation by the basic concept of The Theory of Planed Behavior

As proposed in the previous section, strong unwillingness toward “disposal in the supermarket” might serve as a social filter to allow only recycle-conscious people to participate in PET bottle recycling. When psychological barriers like strong unwillingness are appropriately implemented in waste collection system, it might enable more efficient waste separation and less waste contamination via social filtration. When high quality of collected wastes is necessary, the site location of target waste collection should be determined to make unwillingness toward bringing wastes to the collection site stronger. It will result in waste collection only from high recycle-conscious people. Although it might be promising, careful design of social implementation is absolutely necessary due to complicated and sometimes inconsistent associations between conditional factors and recycling behaviors. For example, as mentioned previously, perceived distance to the waste collection site greatly affects recycling behaviors (Lange et al., 2014). Conversely, it is also suggested that pro-environmental actions such as active participation in recycling are not affected by time and space, but promoted by the good results of these pro-environmental actions (Davis, 2006). According to the TPB, if people believe sufficient controllability of pro-environmental behaviors and accept the environmental actions with a positive attitude, they are able to conquer strong unwillingness to make environmental actions as daily habits (Davis, 2008; Klöckner and Oppedal, 2011). Wilma et al measured the effect of all components of the TPB model and proposed that the influence of perceived behavioral control was more significant than intention (Wilma et al., 2018). It is

contrast to the importance of intention and/or subject norm to trigger behaviors (Oerleman et al., 2016; Fishbein and Ajzen, 2009). Although the associations between conditional factors and recycling behaviors are like chaotic, psychological barrier like unwillingness might yield comprehensive explanations. In the TPB model, it is hypothesized that unwillingness mainly affects intention and perceived behavioral control (Hypothesis 1). Subject norm might mitigate the influence of unwillingness to intention (Hypothesis 2). Personal characteristics and certain conditional factors (e.g. distance) might change the effect of unwillingness on perceived behavioral control (Hypothesis 3). At least, this work on PET bottle recycling supports the hypothesis 2 as mentioned in the previous section.

### 2.3.5 Unwillingness to multiple actions

#### *2.3.5.1 Validation of unwillingness toward multiple actions*

Based on the middle correlation curve of reference actions, a comparison between measured and predicted selection ratios is shown in Figure 2-10. A good agreement was found for most actions. Nonetheless, for some actions such as A-C (Cap removal, Bottle washing), A-B-C-D (Cap removal, Bottle washing, keeping bottles until disposal day, Disposal at waste collection site), for some points, the predicted ratio is larger than the actual selection ratio data, it might suggest that the imagination of the unwillingness when complete some actions such as, “Boil water using a kettle (1.5 L)” were not easy for some questionees, since, everyone may not boil water I this way. In terms of feasibility for most actions, the new method can be applied

in the unwillingness calculation of multiple actions of PET bottle recycling.

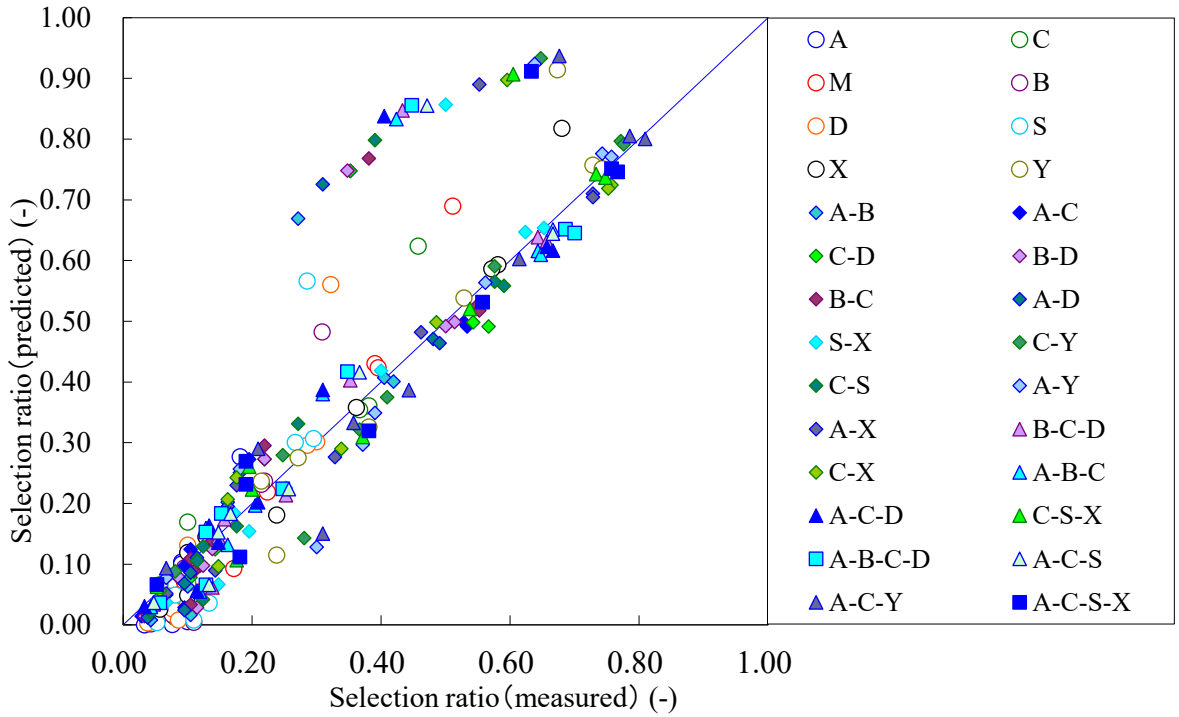



Figure 2-10 Comparisons of measured and calculated selection ratios for unwillingness

### *2.3.5.2 Valuated unwillingness toward multiple actions for PET bottle recycling*

The valuation of unwillingness toward multiple actions was shown in Figure 2-11 (A), (B), and (C), respectively. The maximum and the minimum value of unwillingness were calculated by upper and lower linearity curves of the reference actions. When we focused on the middle line, for 2 actions, the unwillingness strength is C-Y > A-Y > C-X >A-X > S-X > C-S > C-D >B-C > B-D > A-C >A-D >A-B. The highest unwillingness counts for C-Y (73.307 JPY), while the lowest unwillingness is shown in A-B (11.031 JPY). For 3 actions is A-C-Y > C-S-X > A-C-S > B-C-D > A-C-D >A-B-C > A-B-D. The strongest unwillingness for A-C-Y (77.421 JPY);

the weakest unwillingness for A-B-D (21.992 JPY). For four actions is, A-C-S-X > A-B-C-D, their unwillingness was 56.09 JPY and 33.568 JPT, respectively. (A: Cap removal, B: Label removal, C: Bottle washing, D: Bottle crushing, S: Keeping until disposal day, X: Disposal at the waste collection site, Y: Disposal in the supermarket). According to the unwillingness strength, multiple actions, including a longer distance between households and recycling facilities such as Y, X and some complexity such as A, C, and actions, need more time and space as S showed stronger unwillingness. This is in line with the finding of some past studies about the significance of situational factors on recycling behaviors (Saripah Abdul Latif et al., 2012; Chen and Tung, 2010). It also further verifies the result of the unwillingness quantification for single actions.

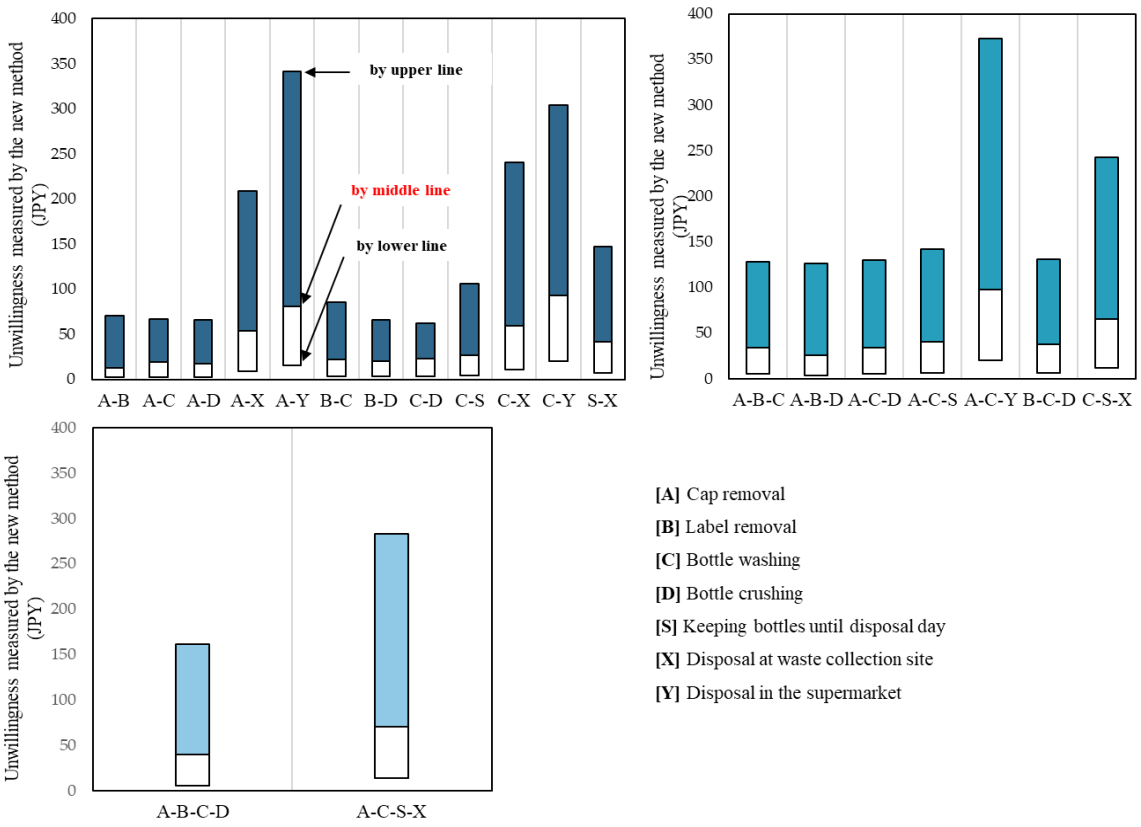



Figure 2-11 Unwillingness toward multiple recycling actions quantified by the new method (A: 2 actions, B:3 actions, C: 4 actions)

#### *2.3.5.3 Comparison of the unwillingness of multiple actions in different cases*

If multiple actions are requested at the same time, in other words, if the pro-environmental actions are requested several steps at the same time, it might cause stronger unwillingness than those actions are completed one by one. With the aim of validating the interaction of the pro-environmental actions in a recycling process, the unwillingness of the multiple actions to be requested to be completed simultaneously and in the case of separate completion were compared. The result is shown in Figure 2-12 (A), (B), and (C). According to some research justified by TPB, shaping a positive attitude might be the cardinal process of developing the intention for a good recycling habit (Lee and Moscardo, 2005; Armitage and Christian, 2003; Huq and Toulmin, 2006; Moser, 2006; Patchen, 2006). Alongside pro-environmental intention, perceived behavior control will determine an individual's pro-environmental performance (Ajzen, 1991; Wilma et al., 2018). In daily life, when individuals are requested to finish multiple recycling actions in a disposal process at a relatively high level if only considering the complexity of the actions, the subject norm is equal to everyone. However, differences in people's environmental attitudes and perceived behavior control will push them to finish those actions with disparate standards. Achieving a perfect recycling state in which everyone actively participates is a task for every recycling scheme. "Ingenious application" of psychological barriers combined with other encouraging factors can be a challenging and practical approach to increasing voluntary involvement of diversified participation in the complex waste

classification process.

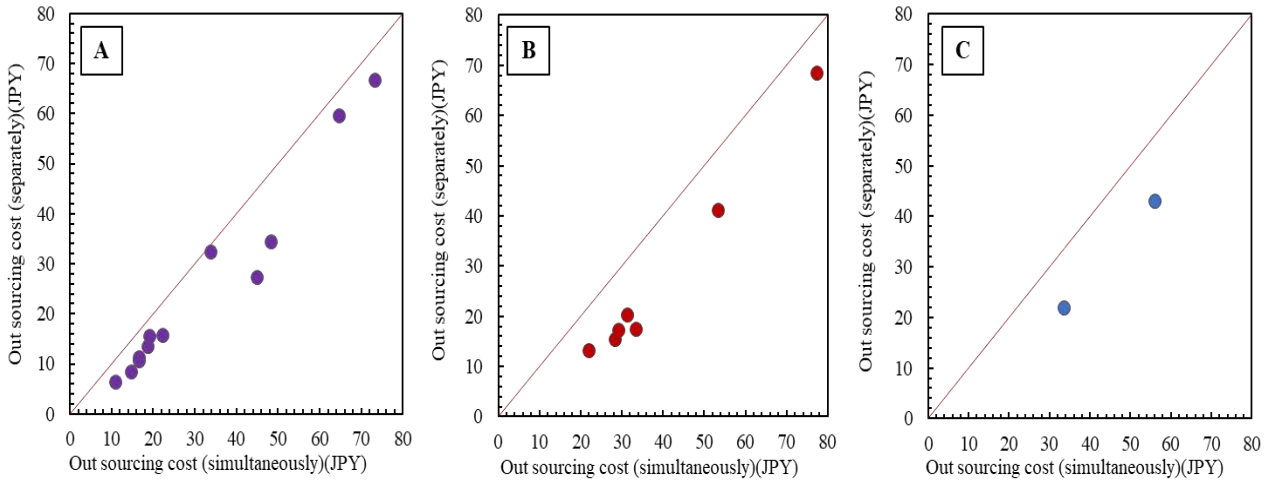



Figure 2-12 Comparisons of valuated unwillingness of multiple actions be requested to do simultaneously and separately (A: 2 actions, B:3 actions, C:4 actions)

## 2.4 Conclusion

A new method was suggested to valuate the unwillingness people perceive when they perform eight actions for PET bottle recycling. The new method consists of two stages; quantification of unwillingness by pairwise comparison method and monetary transform of unwillingness based on outsourcing costs (market prices to outsource reference actions). Compared with WTP method, the new method requests only “fair” comparisons between two actions in terms of unwillingness strength. “Cap removal” receives the weakest unwillingness (0.319 to 8.19 JPN yen). Strong unwillingness toward “understanding the rule of correct waste disposal” probably explains other waste contamination in PET bottles. Good agreement was

found for some actions like “bottle washing” between the new method and WTP method. On the other hand, the new method valuated the unwillingness toward “understanding waste disposal rule”, “disposal at waste collection site”, and “disposal in the supermarket” higher than WTP method. This suggests that the new method might quantify both recognizable and unrecognizable unwillingness. Therefore, coupled use of both WTP and the new methods might be useful to quantitatively detect unconscious unwillingness which might affect recycling behaviors. Complicated and sometimes inconsistent associations between conditional factors and recycling behaviors have been a large scientific question. Unconscious unwillingness might yield comprehensive explanations on the chaotic associations. According to TPB, this study proposed three hypotheses of unwillingness-related mechanisms for further researches. Owing to the new concept of monetary transform logics, the new method includes many questions to be validated. In particular, reasonable selection of the reference actions, appropriate monetary transform model, and impacts of social and cultural properties on monetary transform should be addressed. According to findings of this work, the strongest unwillingness toward “disposal in the supermarket” (17.9 to 358 JPN yen) explains constant high quality of PET bottles collected in supermarket. Strong unwillingness might allow only recycle-conscious people to bring PET bottles to supermarkets.

Unwillingness toward two, three, and four recycling actions are required the same time were also quantified by the new method. Unwillingness shows higher to recycling actions when

they include some situational factors such as distance, time consumption, or complexity. Comparison of the unwillingness of multiple actions required to complete simultaneously and separately further confirmed the psychological botheration caused by complex environmental protection actions. Although this psychological pressure is fair to everyone, people with strong environmental awareness can always overcome and complete the recycling actions without being affected by the tediousness. TPB might help explain the relationship between people's perceived behavior control and environmental behavior, such as active participation in recycling.

Strong unwillingness serves like as a social filter to collect only high-quality PET bottles. Social implementation of psychological barrier like strong unwillingness in waste collection system might be promising for more efficient waste separation. For example, collection site of recyclable wastes might be determined in order to intentionally make it less convenient access. It might decrease the amount of waste collection but increase quality of collected wastes significantly. It is called a "separate recycling participants, not wastes" approach.

# Chapter 3 PET bottle sorting condition in 6 target cities in Japan

## 3.1 Background

As mention in the previous chapter, generally, PET bottle recycling actions are including “Understanding disposal rule”, “cap removal”, “label removal”, “bottle washing”, “bottle crushing”, “keeping bottles until disposal day”, “bringing PET bottles to waste collection site near the house and dispose of them” (disposal at waste collection site), and “bringing PET bottles to a collection box in a supermarket and dispose of them” (disposal in the supermarket).

In Japan, although there is a unified standard, on the whole, each municipality is able to manage its specified waste collection and recycling system according to its characteristics. For instance, some cities use designated plastic bags for waste collection, while others use transparent or translucent plastic bags. Besides, variations exist in rules for the classification accuracy of recyclable waste (Ministry of the Environment, 2014). Additionally, for different types of residential areas, even within the same jurisdiction, the methods of waste collection and classification might have differences, which might lead to inconsistencies in classification behavior. Moreover, collection facilities in the public area such as convenience stores, supermarkets, departments, collection bins near the vending machine, and transitions play a positive role in the convenience of waste collection. However, in terms of quantity, other

contaminates mixed with recyclable waste bring unnecessary reclassification to the waste treatment process (Jiang et al., 2019).

Throughout the whole recycling system, consumers are the central part; that is to say, the completion of pro-environmental actions will be directly related to recycling quality and subsequent process. It is also an important indicator of people's environmental awareness (Barr and Gilg, 2007; Chung and Poon, 2001; Zeng et al., 2016; Mukherji et al., 2016). Numbers of researchers studied the people's waste classification and recycling behavior as well as its influencing factors from different points of view (Song et al., 2016; Han et al., 2019; Huang et al., 2011; De Young, 1986; Nyamwange, 1996). Martine et al. have found that people's attitude toward pro-environmental behavior is not the most critical factor, while Bradley et al. reported its significant impact (Martine et al., 2006; Bradley et al., 1999). Jiang et al. explained the impact of setting conditions for PET bottle collection bins using the Theory of Competition of Attention (Jiang et al., 2019). Some past studies focused on the impact of the distances between recycling facilities and users (Struk, M., 2017). The relationship between the utilization of recycling stations and a positive attitude toward recycling was also reported by a case study in Kiruna (Vencatasawmy and Öhman, 2000). Leeabai et al. have indicated the effect of the setting conditions of separated collection bins on the human behavior of waste classification (Leeabai et al., 2019). O'Connor et al. also researched the influence of the location and number of collection bins on plastic recycling in the university (O'Connor et al., 2010). Although there are

differences in collection methods and locations, in Japan, for consumers, “cap removal,” “label removal,” “bottle washing,” and “bottle crushing” are the basic steps that should be done to contribute to the appropriate recycling (The Council for PET bottle recycling Japan, 2020).

In this chapter, the actual condition of PET bottle sorting was investigated in 6 different cities in Japan. The author participated in the data collection in 2017-2018 and was responsible for the data processing and analysis. The detail of the investigation is introduced in the following context.

## 3.2 Methodology

### 3.2.1 Research area and waste management system

As described in the introduction section, each municipality has the right to formulate an individual recycling rule according to the characteristic of each area. Therefore, to investigate the PET bottle sorting in different regions, the on-site survey was conducted in 6 regions (cities): Kitakyushu city (Nov. 2012), Hiroshima city (Apr. 2013), Nagoya city (Jun. 2013), Edogawa city (Jul. 2017), Saitama city (Mar. 2018), Chiba city (Nov. 2018).

Table 3-1 Basic information of the cities surveyed

| | City | City (Japanese) | Area (km²) | Population density (km²) |
|---|---|---|---|---|
| A City | Kitakyushu City | 北九州市 | 492.00 | 1996.59 |
| B City | Hiroshima City | 広島市 | 906.68 | 1309.09 |
| C City | Nagoya City | 名古屋市 | 326.40 | 6907.65 |
| D City | Edogawa City | 江戸川区 | 49.90 | 13556.95 |
| E City | Saitama City | さいたま市 | 217.40 | 5764.00 |
| F City | Chiba City | 千葉市 | 271.77 | 3532.59 |

The basic information about the cities surveyed is shown in Table 3-1.

Several previous studies have revealed that, sociodemographic factors such as population, age, gender, education background, income public might affect the public awareness of recycling activities and, it might lead to the high or low quality and quantity of waste classification (Wang et al., 2020; Oribe-Garcia et al., 2015; Goduraa et al., 2012; Otoma et al., 2013). In this study, the sociodemographic influencing factors ensured a relatively detailed level within the scope that can be investigated. In parallel, many researchers have pointed out that the legal norms and regulations, collection infrastructures, collection frequency, clean appearance, and the visual design of the waste collection station will also affect the effective waste recycling (Iyer and Kashyap, 2007; Miafodzyeva, 2012; Timlett and Williams, 2009; Miafodzyeva and Brandt, 2013; Thomas and Sharp, 2013; Becker, 2014; Varotto and Spagnolli, 2017). In this regard, Jiang et al. found that various designs of PET bottle collection bins will perform different effects on sorted collection (Jiang et al., 2019).

In Japan, the information about the waste classification is very detailed on the homepage of cities. Besides, residents will receive detailed guidance about daily waste classification and disposal rules when moving to a new place or easily getting it from the city office. Moreover, with the popularity of smartphones, residents also widely use related applications to check the waste disposal rules and schedules. Although, in residential areas, every city follows the system of recycling once a week, in the guidance for the residences, except Nagoya and Saitama cities

not included “bottle crushing,” all of other cities’ requested four basic steps “cap removal,” “label removal,” “bottle washing,” “bottle crushing” for PET bottle disposal. In terms of collection methods, in Edogawa city and Chiba city, PET bottles are collected in a green or blue collection net which is located at each public waste collection site; transparent or translucent plastic bags such as shopping bags from the supermarket were used in Hiroshima city and Saitama city; in Kitakyushu city and Nagoya city, residents required to purchase designated collection bags with a unified price in the city. In addition, residents can also keep PET bottles in the collection facilities in the supermarkets or convenience stores. Generally, the quality of collected PET bottles in the supermarket is very high, even though it is the hardest part of the whole process (Dilixiati et al., 2023). However, due to the lack of supervision and people's lack of awareness of sorted disposal in convenience stores, the quality is far inferior to other recycling methods. According to the homepage of each city and the waste disposal guidance of the residents, the PET bottle disposal rules of 6 target cities were summarized, and the differences and the results caused by those differences were discussed in the next section.

### 3.2.2 Investigation of PET bottle sorting conditions

The on-site surveys on the PET bottle sorting quality were conducted at each city's main local waste sorting and recycling plant. In a self-reported survey, people's imaginative answers may not coincide with their actual actions (Baumeister et al., 2007; Wilson & Gilbert, 2003; Corral-Verdugo,1997). Consequently, an unrealistic result might be leaded. Timlett & Williams,

2008 also reported a gap between what people say and what they do (Timlett & Williams, 2008). Hence, to avoid the over or under-estimation of daily PET bottle recycling activity, the investigation was focused on the final destination of PET bottles collected by each municipality. According to the actual situation, collected PET bottles were treated differently before disposal despite clear disposal regulations.

The investigations were be in processed for 2 days in each target city, therefore, a total of 12 days of on-site investigation was conducted. A total of 54593 PET bottles were collected for the investigation. In the process of sampling, ensures sampling from as many collection bags as possible to confirm the representativeness of samples. In addition, according to the introduction of the person in charge of the site, during the research period and the specific time, transported PET bottles were collected from household waste collection station.

Table 3-2 16 sub-categories of PET bottle sorting actions

| No. | Cap | Label | Crush | Wash |
|---|---|---|---|---|
| 1 | × | × | × | × |
| 2 | × | × | × | O |
| 3 | × | × | O | × |
| 4 | × | × | O | O |
| 5 | × | O | × | × |
| 6 | × | O | × | O |
| 7 | × | O | O | × |
| 8 | × | O | O | O |
| 9 | O | × | × | × |
| 10 | O | × | × | O |
| 11 | O | × | O | × |
| 12 | O | × | O | O |
| 13 | O | O | × | × |
| 14 | O | O | × | O |
| 15 | O | O | O | × |
| 16 | O | O | O | O |

○ :Yes, × :No

Collected PET bottles were divided into 16 sorting sub-categories with consideration of all the situations. The 16 sub-categories are shown in Table 3-2.

## 3.3 Result and discussion

### 3.3.1 PET bottle processing conditions in 6 regions by 16 sub-categories

The investigation of PET bottle processing conditions in 6 regions by 16 sub-categories is shown in Figure 3-1. Different colors represent different sub-categories. For example, from the top (navy) to the bottom (red) of the bar chart, representing poor to the high-quality processing, navy represents the poorest quality while red represents the highest quality. A, B, C, D, E, and F represent six different regions, respectively.

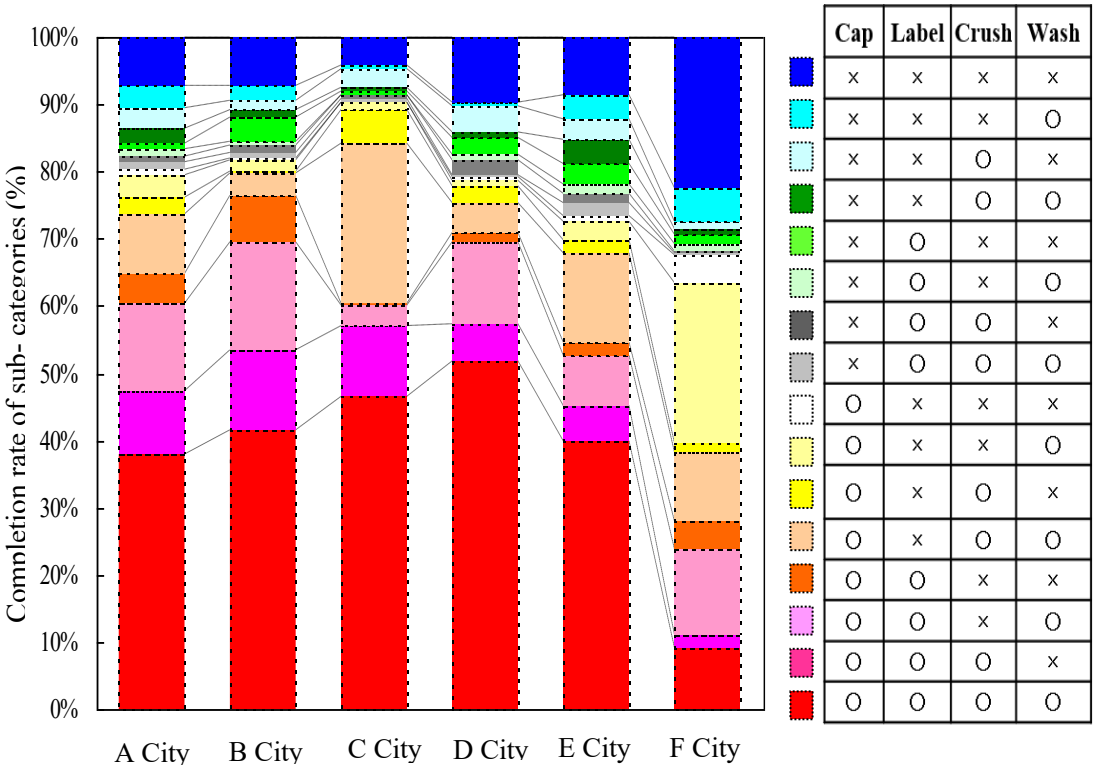



Figure 3-1 PET bottle processing condition in 6 regions by 16 sub categories

According to the Figure 3-1, 67% ~ 90.4% of PET bottles were with caps been removed, the average rate of “Cap removal” between municipalities was 78.8%; 30.8%~82.5% of PET bottles were with labels been removed, and the average rate of “Label removal” was 63.8%; in terms of “Bottle wash,” 63.4%~75.8% of bottles were washed, and the average rate was 70.6%; for “Bottle crush” were 25.2%~90.4%, the average rate between municipalities was 64.1%. Except for F city, the proportion of fully processed PET bottles (red) is 38%~ 52%. In F city, only 9% of PET bottles are fully processed. When the proportion of non-processed PET bottles (navy) was focused on, 7%~10% of PET bottles were disposed of without any treatment. However, in F city, 22% of PET bottles were not processed. PET bottles collected in F city showed relatively poor condition, especially in sub-categories including “Bottle crush”; in C city, the ratio of non-label removal was relatively higher than in other cities. In other cities, no significant differences were found.

### 3.3.2 Influence of sociodemographic factors and local collection rules on PET bottle sorting

The sociodemographic factors and local collection rules of 6 target cities were summarized in Table 3-3.

Some researchers believe that people’s waste recycling behavior is closely related to gender (Ekere et al., 2009), while Some studies reported that educational background and income are critical factors influencing waste recycling actions (Dong and Zeng, 2018). Wang

et al. highlighted that age is the most significant factor in people's environmental behavior (Wang et al., 2020). However, no noticeable relationship was found when those factors were compared with PET bottle sorting conditions in each city. In Japan, waste management has already been a "lifestyle" for people with different backgrounds, age groups, and gender. The publicity, education, and supervision of waste classification are also at an average level nationwide. Based on such characteristics of waste classification and recycling in Japan, the inconsistency with results of some previous research that no apparent correlation between the actual treatment condition and sociodemographic factors can be explained clearly. The quality of classified recycling, that is to say, the participation of residents might be affected by psychological factors of individuals, such as unwillingness which is highlighted in this research.

When PET bottle collection rules are focused on, all cities recycle once a week, except C city and E city; guidelines for classified recycling in other cities require four basic actions, cap removal, label removal, bottle washing, and bottle crushing. The major difference is the collection method. In A city and C city, residents need to purchase designated garbage bags for PET bottle disposal; In B city and E city, any transparent or translucent plastic bags can be used for PET bottle disposal; residents only need to separate recyclables by type, such as PET bottles, CAN, glass; in terms of D city and F city, PET bottles should be collected in designated collection net, located in public collection site after "pretreatment" with the above four steps. Moreover, the implementation time of PET bottle separated recycling is 1997 in A and D city,

2001 in B and F city, 2000 in C city, and 2002 in E city. Similarly, there is no direct and noticeable relationship with the actual recycling quality from the perspective of waste generation, recycling volume, recycling regulation or the implementation time of classified recycling.

In order to conduct a more comprehensive survey, in addition to the data collection and analysis mentioned above, the most commonly used information sources and the most intuitive information related to waste classification have also been investigated. In Japan, the differences in local policies as well as the unified guidance and business handling of citizens' household registration, medical treatment, education, life, and other aspects in each city office, make the office and the official website a life guide for residents to get to know the city more intimately and find answers to their problems. Questions often asked by residents can also be found on the official website of each city. In this part of the survey, it was found that when residents of F City asked about recyclable waste and their disposal methods, in the official answer, the treatment of PET bottles does not include label removal (See Figure 3-2). In Figure 3-1, it is not difficult to find that the sub-categories, including non-label removal, account for a large proportion.

Generally, residents use a simplified garbage classification table in daily recycling activities, except for the official garbage classification manual. When the classification table of each city with the PET bottle recycling quality was compared, the results show that, except for

C city, the classification tables of other cities are included all of the disposal steps. In the table of C city, the recycling rule of PET bottles does not include label removal and bottle crushing (See Figure 3-3). Similarly, in Figure 3-1, the sub-categories, non-label removal accounts for a large proportion. By contraries, the ratio of sub-categories included bottle crush was relatively small even though it was not required in the classification table might be caused by the extra charge for designated garbage bags. If residents can make PET bottles smaller, the more efficient a garbage bag will be.

Table 3-3 Sociodemographic factors and PET bottle collection rules of 6 target cities

| | Demographic characteristics | A City | B City | C City | D City | E City | F City |
|---|---|---|---|---|---|---|---|
| | Area (km²) | 492.00 | 906.68 | 326.40 | 49.90 | 217.40 | 271.77 |
| **Population** | Population | 982320 | 1186928 | 2254656 | 676492 | 1253093 | 960051 |
| | Population density (km²) | 1996.59 | 1309.09 | 6907.65 | 13556.95 | 5764.00 | 3532.59 |
| | Family | 419984 | 539446 | 1046457 | 319329 | 542971 | 429497 |
| | Live alone | 145276 | 209291 | 433574 | 125438 | 158956 | 140014 |
| | Male | 465091 | 574770 | 1118832 | 342284 | 622291 | 478707 |
| | Female | 517229 | 612158 | 1152548 | 334208 | 622593 | 481344 |
| **Non-Japanese** | Population | 11299 | 15902 | 72831 | 23298 | 17479 | 20356 |
| | (%) | 1.15% | 1.34% | 3.23% | 3.44% | 1.39% | 2.12% |
| **Age** | 0~9 (%) | 8.47% | 9.54% | 8.62% | 9.12% | 9.00% | 8.62% |
| | 10~19 (%) | 9.15% | 9.77% | 8.83% | 9.65% | 9.64% | 9.47% |
| | 20~29 (%) | 10.28% | 10.90% | 11.68% | 11.84% | 11.19% | 10.41% |
| | 30~39 (%) | 12.49% | 14.15% | 14.38% | 15.51% | 14.59% | 13.96% |
| | 40~49 (%) | 13.03% | 15.19% | 15.45% | 17.43% | 16.50% | 16.56% |
| | 50~59 (%) | 11.92% | 11.55% | 11.65% | 10.90% | 11.89% | 11.45% |
| | 60~69 (%) | 15.10% | 13.64% | 12.98% | 11.58% | 12.62% | 13.66% |
| | 70~79 (%) | 11.67% | 9.46% | 10.28% | 9.45% | 9.60% | 10.87% |
| | 80~89 (%) | 6.53% | 4.72% | 5.15% | 3.84% | 4.17% | 4.21% |
| | 90~99 (%) | 1.32% | 1.04% | 0.93% | 0.63% | 0.76% | 0.76% |
| | 100~ (%) | 0.05% | 0.04% | 0.03% | 0.02% | 0.03% | 0.03% |
| | Average age (all) | 46.50 | 43.71 | 44.60 | 42.38 | 42.87 | 44.30 |
| | Average age (Male) | 44.30 | 42.29 | 43.20 | 41.33 | 41.83 | 43.30 |
| | Average age (Female) | 48.40 | 45.05 | 45.90 | 43.95 | 43.91 | 45.40 |
| **Senior (over65)** | Population | 261235 | 235206 | 514025 | 132664 | 250019 | 216011 |
| | (%) | 26.59% | 22.74% | 22.80% | 19.61% | 19.95% | 22.50% |
| | Living alone | 60609 | 42600 | 119907 | 31388 | 37084 | 32186 |
| | (%) | 23.20% | 18.11% | 23.33% | 23.66% | 14.83% | 14.90% |
| | With dementia | 33000 | 30367 | 86000 | 18307.632 | 21700 | 21385 |
| | (%) | 12.63% | 11.25% | 16.73% | 13.80% | 8.68% | 9.90% |
| **Education** | High school to higher education (%) | 78.80% | 81.80% | 79.63% | 56.59% | 56.47% | 59.00% |
| | Middle school to higher education (%) | 98.21% | 98.59% | 98.09% | 97.67% | 99.02% | 98.96% |
| | Marriage | 5214 | 6718 | 13885 | 4133 | 6827 | 4749 |
| | (%) | 0.53% | 0.57% | 0.62% | 0.61% | 0.54% | 0.49% |
| | Divorce | 2073 | 2172 | 4430 | 1590 | 2060 | 1775 |
| | (%) | 0.21% | 0.18% | 0.20% | 0.24% | 0.16% | 0.18% |
| | Birth | 8072 | 8072 | 19492 | 6123 | 10860 | 7573 |
| | (%) | 0.82% | 0.68% | 0.86% | 0.91% | 0.87% | 0.79% |
| **Crime** | Number | 12372 | 10472 | 39350 | 8616 | 14643 | 14255 |
| | (%) | 1.26% | 0.88% | 1.75% | 1.27% | 1.17% | 1.48% |
| **Waste Generation and Recycling** | Generation (Per capita daily) (g) | 664 | 500 | 701 | 708 | 696 | 668 |
| | Amount of PET bottle recycling (t) | 1795 | 1896 | 7037 | 2616 | 3074 | 3133 |
| | Amount of PET bottle recycling(per capita)(t) | 0.0018 | 0.0016 | 0.0031 | 0.0039 | 0.0025 | 0.0033 |
| | Amount of recycling (t) | 116389 | 46413 | 202954 | 32895.507 | 96570 | 124140 |
| | Collection rules of PET bottle | ABCD_1/week_DP | ABCD_1/week_P | ABD_1/week_DP | ABCD_1/week_NET | ABD_1/week_P | ABCD_1/week_NET |
| | Implementation time of PET bottle separation (year) | 1997 | 2001 | 2000 | 1997 | 2002 | 2001 |

**P: Plastic bag DP: Designated Plastic bag NET: Waste collection net in public collection site**
**A: Cap removal B:Label removal C:Bottle washing D:Bottle crushing**




更新日：2013年8月7日

FAQのキーワード検索　検索

資源物（びん・缶・ペットボトル）とはどのようなものですか（分別）。

## Q 質問

資源物（びん・缶・ペットボトル）とはどのようなものですか（分別）。

## A 回答

【びん・缶・ペットボトルの主な品目と出し方】

<びん>
○飲食物のびん：ジュース、ジャム、コーヒー、ラムネなど
○調味料のびん：しょうゆ、ドレッシング、食用油など
○酒びん：ウイスキー、ワイン、日本酒など
（ビールびん、一升びんは購入店へ返却してください。引き取ってもらえるお店が近くにない場合は、資源物として出してください。）
○化粧品のびん(医薬品のびんは不燃ごみへ)
※マニキュアのびんは不燃ごみへ

<缶>
○飲食用の缶：ビール、ジュース、缶詰、お菓子の缶など
○食用油の缶
○ペットフードの缶
○ビンの金属製キャップ

<ペットボトル>
※ラベルや底に、ペットボトル材質表示マークがあるもののみ（マークは下記の関連リンクからご覧いただけます）
※裁断など加工されたペットボトルは可燃ごみへ
○飲料・酒類（ペットボトル素材のラムネ容器は不燃ごみへ）　○しょうゆ　○みりん・つゆ・酢　○ノンオイルドレッシング

■出し方
・中身は使い切り、水で軽く洗い流してください。

・アルミ缶・ペットボトルはできるだけつぶしてください。

・びん・ペットボトルのキャップは必ずはずして分別してください。
（キャップの素材により、金属製のキャップは青のコンテナ、プラスチック製は可燃ごみへ）

・種類毎に次の決められた容器へ出してください。（ビニール袋に入れたまま出さないでください）
無色のびん　⇒白のコンテナ
茶色のびん　⇒茶のコンテナ
その他のびん⇒黒のコンテナ
缶　⇒青のコンテナ
ペットボトル⇒専用のネット

千葉市役所コールセンター
WEB　お問い合わせフォームはこちら
電話　しやくしょ　043-245-4894
年中無休　午前8時30分～午後9時
土日休日・年末年始は午後5時まで
FAX　しやくしょ　043-248-4894
お問い合わせFAXフォーム（PDFファイル）

千葉市 CHIBA CITY
千葉市公式ホームページへ

Figure 3-2 Information about the waste recycling on Chiba City homepage

https://www.city.chiba.jp/faq/kankyo/junkan/shushugyomu/1063.html

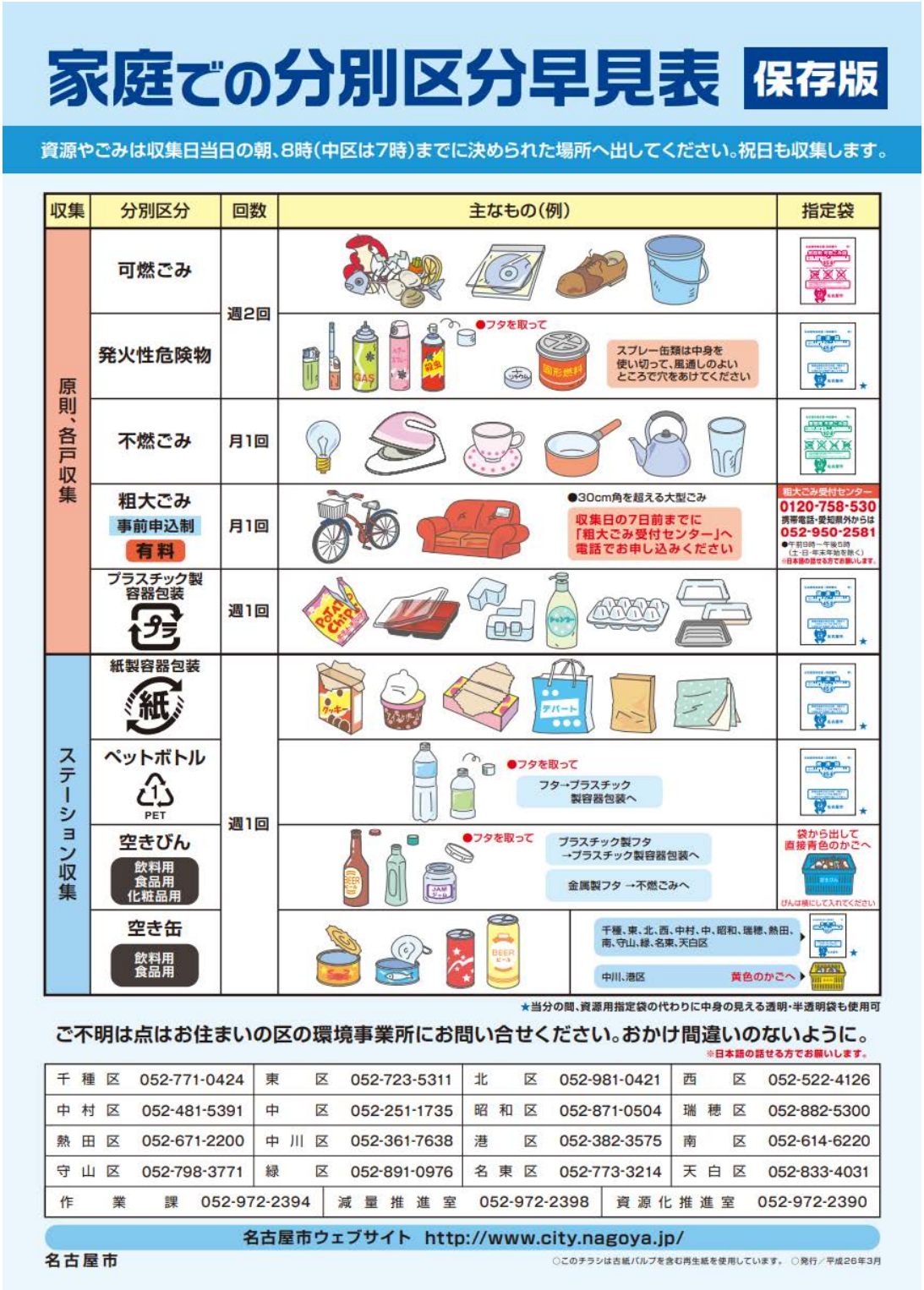



Figure 3-3 Waste recycling guideline of Nagoya City

## 3.4 Conclusion

It can be summarized that, no significant difference in the completion rate of the overall PET bottle sorting actions (except F city), might be determined by the relatively advanced waste sorting and recycling system in Japan. It is also a favorable result of constructing the circular society nationwide in recent years. Besides, in this survey the impact of the sociodemographic factors on PET bottle sorting actions can be ignored, it might also be related to the residents' relatively high participation to the recycling. However, differences between some local rules caused discrepancies in the completion rate of some specific PET bottle sorting processes. Loan et al. suggested that the system trust of residents in the local authority and the recycling scheme is a pivotal factor in participating in recycling (Loan et al. 2017). The influence of the information provided by the local authority is determined by the strong connection between the residents and the government (Jesson et al., 2014). Ando et al. reported that the impact of the subject norm on Japanese people was relatively substantial. Thus, if the information is officially provided by the local authority, people might follow it without doubt, even if it is incomplete. Being misled by such information might affect the quality of classification.

# Chapter 4 Correlation of transformed monetary unwillingness and the completion rate of PET bottle sorting actions

## 4.1 Background

As mentioned in previous sections, the quality of PET bottles collected in different recycling facilities has significant differences, even at the same collection point, such as trash bins in public places. In chapter 2, the unwillingness toward the PET bottle disposal process was monetarily transformed. The stronger unwillingness that people feel about some recycling actions seems to have a negative impact on people's completion of the recycling actions. Numbers of previous researches have discussed the influencing factors on people's willingness or intention to engage in environmental protection activities. Vencatasawmy et al. have reported that people's utilization of recycling stations was directly related to their attitude towards recycling activities (Vencatasawmy et al., 2000), while other researchers, for instance, Huang et al. and Sia et al. have demonstrated that the importance of environmental awareness and positive attitude on recycling behaviors (Huang et al., 2011; De Young, 1986; Nyamwange, 1996; Sia et al., 1985). Lange et al. suggested that perceived distance to the waste collection site was decisive for recycling behaviors (Lange et al., 2014). Fishbein and Ajzen discussed the individual's intention for behavior from the perspective of the subjective norm (Fishbein and Ajzen, 2009).

Why do participants of a PET bottle recycling system have such apparent differences in

overcoming strong unwillingness such as long-distance or complex recycling processes? Will the completion rate of PET bottle disposal actions decrease with the increased unwillingness people feel? In order to investigate the relationship between quantified unwillingness of PET bottle process and actual sorting condition, in this chapter, based on the result of the previous chapters (chapter 2 and chapter 3), further analysis was conducted. Moreover, a web-questionnaire survey and a multi-way-ANOVA test were carried out for the sake of understanding the public environmental awareness, daily environmental behavior, and the influence of the situational factor.

## 4.2 Methodology

### 4.2.1 Comparison of unwillingness and completion rate of PET bottle sorting

The willingness or unwillingness of people when they request to do some environmental actions such as waste recycling might determine their actual environmental behavior (Wang et al., 2011; Song et al., 2016). The strong unwillingness that people feel about a recycling action seems to have a negative impact on people's completion of that action. The more the unwillingness, the lower the completion rate? With this assumption, the investigation on the relationship between unwillingness of PET bottle disposal actions and the actual situation of PET bottle sorting conditions in 6 target cities was conducted.

### 4.2.2 Web questionnaire survey

Although there are explicit relevant provisions on waste classification and recycling, the expected effect may not be achieved due to inconvenient facilities, inadequate supervision, or other factors. Residents' awareness of environmental protection, social morality, and sense of responsibility will also be essential to complete waste classification voluntarily. As described by the Theory of Planned Behavior (TPB), attitude, subjective norm, and perceived behavioral control will affect environmental intention and determine people's environmental behavior (Ajzen, I., 1991). Moreover, perceived behavioral control has a direct impact on behavior. Thus, environmental protection actions are tightly bound to what people think, how they do, and external factors. A web questionnaire survey was conducted on environmental awareness or behavior for an all-inclusive investigation considering those three aspects. Respondents were only requested select "YES" or "No" for each question. A total of 630 questionnaires were collected with balanced genders and age groups from 20 s to 60 s at a 10-year age interval. Besides, a multi-way-ANOVA test is carried out for further analysis.

## 4.3 Result and discussion

### 4.3.1 Relationship between unwillingness and completion rate of PET bottle sorting

Valuated unwillingness of PET bottle disposal actions and corresponding completion rates were comparatively analyzed. The more the unwillingness, the lower the completion rate? The answer is “NO.”

According to our previous research, the valuated unwillingness of “Cap removal” showed the lowest at only 1.8 JPY. It shows that “Cap removal” is the most effortless action for the respondents. Whether in terms of the material difference for bottle body and cap and convenience for completing subsequent actions, it is the most basic classified recycling action. In this comparative analysis, when “Cap removal” was focused on, the results are shown in Figure 4-1 (A), (B). When “Cap is not removed,” the assumption holds that the completion rate decreases with increasing unwillingness (See Figure 4-1 (A)); however, when “Cap is removed,” the completion rate increases with increasing unwillingness (See Figure 4-1 (B)). That is to say, for recycle-conscious respondents who are willing to remove the cap when they dispose of PET bottles, the completion rate of other subsequent actions will continue to rise. Furthermore, for non-recycle-conscious respondents who do not feel even willing to remove a cap, the completion rate of other more complex actions will continue to decrease. “Cap removal” is like a psychological trigger to recycle-conscious respondents to complete other processes, therefore

achieving a higher recycling quality.

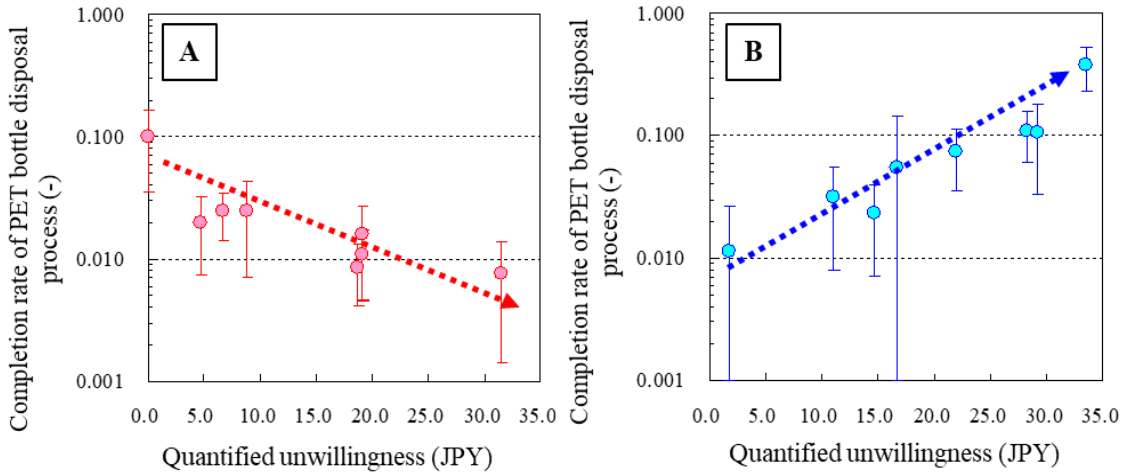



Figure 4-1 Relationship between unwillingness and completion rate of PET bottle sorting (A: Cap is NOT removed, B: Cap is removed)

### 4.3.2 Multi-Way-ANOVA analysis of web questionnaire

As mentioned in the previous section, the web questionnaire survey considered "what do people think about the recycling," "what do people do for recycling," and "external influencing factors." According to the previous finding, respondents can be divided into cap-removers and non-cap-removers two categories by their selection to cap removal (yes or no). A multi-way-ANOVA analysis was carried out to detect the environmental awareness of both cap-removers and non-cap-removers as well as the difference of the environmental awareness. In the analysis "I always remove the cap when disposing of PET bottle" was set as Q0. The relationship of answer of Q0 and the answer of other questions are reported in Table 4-1 and the data is visualized by Figure 4-2.

Table 4-1 Multi-Way-ANOVA analysis of web questionnaire

| | Questions | Method | Answer | Cap removal | Cap removal | Ratio 1 | Ratio 2 | differences of means | F ratio | P value | *: P<0.05 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Q1 | I remember the disposal rules | Tukey | Y | CapY | CapN | 0.119681 | 0.079646 | 0.040035 | 6.182558 | 0.101607 | |
| | | | N | CapY | CapN | 0.005319 | 0.045354 | 0.040035 | 6.182558 | 0.101607 | |
| Q2 | The sorted disposal of PET bottles bothers me | Tukey | Y | CapY | CapN | 0.02176 | 0.028761 | 0.007001 | 1.169102 | 0.450464 | |
| | | | N | CapY | CapN | 0.10324 | 0.096239 | 0.007001 | 1.169102 | 0.450464 | |
| Q3 | Taking out garbage thrown incorrectly into PET bottle collection bins bothers me | Tukey | Y | CapY | CapN | 0.030706 | 0.04646 | 0.015754 | 1.381015 | 0.398975 | |
| | | | N | CapY | CapN | 0.094294 | 0.07854 | 0.015754 | 1.381015 | 0.398975 | |
| Q4 | There is no problem throwing plastic trays and PET bottles together | Tukey | Y | CapY | CapN | 0.019826 | 0.033186 | 0.01336 | 0.726061 | 0.600198 | |
| | | | N | CapY | CapN | 0.105174 | 0.091814 | 0.01336 | 0.726061 | 0.600198 | |
| Q5 | There is no problem throwing plastic bags and PET bottles together | Tukey | Y | CapY | CapN | 0.019826 | 0.034292 | 0.014466 | 0.807559 | 0.56752 | |
| | | | N | CapY | CapN | 0.105174 | 0.090708 | 0.014466 | 0.807559 | 0.56752 | |
| Q6 | I always peel off the label when dispose of PET bottles | Tukey | Y | CapY | CapN | 0.10735 | 0.014381 | 0.09297 | 3.585122 | 0.173096 | |
| | | | N | CapY | CapN | 0.01765 | 0.110619 | 0.09297 | 3.585122 | 0.173096 | |
| Q7 | I always wash the bottles when dispose of PET bottles | Tukey | Y | CapY | CapN | 0.112186 | 0.035398 | 0.076787 | 4.149902 | 0.15042 | |
| | | | N | CapY | CapN | 0.012814 | 0.089602 | 0.076787 | 4.149902 | 0.15042 | |
| Q8 | I always crush the bottles when dispose of PET bottles | Tukey | Y | CapY | CapN | 0.053433 | 0.016593 | 0.03684 | 1.779705 | 0.325889 | |
| | | | N | CapY | CapN | 0.071567 | 0.108407 | 0.03684 | 1.779705 | 0.325889 | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Q9 | I separated PET bottles and other plastics | Tukey | Y | CapY | CapN | 0.101064 | 0.045354 | 0.05571 | 10.32003 | 0.059424 | |
| | | | N | CapY | CapN | 0.023936 | 0.079646 | 0.05571 | 10.32003 | 0.059424 | |
| Q10 | If other garbage is incorrectly thrown into the PET bottle collection bins, I take it out | Tukey | Y | CapY | CapN | 0.090426 | 0.043142 | 0.047284 | 2.278558 | 0.263259 | |
| | | | N | CapY | CapN | 0.034574 | 0.081858 | 0.047284 | 2.278558 | 0.263259 | |
| Q11 | The garbage classification table and manual are hard to understand | Tukey | Y | CapY | CapN | 0.038201 | 0.049779 | 0.011578 | 24.84516 | 0.03731 | * |
| | | | N | CapY | CapN | 0.086799 | 0.075221 | 0.011578 | 24.84516 | 0.03731 | * |
| Q12 | The municipality I am living is separated collects PET bottles | Tukey | Y | CapY | CapN | 0.104207 | 0.065265 | 0.038941 | 58.76413 | 0.037235 | * |
| | | | N | CapY | CapN | 0.020793 | 0.059735 | 0.038941 | 58.76413 | 0.037235 | * |
| Q13 | I want more space for PET bottle collection bins | Tukey | Y | CapY | CapN | 0.037959 | 0.033186 | 0.004774 | 2.603226 | 0.233454 | |
| | | | N | CapY | CapN | 0.087041 | 0.091814 | 0.004774 | 2.603226 | 0.233454 | |
| Q14 | PET bottle collection bin is set up in a convenient place | Tukey | Y | CapY | CapN | 0.094536 | 0.063053 | 0.031483 | 12.7661 | 0.04816 | * |
| | | | N | CapY | CapN | 0.030464 | 0.061947 | 0.031483 | 12.7661 | 0.04816 | * |
| Q15 | PET bottle collection bin is set up in an inconvenient place | Tukey | Y | CapY | CapN | 0.01765 | 0.018805 | 0.001155 | 0.103845 | 0.934126 | |
| | | | N | CapY | CapN | 0.10735 | 0.106195 | 0.001155 | 0.103845 | 0.934126 | |

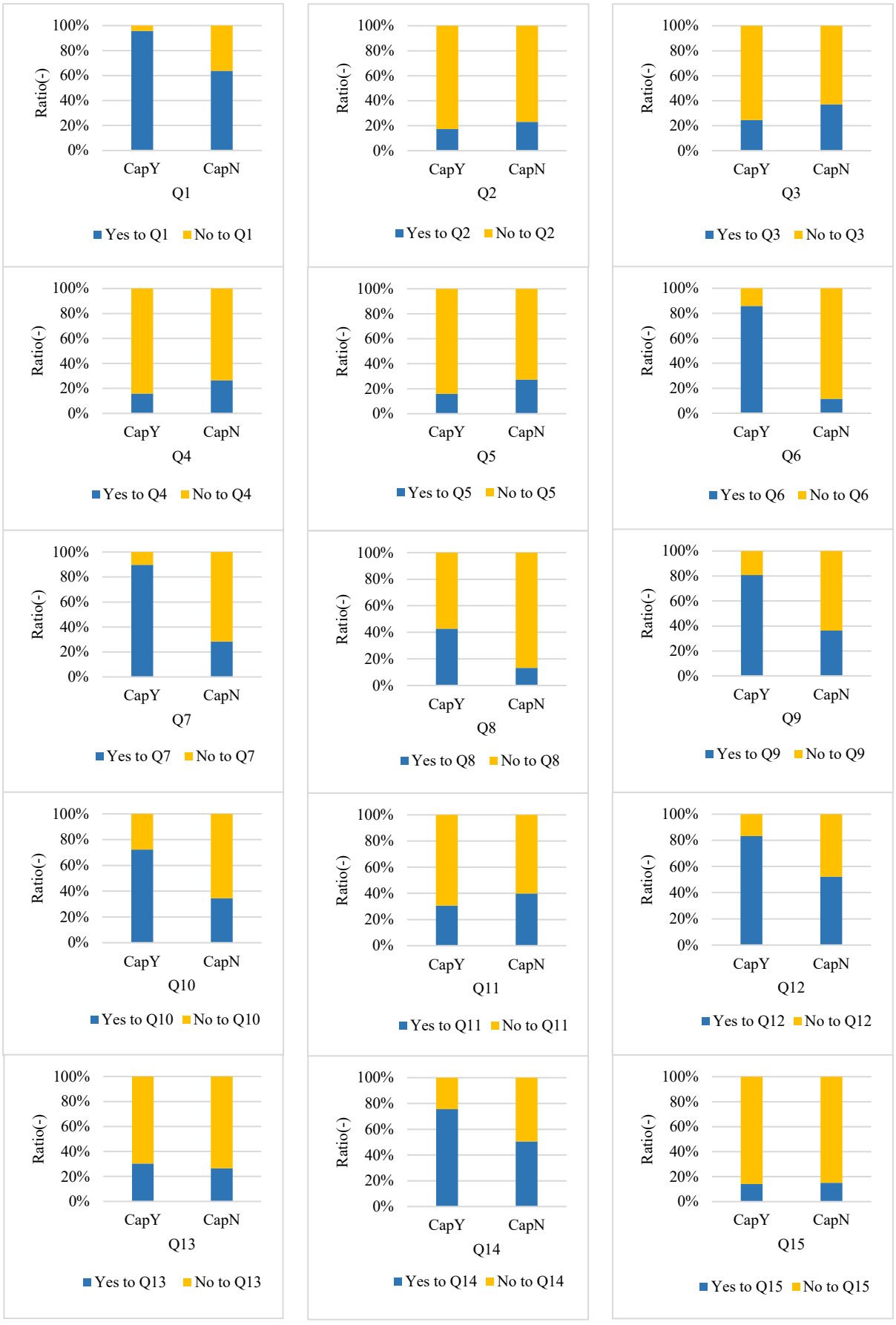



Figure 4-2 Multi-way-ANOVA analysis of web questionnaire

There were significant differences between cap-removers and non-cap-removers were found for some actions. For instance, for Q1 “I remember the disposal rules”, the “YES” answer of cap-removers is significantly higher than the answer of non-cap-removers, it illustrating that cap-removers know disposal rules more than non-cap-removers. Most cap-removers tend to say “YES” to Q1, which might explain that remembering disposal rules play a great role in their environmental behavior. For environmental behavior, remembering might be the most basic condition for realizing it habitually. As TPB described, in the performance of behaviors, perceived behavior control is a crucial subjective factor (Ajzen, 1991). Remembering the disposal rules might have a positive effect on people’s perceived behavior control, so that easier to realize it. For Q6 “I always peel off the label when disposing of PET bottles” and Q7 “I always wash the bottles when disposing of PET bottle”, when the “YES” answers are compared, cap-removers’ is notably higher than non-cap-removers’. It might suggest that cap-removers are easier to complete other subsequence recycling actions consciously, in other words, non-cap-removers might need more encouragement, stimulation, or supervision to complete the recycling of PET bottles. Q9 “I separated PET bottles and other plastics” and Q10 “If other garbage id incorrectly thrown into the PET bottle collection bins, I take it out” might explain why other contaminants always mixed with PET bottles while Q12 “The municipality I am living is separated collects PET bottles” and Q14 “PET bottle collection bins are set up in a convenient place” explains the effect of situational factors such as local disposal rules and

location of collection facilities on the recycling behavior.

For some questions, such as Q2 “The sorted disposal of PET bottles bothers me,” Q3 “Taking out garbage thrown incorrectly into PET bottle collection bins bothers me,” Q4 “There is no problem throwing plastic trays and PET bottles together,” Q5 “There is no problem throwing plastic bags and PET bottles together,” Q11“The garbage classification table and manual are hard to understand,” Q13 “I want more space for PET bottle collection bins,” the difference of cap-removers and non-cap-removers is not significant, for both types of participants, the ratios of “YES” answer are noticeably lower than “NO” answers. It might indicate that the aspects mentioned in the above questions have only a negative impact on the environmental protection behavior of a few people, but most participants are able to overcome their unwillingness to those aspects caused. However, for all the questions, the answers to cap-removers are relatively ideal, in a word, cap-removers have relatively strong environmental awareness.

People's attitude towards environmental protection will not only urge them to perform the required environmental protection actions but also make those actions their habits. Finally, people can adhere to environmental protection behavior intentionally or naturally. Besides, People's environmental protection behavior is also related to collection facilities, effective environmental education, and publicity; meanwhile, the classified recycling system will also motivate them to complete the required recycling processes. It can also be justified by the

interaction of attitude, subjective norm, and perceived behavioral control in the TPB model, and their impact on the intention to behave (Ajzen, 1991; Wilma et al., 2018).

## 4.4 Conclusion

The valuated unwillingness of "cap removal" (1.8 JPY) divided respondents into recycle-conscious and non-recycle-conscious. For recycle-conscious respondents, their completion rate of recycling actions is increased with the unwillingness, while non-recycle-conscious respondents do the opposite. The differences in the trend of completion rate might suggest that, in a comprehensive recycling system, both types of participants need to be considered. Moreover, according to the multi-way-ANOVA analysis, a clear difference was found between cap-removers and non-cap-removers in their environmental awareness. Cap-removers know disposal rules more than non-removers; cap-removers are more willing to complete other recycling activities. It might indicate that cap-removers are more environmentally conscious and easier to comply with environmental policies, therefore, their completion rate of PET bottle sorting actions increase with the unwillingness increase. Non-cap-removers might need additional stimulation and a monitoring system to correct disposal.

In addition, external factors, such as the classification manual, locations of collection bins, and municipalities also support PET bottle-sorted collecting behavior. The result is harmonious with the basic concept of TPB; pro-environmental behavior is determined by a combination of subjective and objective factors. Although it is ideal to realize everyone's active participation

in a waste recycling system, the “ingenious combination” of psychological barriers, environmental education, and appropriate encouragement might be an effective strategy to improve the overall recycling quality. Therefore, in the next chapter, some improvement strategies for the PET bottle recycling system from different aspects will be suggested.

# Chapter 5 Suggestions for improving the PET bottle collection system by "participants screening"

## 5.1 Age and gender distribution of the participants

This study screened participants in the survey into recycle-conscious respondents (82% of all respondents) and non-recycle-conscious respondents (18% of all respondents) by valuated unwillingness (1.8JPY) to "cap removal," which is the most basic action in the PET bottle recycling process. When age distribution and gender of non-recycle-conscious respondents were investigated, the interesting finding is that the younger generation (20–39-year-old) counted for 56% of all non-recycle-conscious respondents. The proportion of males in non-recycle-conscious respondents was 72%, much higher than that of females, 28%. Conversely, recycle-conscious respondents evenly across the age spectrum, the proportion of males and females in recycle-conscious respondents were 45% and 55%, respectively (See Figure 5-1).

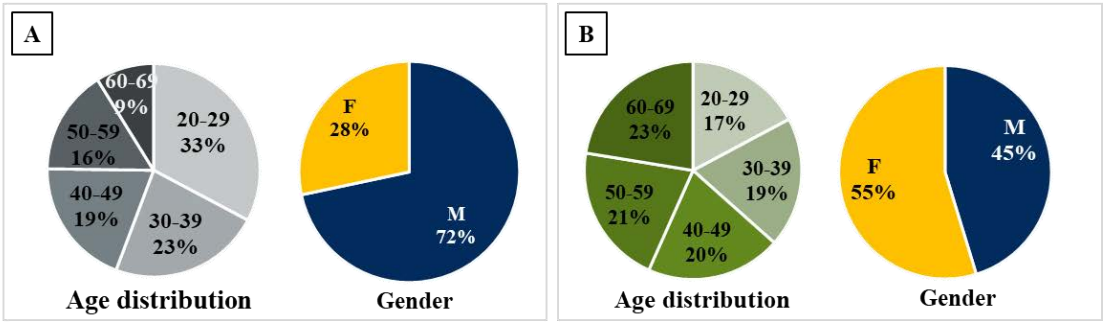



Figure 5-1 Age and gender distribution (A: Cap-removers, B: Non-cap-removers)

## 5.2 Common recycling promotion strategies in past studies

Dilixiati et al. reported that proper implementation of the psychological barrier might have a positive effect on recycling quality (Dilixiati et al., 2023). In particular, people have more vital environmental awareness, they can overcome such a solid barrier to complete the complicated recycling process. How to promote recycling and improve people's participation in environmental protection is a topic all over the world. Especially in recent years, with a continuous increase in marine plastic waste, maximizing the 3R (reduce, recycle, reuse) has become one of the biggest challenges. There have been many studies on this topic, several studies on recycling promotion strategies are listed in Table 5-1, common recycling promotion strategies including prompts and information, feedback, commitment, incentives, environmental alternation and, social modeling.

## 5.3 Main reasons and structure of the promotion strategy

Although Japan is famous for recycling, in the process of studying the waste management system in Japan, several factors that might affect high-quality recycling were found, some examples will be given in the relevant content. Above all, the present study evidently reflects that some people's attitudes towards environmental protection and daily environmental protection actions still need to be improved：

In the previous chapter, a multi-way-ANOVA analysis was carried out to investigate the

difference in environmental awareness of cap-removers and non-cap-removers as well as the relationship between the recycling action of “cap removing” and other actions. For Q1 “I remember the disposal rules” the “YES” answer of “cap-removers” is significantly higher than non-cap-removers, Besides, for Q6 “I always peel off the label when disposing of PET bottles” Q7 “I always wash the bottles when disposing of PET bottles” Q8 “I always crush the bottles when disposing of PET bottles” Q9 “I separated PET bottles and other plastics” Q10 “If other garbage is incorrectly thrown into the PET bottle collection bins, I take it out”, cap-removers are more inclined to say “YES”, especially for Q6 and Q7, the difference is remarkable, it might imply that, existing PET bottle disposal rules and information about waste classification are easier for cap-removers to remember and follow in daily life (See Figure5-2). In addition, it can be clearly seen that cap-removers are more willing to complete other PET bottle disposal actions, such as peeling off the label, washing the bottle, and crushing the bottle. Therefore, the present research believes that for cap-removers who have a relatively ideal attitude towards PET bottle recycling, more complete and accurate information is enough to enable them to achieve correct recycling, thus, the improvement of the recycling guidelines might be a necessary step. The lower ratio of “YES” answers of non-cap-removers might indicate that their recycling awareness is relatively low, in other words, it might be difficult for such low recycling awareness to overcome the botheration caused by PET bottle disposal actions and complete correct recycling consciously, for this reason, the present study suggests that non-cap-removers

might need additional stimulation such as economic stimulus and monitoring system to encourage and correctly guide their recycling activities.


Figure 5-2 Main reasons of the promotion strategy

Previous research indicated that the role of recycling facilities in the recycling system is crucial (Lin, Wang, Li, Gordon, and Harder, 2015, Jiang et al., 2019). For Q12 "The municipality I am living is separated collects PET bottles," and Q14 "PET bottle collection bins are set up in a convenient place", similarly, cap-removers still tend to say "YES", which means that, they affirmed the recycling system and the convenience of recycling. It is also reflecting the positive effect of external factors such as a comprehensive separated collection system, location, and convenience of disposal facilities on recycling behavior. thus, the result further suggests that the improvement of the recycling facilities might have a non-neglectable role in high-quality recycling (See Figure 5-3).

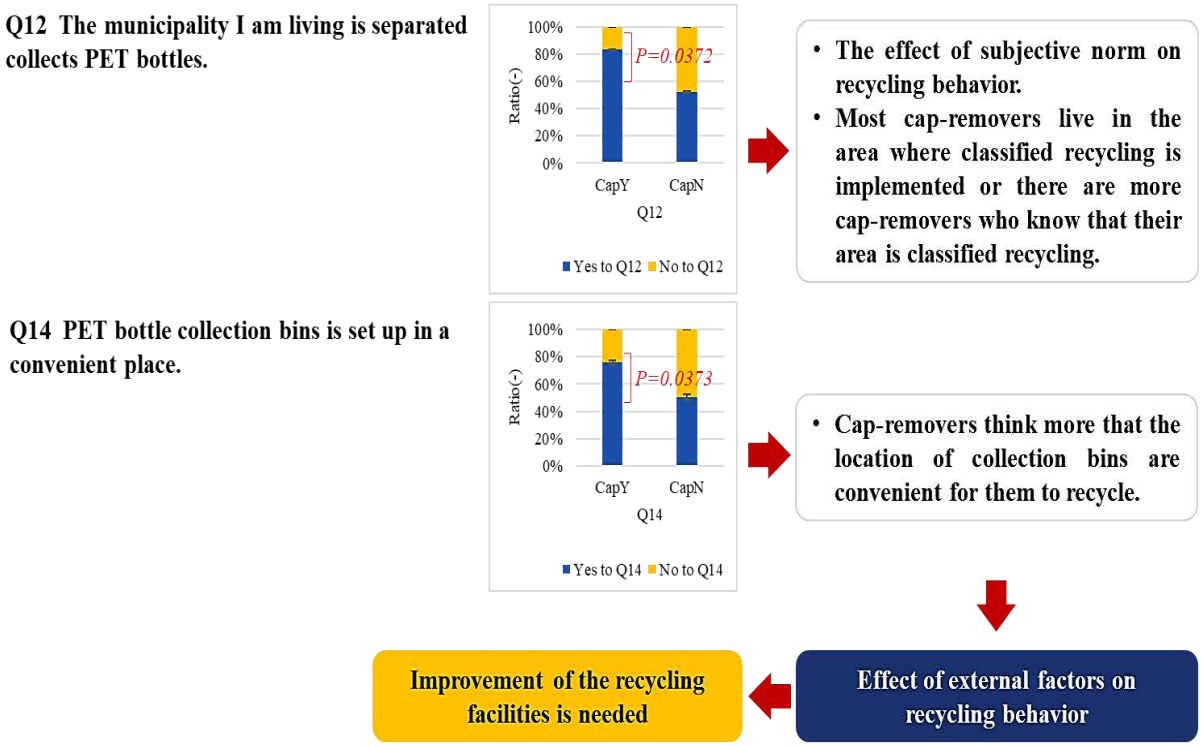



Figure 5-3 Effect of recycling facilities on recycling behavior

According to the findings of the present study, combined with the conclusions of previous researchers, moreover, based on the Japanese waste classification system and the current situation of classification, this study puts forward several initial suggestions, that considered both recycle-conscious and non-recycle-conscious groups, for the promotion of PET bottle sorting in Japan. The main structure of the promotion strategy is shown in Figure 5-4. It is a "Participant screening" approach to improving the PET bottle collection system which is the combination of the promotion strategies of information, incentives, environmental alternation, and feedback Detailed explanation will be given in the following content.

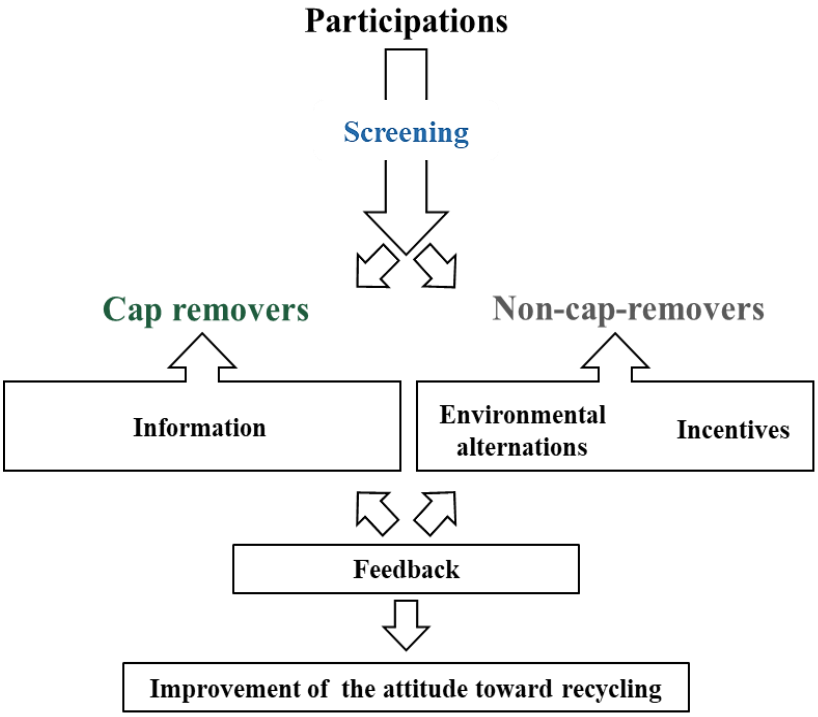



Figure 5-4 Structure of the promotion strategy

Table 5-1 List of prior studies on recycling promotion strategies

| Type | References |
|---|---|
| **Prompts and information** | Everet, Jacobs,&Pierce,1991; Miranda Carreno &Blanco Suarez 2010; Mee, 2005; White, MacDonnell,& Dahl, 2011; Guyer et al., 2009; Dupre et al., 2014, Smeesters, Warlop,Cornelissen, & Abeele, 2003; Timlett, & Williams, 2009; Refsgaard & Magnussen, 2009; McKenzie-Mohr, 2013 |
| **Feedback** | Abrahamse and Steg, 2013; Froehlich, Findlater, & Landay, 2010; Boulay, Metcalfe, Barr, and Shaw, 2014; Dupre et al., 2014; De Young et al., 1995; Perrin & Barton, 2001; Schultz, 1999; Timlett & Williams, 2008 |
| **Commitment** | Cialdini, 1988; Wang & Katzev, 1990; Wang and Katzev,1990; Dupre, 2014; Werner et al., 1995 |
| **Incentives** | Diamond &Loewy, 1991; Harder & Woodard, 2007; Burn, 1991; Schultz et al., 1995; Iyer and Kashyap 2007; Boonrod et al., 2015, Zhang and Wen, 2014; Zhou et al., 2020; Morawski et al., 2016 |
| **Environmental alternation** | Phillips, 2011; Willman, 2015; Lin, Wang, Li, Gordon and Harder, 2015, Jiang et al., 2019 |
| **Social modeling** | Moreland and Melsop, 2014; . Lin et al., 2015; Maddox, Doran, Williams, and Kus, 2011 |

## 5.4 Introduction of each component of the strategy

### 5.4.1 Information

Information in written form is an effective way for a larger number of people to access information (Carreno and Suarez, 2010). The signs or posters describing recycling and its benefits might have a significant impact on correct disposal (Goldenhar & Connell, 1991; Schultz, 2011). In the process of investigating the garbage classification and recycling guidelines of various cities, it is found that these guidelines clearly explain the classification rules but lack of some text or illustrated descriptions about why to recycle and how to treat and reuse after recycling. Lack of information is one of the most crucial factors in residents' cooperation in a recycling program (McKenzie-Mohr, 2013). If people realize the benefit and positive impacts of their personal environmental actions, it might help them to participate more actively (Alexander et al., 2009; Smeesters et al., 2003). Besides, according to the finding of this research (Section 3.2.2), the incorrect or incomplete information might mislead people's recycling behaviors.

As describe above, information is the key factor in guiding and educating people's environmental behavior in a waste treatment system. Although there are still many details to be further improved, the information on environmental protection and recycling provided by each municipality in Japan is comparatively comprehensive; most people are relatively active and habitually involved. Consequently, garbage classification and recycling in Japan might be a

model in many other countries worldwide. Nevertheless, in such a typical recycling society, there are still a large group of people that do not complete environmental protection actions as required. Moreover, it is an arduous task to capture non-recycle-conscious residents and provide targeted environmental information. Therefore, the present research suggests that an improvement of the existing environmental information, mainly targeting recycle-conscious people, is needed to guide them correctly. Although the completeness of information might also positively impact non-recycle-conscious, it seems that they need more psychological stimulation to actively participate in the correct recycling from the perspective of the current system and its recycling quality; measures from other aspects might have more substantial effects.

### 5.4.2 Environmental alternation

In most areas, traditional PET bottle collection facilities are used in Japan. For instance, plastic bags or collecting nets in 6 target cities surveyed in this study. However, developed countries like Germany, Australia, and Sweden have widely used intelligent recycling bins for recyclable waste (Zhou et al., 2020). Especially for PET bottles, cans, and bins, these recycling bins also have the functions of automatic identification and crushing, which also brings great convenience to the transportation after recycling. Besides, the corresponding amount of money will be returned to users for different recyclables in these deposit-refund systems. Although some supermarkets in Japan have begun to use intelligent recycling bins, the penetration is not

high. It is only limited to the specific recycling areas of these supermarkets.

In this research, the younger generation counted a higher proportion of non-recycle-conscious Participants (56% of all non-recycle-conscious respondents) (See Figure 5-1). Since the young generation has a relatively high acceptance of new high-tech products, it may improve recovery efficiency if such intelligent collection bins are widely used. Meanwhile, it can also administer the recycling actions of non-recycle-conscious users. Moreover, an intelligent recycling system will not only bring convenience and supervision to classified recycling but also help to improve the environment around the recycling facilities.

### 5.4.3 Incentives

Monetary rewards, point rewards, gifts, prizes, coupons, and discount vouchers are common forms of incentives (Varotto and Spagnolli, 2017). Song et al. indicated that monetary incentives might improve people's enthusiasm for waste recycling (Song et al., 2019). In Japan, the very first known point card started in 1916, and since 1985, it has rapidly spread to the electrical industry, banks, hotels, shopping malls, and other industries (Keisho Komoto, 2007). With the development of electronic payment, “point card” has become an essential part of Japanese life in recent years. Whether transportation cards, membership cards of supermarkets and convenience stores, or mobile companies, people are used to getting corresponding returns for their consumption as points, and finally use the saved points to circularly consume or exchange some products. In mainly, it is more common among younger generations. Such

economic incentives might stimulate both recycle-conscious and non-recycle-conscious groups. In particular, for the latter, it might be one of the most direct ways to benefit from environmental actions. Although economic incentives might not fundamentally change people's attitude toward waste separation, for non-recycle-conscious participants, using this strategy to inspire their enthusiasm to recycle correctly, thereby achieving a higher recycling quality, is an effective process to improve the overall quality of environmental protection. Assuming that, the "point refund system" is combined with the intelligent recycling bins mentioned above, it might be more suitable for Japan's current waste recycling system.

### 5.4.4 Feedback

Feedback is an affirmation of the environmental activities of participants in a waste classification system. It can be for groups or individuals. Abrahamse and Steg, highlighted that the effect of personal feedback is often better than that of a group (Abrahamse and Steg, 2013). whether positive or negative feedback, it may enable people to feel their environmental actions are being “supervised.” Undoubtedly, positive feedback can be a psychological motivator to encourage people’s pro-environmental intentions (Froehlich et al., 2010). In the traditional recycling method, it might not easy to give participants proper feedback on recycling behavior. Especially in some residential areas in Japan, people often receive warnings about their incorrect classification, besides, disposed garbage might be returned instead of collecting by local staff. On the contrary, it is unrealistic to give positive feedback on the correct classification

based on the current infrastructure. It may lead to feedback not playing its full role in the whole system.

Feedback might take many forms. With the rapid popularization of digitalization and intelligence, faster and intuitive feedback is no longer challenging to provide. Moreland and Melsop, provided corresponding feedback on social media in research about the waste separation in a university residence hall (Moreland and Melsop, 2014). Varotto and Spagnolli, also reported that feedback based on the computer system could be an effective way to track recycling activities and send the feedback to mobile devices (Varotto and Spagnolli, 2017). Besides, some researchers also determined that feedback seems more practical when received repeatedly (Nomura et al., 2011). Therefore, if "smart" feedback, which is a more advanced form in intelligent recycling system, for example, users will be praised for their correct recycling or upgraded to the corresponding level when their recycling reaches a certain amount or, users will be prompted for incorrect recycling, it might have a non-neglectable positive effect on people's recycling behavior. It might be the recognition of correct recycling and motivation to continue their good habits.

## 5.5 Conclusion

To improve people's recycling behavior, the strategy includes various factors that might be ideal (Varotto and Spagnolli, 2017). Based on the characteristics of both recycle-conscious

and non-recycle-conscious participant; prior studies on the improvement strategies of recycling; current situation in Japan and the result of multi-way-ANOVA analysis, improvement strategy of PET bottle disposal was indicated. For recycle-conscious participants, comprehensive information might be the key to ensuring that they are adequately guided and maintain good recycling behavior. For non-recycle-conscious people, additional stimulation such as economic incentives such as “point refund system” and the intelligent recycling bins with monitoring system might have a positive effect to improve their environmental attitude. Indeed, these improvement measures might also further enhance the enthusiasm of recycle-conscious participants. Encouraging feedback to individuals might be essential for a recycling system, and it might be easier to achieve in intelligent recycling system. If a PET bottle recycling system can comprehensively consider different types of people, that is to say, enable to use of rules to limit while implementing encouragement, it might achieve the ultimate goal of everyone-correct-recycling.

# Chapter 6 Conclusion

## 6.1 Overall conclusion

This thesis aims to quantify the unwillingness toward PET bottle recycling actions by a new contingent valuation method based on pairwise comparison and analyze the correlation between unwillingness and actual PET bottle sorting conditions. In addition, according to the characteristics of the current recycling system and the result of the present study, put forwards the improvement strategies for PET bottle recycling. According to the conclusion of previous Chapters, all results and discussions in this study have been summarized as follows.

Chapter 1 briefly introduced the current situation and future trends of global waste management, particularly the management of municipal solid waste (MSW). Then introduced the history of waste management in Japan, the classification methods, and MSW. In addition, the types of recyclable waste in Japan and the reasons for making PET bottles as an example are also introduced. Besides, the significance of social psychology and theory of behavior study as well as web questionnaire survey in environmental-related research was given. Finally, the research object of this thesis and the related papers published by the author were mentioned.

In Chapter 2, a new method was suggested to evaluate the unwillingness people perceive when they perform actions for PET bottle recycling. The new method was applied to the eight

single and multiple actions (two, three, and four recycling actions are required simultaneously). The new method consists of two stages; quantification of unwillingness by pairwise comparison method and monetary transformation of unwillingness based on outsourcing costs (market prices to outsource reference actions). In the unwillingness calculation of single actions, "Cap removal" receives the weakest unwillingness (0.319 to 8.19 JPN yen). In contrast, the strongest unwillingness toward "disposal in the supermarket" (17.9 to 358 JPN yen) explains the consistently high-quality PET bottles collected in the supermarket. Strong unwillingness might allow only recycle-conscious people to bring PET bottles to supermarkets. "Understanding the rule of correct waste disposal" also receives relatively strong unwillingness. It probably explains other waste contamination in PET bottles. The result of unwillingness toward multiple actions indicated that unwillingness shows higher to recycling actions when they include situational factors such as distance, time consumption, or complexity. Besides, comparing the unwillingness of multiple actions required to complete simultaneously and separately further confirmed the psychological botheration caused by complex environmental protection actions. The difference in performances of participants in a recycling system might be explained by the Theory of Planned Behavior (TPB) (Ajzen, 1991). In the same recycling system, the subjective norm, a social norm, is fair to every participant, but not everyone can overcome the strong unwillingness caused by recycling rules. People's recycling behavior is also determined by attitude and perceived behavioral control. Thus, for some participants, the possibility of

overcoming strong unwillingness to complete the recycling activities as requested is higher. The new method might be able to separate the participants of a recycling system by their ability to overcome the unwillingness. Further analysis was continually carried out in chapter 4.

Moreover, the result of quantified unwillingness using the new method was compared to the willingness-to-pay (WTP) method. Good agreement was found for actions like “bottle washing” between the new and WTP methods. On the other hand, the new method valuated the unwillingness toward “understanding waste disposal rule,” “disposal at waste collection site,” and “disposal in the supermarket” higher than the WTP method. It suggests that the new method might quantify both recognizable and unrecognizable unwillingness. Furthermore since, in the new method, the respondent did not go through a process of directly converting actions into amounts, which reduced the biased results caused by the characteristics of the questionnaire.

In Chapter 3, the actual PET bottle sorting conditions in six targeted cities in Japan by on-site investigations. No significant difference in the completion rate of the overall PET bottle sorting actions (except F city). Besides, the impact of sociodemographic factors was not significant. It might be determined by the relatively advanced waste sorting and recycling system in Japan. However, there were some differences found caused by differences in local classification rules or provided information. Ando et al. reported that the impact of the subject norm on Japanese people was relatively more substantial (Ando et al., 2010). Thus, if the information is officially provided by the local authority, people might follow it without doubt,

even if it is incomplete. Being misled by such information might affect the quality of classification.

In Chapter 4, the results of Chapter 2 and Chapter 3, the unwillingness toward PET bottle recycling actions, and the actual completion rate of PET bottle sorting were compared, and a correlation was found. It was assumed that the more unwillingness, the lower the completion rate. However, the finding of this Chapter was unexpectedly interesting. The valuated unwillingness of "cap removal" (1.8 JPY) divides respondents into recycle-conscious and non-recycle-conscious. For recycle-conscious respondents, their completion rate of recycling actions is increased with the unwillingness, while for non-recycle-conscious respondents, the completion rate is decreased with the increase of unwillingness. According to the multi-way-ANOVA analysis of the Web questionnaire survey, significant correlations were found between "cap removal" and other pro-environmental activities. Besides, a noticeable difference was found between cap-removers and non-cap-removers in their environmental awareness. Cap-removers know disposal rules more than non-removers; cap-removers are more willing to complete other recycling activities. It might indicate that cap-removers are more environmentally conscious and easier to comply with environmental policies. Non-cap-removers might need additional stimulation and a monitoring system to correct disposal. In terms of external factors, for instance the classification manual, locations of collection bins, and municipalities also support PET bottle-sorted collecting behavior. The result is harmonious with

the basic concept of TPB; pro-environmental behavior is determined by a combination of subjective and objective factors. Although it is too ideal to realize everyone's active participation in a waste recycling system but, if a recycling system could comprehensively consider different types of users and combine the proper psychological barrier with psychological stimulation, the recycling efficiency might be further improved.

Chapter 5 suggests several suggestions for improving the PET bottle collection system by "participants screening." Based on the result of previous chapters, the participants of this study can be divided into recycle-conscious and non-recycle-conscious groups; it is called a "participants screening" approach. Some prior studies on recycling promotion strategies were reviewed. Based on the findings of previous researchers, the promotions strategies could be considered from different aspects, such as prompts and information, feedback, commitment, incentives, environmental alternations, and social modeling. According to the current situation of the PET bottle recycling system in Japan and the conclusion of previous chapters, this study suggested a strategy that combined the improvement in information, feedback, incentives, and environmental alternations. In more detail, for the recycle-conscious participants, the improvement of information might necessary while the incentives and environmental alternations for the non-recycle-conscious. It is suggested that recycle-conscious participants could be correctly guided by comprehensive information. For non-recycle-conscious participants, it might be necessary to implement the intelligent recycling bins with monitoring

functions, which might be the “smart” supervision of recycling actions, bring convenience to the transportation as well as improve the environment around the recycling facilities. In addition, the economic incentive is considered one of the most effective strategies (Song et al., 2019). According to the popularity of point cards in Japan, this study suggested that intelligent recycling bins, including a “point refund system,” might be suitable for the Japanese recycling system. It might be a combination of supervision, convenience, and economic incentives for non-recycle-conscious users. Another important point for both recycling-conscious and non-recycling conscious people might be a positive feedback system which might easier to achieve in the intelligent recycling system. It might encourage correct recycling behavior, ensure that the performer of recycling behaviors receive corresponding psychological stimulation, so as to ensure the long-term sustainability of correct recycling behaviors.

In conclusion, this study suggested a new contingent valuation method to quantify the unwillingness toward the PET bottle disposal process. In addition, according to the quantified unwillingness and situation of PET bottle sorting condition, the participants of this study were screened and further analyzed. Moreover, the improvement strategies were put forward accordingly to different types of participants. It is suggested that, if a recycling system enables to use of rules to limit while implementing encouragement, it might achieve the ultimate goal of everyone-correct-recycling.

## 6.2 Limitations and recommendations

This study includes some limitations that should be addressed. Although the new method quantified unwillingness using Thurstone's model (Gaussian normal distribution between unwillingness gap and selection ratio), the other models like the logit model might be more appropriate. In addition, Thurstone's model is likely too simple to predict respondents' decisions driven by unwillingness. Figure 2-6 shows partial disagreement between model predictions and measurements. In this sense, Scheffe's method using a multi-grade Likert scale is recommended rather than Thurstone's and other uni-variate models (Scheffé, 1952; Inoue, 2012). Further statistical analysis like the significance test of unwillingness gaps is possible. In addition, it is also possible to valuate individual unwillingness. Individual unwillingness is very helpful in analyzing the impact of personal characteristics on unwillingness and recycling behaviors.

Monetary transformation of unwillingness should also need further researches, in particular finding an appropriate calibration curve between unwillingness degree and outsourcing costs (see Figure 2-5). This study divided the reference actions to 3 groups, in order to maximize the linearity between unwillingness and outsourcing cost. If time permits, more detailed divisions might lead to more accurate results. Although this study tested single logarithmic regression, a multi-regression analysis might be better because outsourcing costs are controlled by not only unwillingness but also internal/external economic factors like

demand curve, costs, competitors, marketing objects, and others (Cant et al., 2016).

In addition, the reference actions should be carefully selected regarding reasonable outsourcing costs. As described in section 2.2.2, the reference actions of B8, C2, and D6 were not used for the monetary transform of unwillingness. In particular, “Cook a strawberry cake (D6)” had greatly higher outsourcing costs (>3000 JPN yen) than expected costs by the calibration curves. Large variations in strawberry prices might have caused this gap. Owing to the price volatility of agricultural products (Zheng et al., 2008), reference actions, including the high cost of agricultural products, might need careful screening. Although given values (volume, area, or time) of some reference actions (e.g., A2) in Table 2-1 aimed to support the questionees to perceive unwillingness toward performing the actions easily, they might have affected the questionee’s choice in pairwise comparison but were not optimized in this study. Finally, the dependency of reference actions on public lifestyle, Japanese culture, and social properties should be noted. The list of appropriate reference actions likely depends on socio-cultural properties and geo-environmental localities. In this research, all questionnaires were conducted in Japan, where waste recycles is already accepted as one of the prior social challenges.

The investigation of plastic bottle sorting conditions was mainly concentrated in 6 target cities, and if the investigation could be conducted in more places, more all-inclusive results might be obtained. Besides, one of the recycling actions, “bottle washing,” might include biased results caused by visual judgment. In present research, participants are divided into recycle-

conscious and non-recycle-conscious according to “cap-removal” only and explained by environmental awareness. Through further research, participants in the recycling system might be grouped in more detail. Besides, a more appropriate grouping basis will be found. Why the completion rate of cap-removers increases with the increase of unwillingness? This study discusses the relationship between unwillingness and completion rate from the perspective of environmental awareness, without doubt, it can also be discussed in a broader scope, therefore, further research might be needed form different possibilities.

The suggestions for promoting PET bottle sorting are still in the initial stage; a more comprehensive investigation and impact estimation is needed. Furthermore, the new method needs validity checks in terms of its applicability to regions/areas where waste recycling is at the early stage of social implementation.

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## Supplementary materials

Table S1. Average outsourcing costs of and unwillingness scores toward the reference actions

| Item | Reference action | Outsourcing cost (JPN yen) | Unwillingness Score (-) | Correlation Group* |
|---|---|---|---|---|
| A1 | Wash two set of chopsticks | 23.6 (±26.1, N=10) | 0.000 | U |
| A2 | Boil water using a kettle (1.5 L) | 4.39 (±1.19, N=10) | 0.171 | M |
| A3 | Cook four rice balls (onigiri) | 331 (±31.3, N=10) | 1.191 | U |
| A4 | Cook noodle sauce for two persons | 145 (±83.4, N=10) | 0.922 | U |
| A5 | Boil two cups of rice using a rice cooker | 343 (±172, N=10) | 0.901 | U |
| A6 | Fix a flat tire of a bicycle | 1101 (±240, N=10) | 2.388 | M / L |
| A7 | Wash and iron two cuter shirts | 241 (±47.1, N=8) | 2.085 | L |
| A8 | Wash a car manually | 1889 (±648, N=7) | 2.293 | U |
| B1 | Wash two cups | 10.0 (±31.3, N=10) | 0.693 | M |
| B2 | Clean up the floor using a broom (about 19 $m^2$) | 19.9 (±1.57, N=10) | 1.303 | L |
| B3 | Cook curry and rice for two persons | 203 (±183, N=10) | 1.698 | M |
| B4 | Boil pasta for two persons | 271 (±126, N=10) | 1.276 | U |
| B5 | Shred cabbage for two persons' salad | 78.1 (±7.84, N=9) | 1.408 | M |
| B6 | Sharpen a kitchen knife | 389 (±286, N=10) | 1.536 | U |
| B7 | Walk to next train station (20 min) | 158 (±31.1, N=41) | 1.791 | M / L |
| B8 | Clean filters inside an air conditioner | - | 1.793 | - |
| C1 | Wash two dishes | 25.3 (±13.5, N=10) | 0.707 | M |
| C2 | Go up to the third floor by upstairs | - | 1.182 | - |
| C3 | Refill shampoo into a container | 125 (±300, N=10) | 0.960 | U |
| C4 | Cook roasted barley tea (1.5 L) | 167 (±55.1, N=10) | 0.950 | U |
| C5 | Sweep the floor with a dustcloth (about 19 $m^2$) | 131 (±89.0, N=10) | 1.587 | M |
| C6 | Grill two fishes | 147 (±24.0, N=6) | 1.585 | M |
| C7 | Cook fried chickens for two persons | 173 (±9.83, N=6) | 1.782 | M |
| C8 | Repair a hole in a sock | 475 (±266, N=10) | 1.829 | U |
| D1 | Take a shopping bag | 1.00 (±1.10, N=6) | 0.518 | L |
| D2 | Call a friend using a land-line phone | 4.00 (±0, N=1) | 0.967 | L |
| D3 | Drip a cup of coffee | 50.3 (±18.5, N=10) | 1.119 | M |
| D4 | Cook miso soup for two persons | 40.4 (±62.3, N=10) | 1.454 | L |
| D5 | Wash two cups of rice | 30.3 (±15.8, N=10) | 1.159 | M |
| D6 | Cook a strawberry cake | - | 2.223 | - |
| D7 | Hang out ten T-shirts | 51.2 (±1.48, N=10) | 1.611 | L |
| D8 | Weed a yard (30 min) | 376 (±176, N=6) | 2.166 | M / L |

* U: Upper correlation curve, M: Middle correlation curve, L: Lower correlation curve

Table S2. Selection reasons and survey methods of the reference actions

| Item | Reference action | Selection reason | Survey method of outsourcing cost |
|---|---|---|---|
| A1 | Wash two set of chopsticks | Repeated use of privately-owned chopsticks and single-use disposable chopsticks are common in Japan | ➢ Cost difference between privately-owned and single-use disposable chopsticks<br>➢ One-year use (1 set of privately-owned chopsticks and 365 single-use disposable chopsticks)<br>➢ Price source: Amazon Japan® web site |
| A2 | Boil water using a kettle (1.5 L) | Frequent opportunities to use boiled water (e.g. tea, coffee, instant noodle) | ➢ 8.5-year use of an electric kettle<br>➢ 14 times use of an electric kettle in a week<br>➢ 30-min to boil water<br>➢ Including electricity consumption cost<br>➢ Price source: Amazon Japan® web site |
| A3 | Cook four rice balls (onigiri) | Rice balls are popular item in convenience stores | ➢ Cost difference between privately cooked rice balls and ready-cooked rice balls<br>➢ 8.5-year use of a rice cooker<br>➢ 1 time use of a rice cooker in a day<br>➢ 43-min to cook rice<br>➢ Rice ball weight: 100 g/piece<br>➢ Including electricity consumption cost<br>➢ Price source: Amazon Japan® web site |
| A4 | Cook noodle sauce for two persons | Frequent opportunities to eat Japanese traditional noodles (Soba, udon, somen) | ➢ Cost difference between privately cooked sauce and bottled sauce<br>➢ 100 ml-sauce for one person<br>➢ Recipe (1200 ml sauce): Giant kelp: 10 g, Dried bonito: 3 g, Soy sauce : 200 ml, Sweet rice wine: 200 ml, Water: 800 ml<br>➢ Sauce recipe source: Cookpad® web site<br>➢ Price source: Amazon Japan® web site |
| A5 | Boil two cups of rice using a rice cooker | Frequent opportunities to eat rice | ➢ Cost difference between privately cooked rice and ready-cooked rice<br>➢ 8.5-year use of a rice cooker<br>➢ 1 time use of a rice cooker in a day<br>➢ 43-min to cook rice<br>➢ 340 g for one-cup of rice<br>➢ Price source: Amazon Japan® web site |
| A6 | Fix a flat tire of a bicycle | Limited but at least once opportunities of a flat tire when riding a bicycle | ➢ Price source: On-site survey of bicycle retailors in Japan |
| A7 | Wash and iron two cuter shirts | Frequent opportunities to wash and iron cuter shirts | ➢ Price source: On-site survey of dry cleaners or laundries in Japan |
| A8 | Wash a car manually | Moderate opportunities to wash a private car | ➢ Price source: On-site survey of car washing machines in gas stations in Japan |

| | | | |
|---|---|---|---|
| B1 | Wash two cups | Repeated use of privately-owned cups and single-use disposable cups are common in Japan | ➢ Cost difference between privately-owned and single-use disposable cups<br>➢ One-year use (1 set of privately-owned cups and 365 single-use disposable cups)<br>➢ Price source: Amazon Japan® web site |
| B2 | Clean up the floor using a broom (about 19 $m^2$) | Frequent opportunities to clean the floor | ➢ 9.5-year use of a vacuum sweeper<br>➢ 2.87 times use of a vacuum sweeper in a week<br>➢ 19.9-min to clean the floor<br>➢ Average floor area of one room<br>➢ Including electricity consumption cost<br>➢ Price source: Amazon Japan® web site |
| B3 | Cook curry and rice for two persons | Moderate opportunities to eat curry and rice | ➢ Cost difference between privately cooked curry/rice and packed curry/rice<br>➢ 202.5 g-curry for one person<br>➢ Recipe (one person): Potato: 17.9 g, Carrot: 4.52 g, Onion : 62.7 g, Beaf: 8.69 g, curry sauce: 202.5 g<br>➢ Curry recipe source: Cookpad® web site<br>➢ Price source: On-site survey of supermarkets in Japan |
| B4 | Boil pasta for two persons | Moderate opportunities to eat pasta | ➢ Cost difference between privately cooked pasta and ready-cooked pasta<br>➢ Packed sauce is used<br>➢ Price source: On-site survey of supermarkets in Japan |
| B5 | Shred cabbage for two persons' salad | Frequent opportunities to eat shred cabbage | ➢ 126.7 g cabbage for two persons<br>➢ Price source: On-site survey of supermarkets in Japan |
| B6 | Sharpen a kitchen knife | Limited but at least once opportunities of knife sharpening | ➢ Cost difference between private sharpening and sharpening service<br>➢ 4 time use of a private sharpener<br>➢ Price source: Amazon Japan® web site (sharpener) and online survey of sharpening service in Japan |
| B7 | Walk to next train station (20 min) | Frequent opportunities to use public train/subway | ➢ Acceptable walk time: 20 min<br>➢ Price source: Online survey of train/subway ticket in Japan |
| B8 | Clean filters inside an air conditioner | Moderate opportunity to clean air conditioner filter | ➢ Price source: Online survey of filter cleaning service in Japan |
| C1 | Wash two dishes | Repeated use of privately-owned dishes and single-use disposable dishes are common in Japan | ➢ Cost difference between privately-owned and single-use disposable dishes<br>➢ One-year use (1 privately-owned dish and 365 single-use disposable dishes)<br>➢ Price source: Amazon Japan® web site<br>➢ |

| | | | |
|---|---|---|---|
| C2 | Go up to the third floor by upstairs | Frequent opportunities to go up the floor when living in condominium building | (Not calculated) |
| C3 | Refill shampoo into a container | Moderate opportunities to buy a new bottle shampoo | ➢ Cost difference between packed shampoo for refill and a new bottle shampoo<br>➢ Price source: Amazon Japan® web site |
| C4 | Cook roasted barley tea (1.5 L) | Frequent opportunities to drink roasted barley tea | ➢ Cost difference between privately cooked tea and bottled tea<br>➢ Price source: Amazon Japan® web site |
| C5 | Sweep the floor with a dustcloth (about 19 $m^2$) | Frequent opportunities to clean the floor | ➢ 1.21-time cleaning using dustcloth in a week<br>➢ Dustcloth consumption: 3 pieces in a month<br>➢ Average floor area of one room<br>➢ Price source: Amazon Japan® web site |
| C6 | Grill two fishes | Moderate opportunities to cook fishes | ➢ Cost difference between privately cooked fishes and ready-cooked fishes<br>➢ 80 g for one fish<br>➢ Price source: On-site survey of supermarkets in Japan |
| C7 | Cook fried chickens for two persons | Moderate opportunities to cook chickens | ➢ Cost difference between privately cooked chickens and ready-cooked chickens<br>➢ 200 g chicken for one person<br>➢ Price source: On-site survey of supermarkets in Japan |
| C8 | Repair a hole in a sock | Moderate opportunities of hole generation in a sock | ➢ Cost of new sock<br>➢ Negligible cost of privately repairment of a sock<br>➢ Price source: Amazon Japan® web site |
| D1 | Take a shopping bag | Frequent opportunities to use a shopping bag (Social implementation of plastic bag charge in Japan) | ➢ Cost difference between a privately-owned shopping bag and shopping bag charge<br>➢ 365 times use of a owned shopping bag<br>➢ Price source: Amazon Japan® web site |
| D2 | Call a friend using a land-line phone | Limited but at least once opportunities to use a land-line phone | ➢ Call time: < 5 min<br>➢ Price source: NTT company |
| D3 | Drip a cup of coffee | Frequent opportunities to drink coffee | ➢ Cost difference between privately cooked coffee and bottled coffee<br>➢ 200 ml for a cup of coffee<br>➢ Price source: Amazon Japan® web site<br>➢ |

| | | | |
|---|---|---|---|
| D4 | Cook miso soup for two persons | Frequent opportunities to cook miso soup<br>(Traditional soup in Japan) | ➢ Cost difference between privately cooked miso soup and instant miso soup<br>➢ Recipe (2 persons): Miso: 25 g, Tofu (soybean curd): 100 g,<br>➢ Soup recipe source: Cookpad® web site<br>➢ Price source: On-site survey of supermarkets in Japan and Amazon Japan® web site |
| D5 | Wash two cups of rice | Frequent opportunities to cook rice<br>(Normal rice is necessary to be washed before cooking) | ➢ Cost difference between normal rice and ready-washed rice<br>➢ 150 g for one cup of rice<br>➢ Price source: Amazon Japan® web site |
| D6 | Cook a strawberry cake | Moderate opportunities to eat a cake<br>(Birthday event, etc) | ➢ Cost difference between privately cooked cake and ready-cooked cake<br>➢ High dependency of strawberry costs to the total cost<br>➢ Price source: On-site survey of cake shops in Japan |
| D7 | Hang out ten T-shirts | Frequent opportunities to dry T-shirts after washing | ➢ 10.5-year use of a drying machine<br>➢ 3 times use in a week<br>➢ 130-min to dry T-shirts<br>➢ 150 g of one T-shit<br>➢ Including electricity consumption cost<br>➢ Price source: Amazon Japan® web site |
| D8 | Weed a yard (30 min) | Moderate opportunities to clean the yard when living in a house with private yard | ➢ Weeding efficiency: 10 min/$m^2$<br>➢ Average yard area: 6.61 $m^2$<br>➢ Price source: Online survey of yard cleaning service in Japan |

Table S3. BID for DBDCCV questionnaire, answer data, and mean WTP (Unit: JPN yen)

| PET bottle recycling action | BID | BIDU | BIDL | Answer data (N=400) | | | | Weibull parameter | | Mean WTP |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Yes/Yes | Yes/No | No/Yes | No/No | Location | Scale | |
| [X1] Understanding disposal rule | 6 | 11 | 2 | 28 | 26 | 46 | 300 | -2.78 | 5.04 | 6.40 |
| | 11 | 101 | 6 | 11 | 17 | 26 | 346 | | | |
| | 101 | 201 | 11 | 7 | 4 | 17 | 372 | | | |
| [X2] Cap removal | 6 | 11 | 2 | 18 | 13 | 35 | 334 | -2.78 | 5.04 | 4.74 |
| | 11 | 101 | 6 | 9 | 9 | 13 | 369 | | | |
| | 101 | 201 | 11 | 6 | 3 | 9 | 382 | | | |
| [X3] Label removal | 6 | 11 | 2 | 23 | 29 | 49 | 299 | -0.916 | 3.71 | 5.57 |
| | 11 | 101 | 6 | 11 | 12 | 29 | 348 | | | |
| | 101 | 201 | 11 | 5 | 6 | 12 | 377 | | | |
| [X4] Bottle washing | 6 | 11 | 2 | 32 | 31 | 57 | 280 | -0.314 | 3.37 | 6.53 |
| | 11 | 101 | 6 | 10 | 22 | 31 | 337 | | | |
| | 101 | 201 | 11 | 7 | 3 | 22 | 368 | | | |
| [X5] Bottle crushing | 6 | 11 | 2 | 30 | 28 | 52 | 290 | -0.666 | 3.71 | 6.67 |
| | 11 | 101 | 6 | 12 | 18 | 28 | 342 | | | |
| | 101 | 201 | 11 | 6 | 6 | 18 | 370 | | | |
| [X5] Keeping bottles until disposal day | 6 | 11 | 2 | 35 | 28 | 49 | 288 | -0.478 | 3.62 | 7.11 |
| | 11 | 101 | 6 | 11 | 24 | 28 | 337 | | | |
| | 101 | 201 | 11 | 6 | 5 | 24 | 365 | | | |
| [X6] Bringing PET bottles to waste collection site near the house and dispose of them | 6 | 11 | 2 | 63 | 52 | 68 | 217 | 0.929 | 3.26 | 14.8 |
| | 11 | 101 | 6 | 29 | 34 | 52 | 285 | | | |
| | 101 | 201 | 11 | 14 | 15 | 34 | 337 | | | |
| [X7] Bringing PET bottles to a collection box in a supermarket and dispose of them | 6 | 11 | 2 | 57 | 38 | 83 | 222 | 0.662 | 3.33 | 13.0 |
| | 11 | 101 | 6 | 25 | 32 | 38 | 305 | | | |
| | 101 | 201 | 11 | 13 | 12 | 32 | 343 | | | |