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# Behavioral barrier-based framework for selecting intervention measures toward sustainable plastic use and disposal

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ABSTRACT

There is an urgent need to implement sustainable plastic use and disposal to prevent further negative consequences. As it involves human behavior, intervention measures that induce individual human behavioral changes are essential. While studies and good practices are rapidly increasing in this regard, there is no guarantee that good practices in one area will work equally well in other areas. Therefore, policymakers require appropriate guidance to choose suitable intervention measures for their context. This study proposes a behavioral barrier-based framework (BBBF) to aid policymakers in selecting context-appropriate intervention measures. The BBBF is built on the assumption that certain barriers prevent people from making desirable behavioral changes. The BBBF can help policymakers choose suitable intervention measures for lowering the barriers that inhibit desirable sustainable plastic use and disposal-related behaviors. The framework includes a generic list of barriers derived from possible intervention measures that integrate market-based, regulatory, and behavioral approaches to expedite the identification of critical barriers and corresponding intervention measures. Local stakeholders are involved in the whole process to reflect contextuality and elicit context-specific intervention measures, desirable behavioral measures, and their barriers. A BBBF application was developed and tested in Kyoto City, Japan. This application involved 1000 residents, two focus groups, 14 businesses, and three city officials connected to the issue. Fifteen intervention measures and three barrier types to induce sixteen desirable behavioral changes for achieving Kyoto City's four established policy targets were identified. All barriers were categorized per behavioral approach. The feasibility of the proposed intervention measures was assessed by stakeholders.

## 1. Introduction

Plastic production has increased since the inception of mass production in the 1950s and has resulted in over 8300 million metric tons of virgin plastics and over 6300 million metric tons of plastic waste globally (Geyer et al., 2017). The negative impact of plastic waste permeated global social-ecological systems deeply and irreversibly (Persson et al., 2022; Villarrubia-Gómez et al., 2018). Plastic debris has harmed marine species through entanglement, ingestion, chemical contamination, and smothering (Derraik, 2002; Kühn et al., 2015; Wilcox et al., 2016). Additionally, plastic debris can function as a substratum for pathogenic micro-organisms and parasites (Vethaak and Leslie, 2016). The plastic problem is irreversible because macro plastic eventually breaks down into microplastic and nanoplastic particles, which are difficult to clear due to their small size and ubiquity (Hohn et al., 2020; Lebreton et al., 2019; Uehara, 2020). Thus, there is an undeniable need to address the plastic waste problem.

Though there is a growing body of research that reveals the negative impact of plastic on human health, such as disrupting endocrine signaling (Landrigan et al., 2020), further research on this topic is warranted. Even if we can prevent plastic waste from entering the ocean using good waste management practices, the production and incineration of plastic have a significant effect on the global atmospheric carbon budget (Hohn et al., 2020).

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Studies on the economic impacts of plastic and plastic waste include a comprehensive analysis of the natural capital valuation (UNEP, 2014), reduction of ecosystem services (Beaumont et al., 2007), social costs of marine litter measured by willingness to pay and volunteering to clean it up (Brouwer et al., 2017), and economic costs of addressing marine plastic problems (Cordier and Uehara, 2019).

There has been an increasing number of modeling and simulation analyses of long-term changes in plastic pollution (Borrelle et al., 2020; Chenillat et al., 2021; Cordier et al., 2021; Cordier and Uehara, 2019; Geyer et al., 2017; Hohn et al., 2020; Lau et al., 2020; van Wijnen et al., 2019); however, only two common outcomes have been noted. First, all business-as-usual scenarios project an increase in plastic waste. Second, reducing the amount of accumulated plastic waste requires significant effort, including a systemic change in plastic production (Lau et al., 2020), transformation of the global plastic economy (Borrelle et al., 2020), or a combination of solutions (Hohn et al., 2020; Lau et al., 2020). Furthermore, as studies claim that technological solutions are insufficient, implementing non-technological measures, such as changing people's behavior, has become urgent (Cordier et al., 2021; Cordier and Uehara, 2019).

Two primary phenomena cause unsustainable plastic use and waste problems: overproduction and overuse of plastic and inadequate management of plastic waste (e.g., littering and failure to sort plastic waste for recycling). The social-ecological negative impacts of plastic use and waste indicate that the production and consumption of plastic are in an undesirable state (Villarrubia-Gómez et al., 2018). Inadequate plastic waste management is a primary cause of marine plastic pollution (Jambeck et al., 2015; Lebreton et al., 2017).

### 1.1. Intervention measures for behavioral changes

The problems caused by plastics can be considered a conventional economic problem (e.g., externalities, misaligned incentives, information asymmetries), behavioral problem outside the scope of conventional economic problems (e.g., internalities, bounded rationality, bounded willpower, and bounded selfishness), or their combination (Carlsson et al., 2019; Kahneman, 2003; Loewenstein and Chater, 2017; Mullainathan and Thaler, 2015; Thaler and Sunstein, 2008). An example of a conventional economic problem is overproduction; that is, a type of market failure referred to as negative externalities (Sterner et al., 2019). If the social-ecological cost of plastic use and disposal is not fully reflected in the market prices of plastic, the production and consumption of plastic exceed an optimal level. The price signals that govern producers' and consumers' behavior send the wrong message. An example of a behavioral problem is failure to sort garbage, indicative of inadequate internalization of social norms into people's decision-making (Akbulut-Yuksel and Boulatoff, 2021; Czajkowski et al., 2019).

Table 1 presents a comprehensive list of intervention measures, which could change individuals' behavior. The list was compiled based on previous studies by Alpizar et al. (2020), House of Lords (2011), ICF (2018), Lehner et al. (2016), Organization for Economic Co-operation and Development (2017a), Sterner et al. (2019), Sterner and Coria (2011), and World Bank (1997). While the first two types of measures are drawn from conventional economics (Sterner and Coria, 2011), behavioral measures are gathered from various disciplines, including neuroscience, psychology, sociology, and behavioral economics (House of Lords, 2011). Market-based measures include price-based (Pigouvian) and rights-based (Coasian) measures. Price-based measures exert control over price signals, which lead to the internalization of negative environmental externalities such as climate change induced by economic activities (World Bank, 1997). While price-based measures control price signals by using existing markets (e.g., taxation on gasoline), right-based measures directly control quantities, such as those of pollutants (e.g., carbon dioxide emissions), by creating a trading market for pollution allowances (Tietenberg, 2005). Regulatory measures change people's behaviors by eliminating or restricting their choices (House of Lords, 2011).

**Table 1**
Types and examples of intervention measures to change individuals' behavior.

| Types of measures | Examples |
|---|---|
| Market-based | Taxes, fees, or charges |
| | Deposit-refund schemes |
| | Subsidies |
| Regulatory | Bans |
| | Standards |
| | Permits (non-tradable) |
| | Mandatory rules |
| Behavioral | Simplification and framing information |
| | Changes to the physical environment |
| | Changes to the default policy |
| | Use of social norms and salience |
| | Use of feedback mechanisms |
| | Goal setting and commitment devices |
| | Persuasion Non-monetary incentives and disincentives |

Although behavioral measures are often limited to nudging, the behavioral measures presented in Table 1 include other non-market-based and non-regulatory measures, such as non-monetary incentives, deterrents, and persuasions (House of Lords, 2011; Sunstein, 2014). A nudge is "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler and Sunstein, 2008, p. 6). Nudging is intended to take advantage of or change people's choice architecture to ensure that they behave for their own sake or a collective end (Beshears and Kosowsky, 2020).

### 1.2. Study aim

This study aims to develop and test the application of a behavioral barrier-based framework (BBBF) for selecting intervention measures to lower barriers inhibiting behaviors that contribute to sustainable plastic use and disposal. While there is a wealth of literature on intervention measures (ICF, 2018; Sterner et al., 2019; Sterner and Coria, 2011; World Bank, 1997) and good practices (European Environment Agency, 2019), such studies are inadequate because the measures are context dependent (Fogt Jacobsen et al., 2022; Grilli and Curtis, 2021; Löhr et al., 2017; Sterner et al., 2019). Further, good practices in one context may not be suitable in other contexts. Additionally, not all measures are equally effective (Grilli and Curtis, 2021). Policymakers face countless choices regarding policy targets, desirable behavioral changes that contribute to them, barriers to changes, and intervention measures to lower the barriers. While the body of knowledge on intervention measures drawn from behavioral sciences has increased, its use has been unsystematic (Lehner et al., 2016). Therefore, a framework for selecting appropriate measures for each context from a wealth of literature is needed (Alpizar et al., 2020).

To fill this gap, the BBBF provides guidance for selecting appropriate measures for each context from a comprehensive list of intervention measures. The BBBF includes intervention measures from classical economics and behavioral sciences and aims to address environmental issues (Table 1). Compiling a single framework will assist policymakers in systematically selecting an intervention measure from various options.

This paper explains each step of the BBBF, followed by examples of its outcomes, using Kyoto City as a case study. Subsequently, we discuss the strengths and limitations of the BBBF identified during the case study and draw conclusions.

## 2. Proposed framework

Fig. 1 provides an overview of the BBBF. Except for Step 0, policymakers and residents were involved in the entire process to ensure the feasibility and appropriateness of the selected intervention measures.

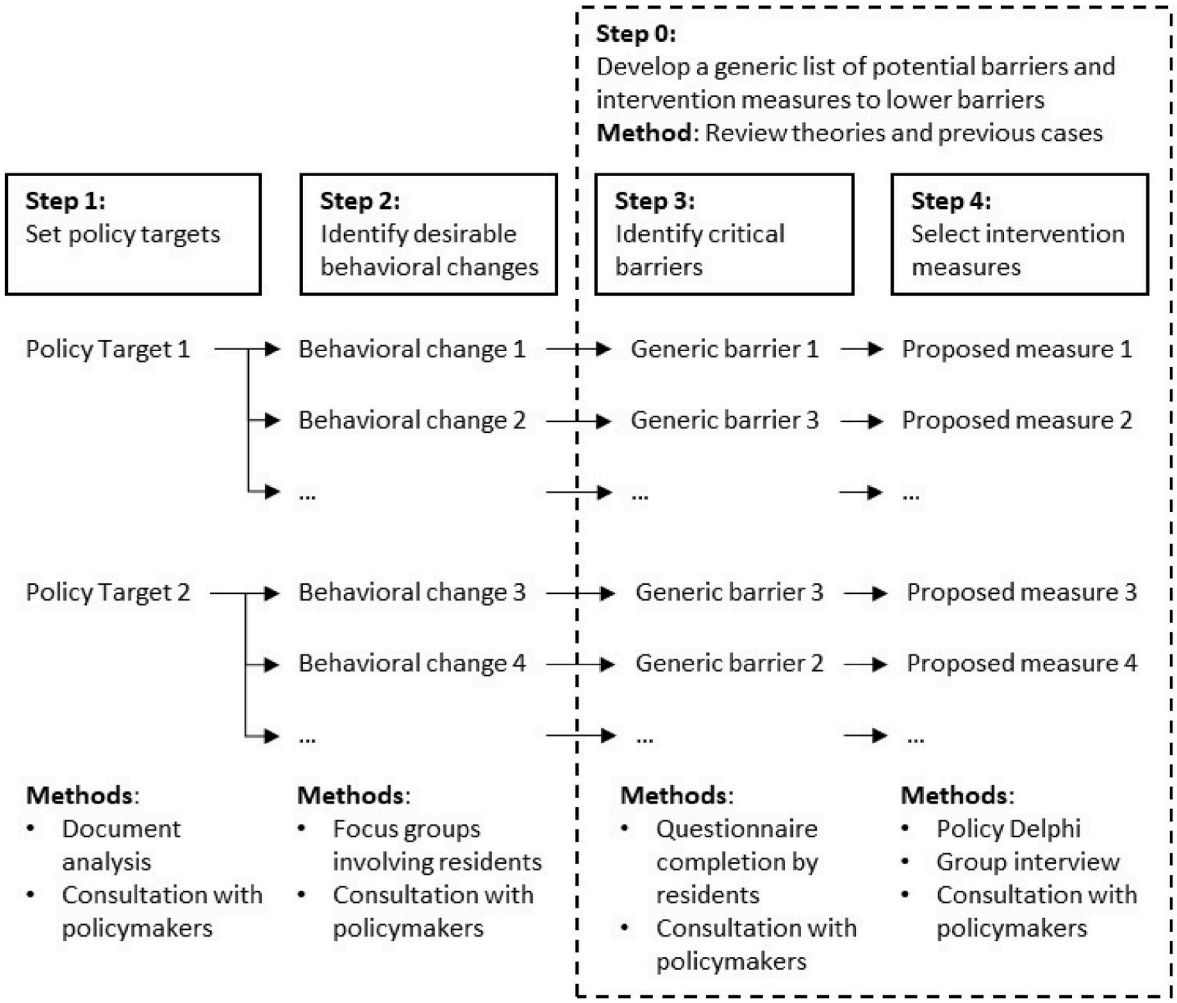



**Fig. 1.** Overview of the BBBF
Note. The dashed line indicates that Step 0 is the foundation for Steps 3 and 4.

Throughout BBBF development and application, we consulted concerned policymakers to ensure its usefulness.

Step 0. Developing a generic list of barriers to intervention measures

Step 0 is optional as policymakers can adopt the generic list prepared for this study (Table 2). We identified 11 barriers (B1–B11) corresponding to 15 intervention measures (I1–I15). The barriers corresponding to each intervention measure type (Table 1) were drafted by drawing on relevant theories and case studies. They were finalized through discussion among the authors, who are from diverse fields including waste management, environmental economics, environmental education, and psychology. The list of barriers matched with intervention measure types provides input for identifying context-specific barriers in Step 3 and intervention measures in Step 4. While the term "barriers" is widely used in behavioral measures (The Behavioural Insights Team, n.d.), we use this term in a broader sense, following the notion of the "sciences of human behavior" proposed by the House of Lords (2011, p. 9).

Step 1. Setting policy targets for behavior change

The BBBF adopts policy targets set by municipalities identified during document analysis and through consultations with policymakers (Fig. 1). It is critical to elicit intervention measures readily useful for municipalities. Such intervention measures must be context-specific; if they are not coordinated with policy targets, they are of little use (Grilli and Curtis, 2021; Löhr et al., 2017; Sterner et al., 2019).

Step 2 . Identifying desirable behavioral changes to achieve policy targets

Given the policy targets agreed upon, desirable behavioral changes corresponding to each target are identified through focus groups. As the purpose of the focus group is to list desirable behavioral changes rather than rank them, participant recruiting is purposive. Participants should satisfy one of two criteria. First, they should be interested in and knowledgeable about sustainable plastic use and disposal. People with little interest in this issue might not be aware of possible behavioral changes. Second, participants must live in the target area and know the context. Focus groups can be held online using an online whiteboard and a visual collaboration platform where multiple participants can simultaneously post and edit sticky notes.

The researchers using the BBBF subsequently filter and amend the desirable behavior changes proposed by the focus groups using four criteria. First, only changes in individual behaviors are included, not organizational behaviors or other people's behaviors. Second, the identified desirable behavioral changes must contribute directly to policy targets. For example, learning about the seriousness of plastic waste problems is not included. Third, changes must be appropriate. For example, some behaviors may not be recommended for sanitary or safety reasons. Fourth, if critical behaviors are not covered, researchers

**Table 2**
Generic list of barriers corresponding to intervention measures.

| Barrier | | Corresponding intervention measure | | |
|---|---|---|---|---|
| No. | Barrier | No. | Intervention measure type | Intervention measure category |
| B1 | Lack of financial incentives/disincentives | I1 | Taxes, fees, or charges | Market-based |
| | | I2 | Deposit-refund schemes | |
| | | I3 | Subsidies | |
| B2 | Current behavior goes unchecked (i.e., no bans or restrictions enforced by governments or municipalities) | I4 | Bans | Regulatory |
| | | I5 | Standards | |
| | | I6 | Permits (non-tradable) | |
| B3 | Lack of rules that mandate required behavior | I7 | Mandatory rules | |
| B4 | Approaches for required behavior are unclear | I8 | Simplification and framing information | Behavioral |
| B5 | Necessary conditions or facilities for required behavior are lacking | I9 | Changes to the physical environment | |
| B6 | Current behaviors are familiar or habitual | I10 | Changes to default policy | |
| B7 | No monitoring, behavior goes unnoticed | I11 | Use of social norms and salience | |
| B8 | Effectiveness and meaning of required behavior are unknown | I12 | Use of feedback mechanisms | |
| B9 | Details regarding extent and quality of required behavior are unclear | I13 | Goal setting and commitment devices | |
| B10 | Lack of persuasion to engage in required behavior | I14 | Persuasion | |
| B11 | Lack of non-monetary incentives/disincentives | I15 | Non-monetary incentives and disincentives | |

may add them to the list.

Step 3 . Identifying critical barriers that must be overcome to promote desirable behavioral changes

Step 3 identifies the critical barrier to each desirable behavioral change revealed in Step 2 using a questionnaire completed by residents of the target city or town. The questionnaire asks participants to choose barriers from a set of generic barriers in Table 2 (1 if selected as a barrier; 0 otherwise) for each identified desirable behavioral change. It rates the frequency with which a desirable behavior is implemented on a 6-point Likert scale (*always*, *very often*, *sometimes*, *rarely*, *never*, and *don't know*). We adopted a multiplicative model (Smith and Beran, 2012; Stutsky et al., 2012) to identify the most significant barriers to the proposed desirable behavioral changes. The model combines the frequency of implementing a desirable behavior and the criticality of a barrier to the behavior. Frequency is a weighting factor that measures the scope to improve participants' behavior. The most significant barrier corresponding to each behavior is chosen using a multiplicative model based on the following index:

$$standardized\ B_{i,j} = \frac{1}{n}\sum_{k=1}^{n} F_{j,k} C_{i,k} \quad (1)$$

where *standardized* $B_{i,j}$ is the standardized score, divided by the number of participants of the survey, $n$; it captures the significance of barrier $i$ to behavior $j$. $F_{j,k}$ is the frequency of participant $k$'s involvement in the behavior $j$ rated on a Likert scale (always = 0, very often = 1, sometimes = 2, rarely = 3, never = 4, don't know = 0). We assigned 0s to "always" and "don't know." The former indicates no barrier (i.e., no intervention is required, as they implement desirable behaviors) and the latter does not provide any information about the frequency. $C_{i,k}$ is the criticality of the barrier $i$ (1 if selected as a barrier, 0 otherwise) for participant $k$. For each behavior, a barrier with the highest *standardized* $B_{i,j}$ is chosen to consider intervention measures.

Step 4 . Select intervention measures by evaluating feasibility from a multi-perspective

Considering critical barriers to behavioral changes identified in Step 3, relevant potential intervention measures to lower these barriers are listed. As barriers are derived from the 15 intervention measure types (Table 2), intervention measures are chosen from those matched with the corresponding intervention measure type. Local stakeholders, such as municipalities and local businesses, should implement the identified measures. For example, the development of water bottles made of bioplastic would not be considered, as it would need cooperation with non-local manufacturers.

Two methods are employed to evaluate the feasibility of intervention measures according to its key stakeholder. A semi-structured group interview is conducted to evaluate intervention measures implemented by municipalities. This method is desirable because it obtains views from several officials (Punch, 2013) and does not require collecting diverse opinions from multiple organizations. The interview participants jointly answer questions about the feasibility of intervention measures using a 5-point scale (1: *very easy to implement* to 5: *very difficult to implement*) and provide remarks. However, intervention measures for retailers need an approach that can reflect their diverse opinions. Therefore, the BBBF proposes a policy Delphi to evaluate the feasibility of intervention measures led by retailers.

A policy Delphi aims to identify diverse views on an issue through iterative questionnaires completed by participants who have knowledge of the issue (de Loë et al., 2016; Uehara et al., 2021). It is suitable because the BBBF intends to provide policymakers with useful complementary information, such as feasibility and necessary conditions to implement measures, rather than a final decision. The design of the policy Delphi follows the specifications developed by de Loë et al. (2016).

## 3. Application of the BBBF: the case study with Kyoto City

The BBBF was applied to Kyoto City. Informed consent was obtained from all participants involved in the BBBF application.

### 3.1. Policy targets

Kyoto City is in central Japan and has 1,464,890 residents and 727,566 households (Statistics Bureau of Japan, 2021). In 2019, the emission of single-use plastic was estimated at 51,000 metric tons, and the estimated use of plastic shopping bags and polyethylene terephthalate (PET) bottles was 2500 metric tons (220 bags per person) and 3400 metric tons (90 PET bottles per person), respectively (Kyoto City, 2021). Kyoto City designed a plan for a recycle-based society, which includes policy targets to realize sustainable use and plastic disposal (Kyoto City, 2021). It comprises a reduction in the use of plastic shopping bags, PET bottles, and single-use plastic, improving the separation of plastic waste, and increasing the use of products made of bioplastic (Kyoto City, 2021). Throughout the process, we consulted Kyoto city officials to maintain BBBF application validity. These officials were from the section of the organization that was involved in developing the plan for a recycle-based society.

### 3.2. Desirable behavioral changes to achieve policy targets (steps 1 and 2)

Table 3 presents the policy targets and corresponding desirable

**Table 3**
Policy targets and corresponding desirable behavioral changes.

| Policy target (Kyoto City) | Desirable behavioral change | |
|---|---|---|
| 1. Reduction of plastic bag use from 2500 tons (2019) to 400 tons (2030), and from 220 bags per resident (2019) to 35 bags per resident (2030) | D1 | Reuse plastic bags repeatedly |
| | D2 | Use alternatives to plastic bags (excluding bioplastics) |
| | D3 | Use bioplastic bags |
| | D4 | Adopt lifestyles that avoid plastic bag use |
| 2. Reduction of plastic bottle waste from 3400 tons (2019) to 1600 tons (2030), and from 90 bottles per resident (2019) to 45 bottles per resident (2030) | D5 | Do not buy or accept plastic bottles |
| | D6 | Use alternatives to plastic bottles (excluding bioplastics) |
| | D7 | Use plastic bottles with low environmental impact |
| 3. Reduction of disposable plastic waste from 51,000 tons (2019; 2030 not set) | D8 | Do not accept or use plastic, or return plastic without using it |
| | D9 | Choose non-disposable alternatives (excluding bioplastics) |
| | D10 | Choose bioplastic products |
| | D11 | Choose products that use less plastic packaging |
| | D12 | Adopt lifestyles that use less or no disposable plastics |
| 4. Improve plastic waste sorting from 46% (2019) to 60% (2030) | D13 | Follow correct methods of waste sorting |
| | D14 | Make it easy to sort waste |
| | D15 | Cooperate with in-store collection |
| | D16 | Choose products based on ease of waste sorting |

behavioral changes for Kyoto City listed in focus groups and in consultation with city officials. Examples of each change raised in the focus groups are provided in Appendix A.

After consulting with city officials, we included all policy targets the city had proposed, except for increasing the use of bioplastic containers. While bioplastic is a promising alternative to fossil-based plastic (Ministry of the Environment Japan, 2021), the quantification of a target for its use is undetermined, as its future availability is difficult to predict. Furthermore, the current amount being used is unknown. However, because of its importance, we reflected it in the questionnaire with residents of Kyoto to capture the current use of bioplastic with other policy targets.

We held two online focus groups using miro on July 30 and September 2, 2021. The participants were recruited using snowball sampling. The first focus group comprised five Kyoto residents, who were split into two groups. Each group worked on identifying behavioral changes to achieve an assigned policy target, and 60 sticky notes were created. Following the four filtering criteria for identifying and amending the list of desirable behaviors, the authors reorganized and summarized the notes as 18 behavioral changes.

The second focus group comprised 10 participants, including 4 participants who did not live in Kyoto City but were interested in and knowledgeable about plastic use and disposal issues. Participants were presented with the 18 behavioral changes obtained from the first focus group and produced 109 sticky notes. We applied the four filtering criteria and reorganized the notes into 16 behavioral changes (D1–D16 in Table 3). Some behavioral changes were excluded, such as "reusing plastic bottles." Although it can reduce plastic bottle consumption, it is not recommended for sanitary and safety reasons (Japan Soft Drink Association, n.d.; Ono et al., 2004). We separated bioplastics from alternatives to plastic shopping bags, PET bottles, and single-use plastic for two reasons. First, bioplastic is of special policy importance. Increasing the rate of bioplastic container use is one of Kyoto City's primary targets; however, we did not include it as a policy target in our study because of feasibility constraints. Additionally, the Japanese government developed a roadmap for introducing bioplastics as part of the resource circulation strategy for plastics (Ministry of the Environment Japan, 2021), although its impact on the environment remains unclear (Emadian et al., 2017). Second, as it differed from other alternatives in terms of its convenience and function, we presumed that the barriers related to bioplastics might differ from the other alternatives. While there may be a difference in market prices, bioplastics offer convenience and function, such as lightness and durability, similar to fossil-based plastics.

### 3.3. Critical barriers to the desired behavioral changes (Step 3)

An online questionnaire (Appendix B) was administered to Kyoto residents in November 2021 to identify barriers to desirable behavioral changes for each policy target. Participants were selected from a pre-registered panel at a survey company to represent the age and sex distribution of the population (Appendix C). The barriers were rephrased from the generic barriers in Table 2 to fit each desired behavioral change. We consulted city officials on October 20, 2021 to verify the validity of the questions. The questionnaire was tested with 100 participants before the survey. Finally, 1000 residents participated in the survey. The data needed to replicate the results of this study are provided as supplementary materials.

Fig. 2 shows the ranking of the criticality of barriers corresponding to desirable behavioral changes based on Eq. (1) (Appendix D). The matrix of criticality is read horizontally, that is, row by row for each policy target, and cells with maximum values are selected. Out of 11 barriers (B1–B11), 3 barriers were selected as critical: "B4. Approaches to carry out the required behavior are unclear (How to)," "B6. Current behaviors are familiar or habitual (Habits)," and "B9. Details of how much to do or how well one is doing in terms of the required behavior are unclear (Contributions)." All barriers were categorized per behavioral approach (Table 2).

### 3.4. Intervention measures for lowering barriers to desirable behavioral changes (Step 4)

Step 4, the final step, proposes intervention measures to induce desirable behavioral changes toward the policy targets. Table 4 is the final output of the BBBF.

We designed the proposed intervention measures for Kyoto City by applying the intervention measure types corresponding to critical barriers identified in Step 3 (white numbers in Fig. 2). Accordingly, we proposed intervention measures categorized per type "P8. Simplification and framing information" for the barrier "B4. Approaches to carry out the required behavior are unclear (How to)," type "P10. Changes to the default policy" for the barrier "B6. Current behaviors are familiar or habitual (Habits)," and type "P13. Goal setting and commitment devices" for the barrier "B9. Details of how much to do or how well one is doing in terms of the required behavior are unclear (Contributions)."

As simplification and framing of information (intervention measure type I8) can prevent information overload, such interventions can effectively activate individuals' targeted values and attitudes (OECD, 2017b). Eco-labeling is a commonly-used measure (OECD, 2017b; Prieto-Sandoval et al., 2016; van der Ven et al., 2018; Wensing et al., 2020). However, as eco-labels are applied by manufacturers rather than local businesses, it was not proposed in the BBBF. We proposed that retailers place information displays in-store, such as in front of products made of bioplastics.

There are six behavioral changes in which the barrier "B6. Current behaviors are familiar or habitual (Habits)" is critical (Fig. 2). The corresponding intervention measure type is to change to the default policy. People tend to resist change by maintaining the status quo (or default) until or unless change is inevitable (Johnson and Goldstein, 2003; OECD, 2017a). Mundt et al. (2020) found that separating straws from drinking cups by default decreased the use of plastic straws. We proposed to reduce the sales of targeted products, such as plastic bottles, as changes to the default policy.

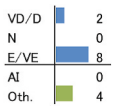
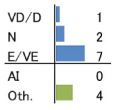
| Policy target | Desirable behavioral change | | Barrier | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Description | 1 Monetary | 2 Allowed | 3 No rules | 4 How to | 5 Conditions | 6 Habits | 7 Social pressure | 8 Meaningfulness | 9 Contributions | 10 Request | 11 Non-monetary |
| Reduction of plastic bag use | 1 | Reuse plastic bags repeatedly | 3 | 6 | 9 | 10 | 5 | 2 | 11 | 4 | 1 | 8 | 7 |
| | 2 | Use alternatives to plastic bags (excluding bioplastics) | 6 | 8 | 11 | 3 | 3 | 2 | 10 | 7 | 1 | 9 | 5 |
| | 3 | Use bags made of bioplastic | 7 | 6 | 9 | 1 | 2 | 4 | 10 | 8 | 3 | 5 | 11 |
| | 4 | Adopt a lifestyle that avoids the use of plastic bags | 4 | 7 | 9 | 3 | 5 | 2 | 11 | 6 | 1 | 10 | 8 |
| Reduction of plastic bottle waste | 5 | Do not buy or accept plastic bottles | 7 | 3 | 4 | 5 | 2 | 1 | 11 | 10 | 6 | 8 | 9 |
| | 6 | Use alternatives to plastic bottles (excluding bioplastics) | 6 | 3 | 7 | 4 | 2 | 1 | 11 | 9 | 5 | 8 | 10 |
| | 7 | Use plastic bottles with low environmental impact | 6 | 5 | 7 | 1 | 3 | 2 | 10 | 9 | 4 | 8 | 11 |
| Reduction of disposable plastic waste | 8 | Do not accept or use plastic, or return plastic without using it | 3 | 4 | 8 | 9 | 5 | 1 | 11 | 6 | 2 | 10 | 7 |
| | 9 | Choose non-disposable alternatives (excluding | 5 | 6 | 8 | 4 | 3 | 1 | 11 | 9 | 2 | 10 | 7 |
| | 10 | Choose products made from bioplastics | 5 | 6 | 7 | 1 | 2 | 4 | 10 | 8 | 3 | 9 | 11 |
| | 11 | Choose products that use less plastic packaging | 6 | 5 | 10 | 1 | 4 | 2 | 11 | 7 | 3 | 8 | 9 |
| | 12 | Adopt a lifestyle that uses less or no disposable plastics | 5 | 6 | 7 | 3 | 2 | 1 | 11 | 8 | 4 | 10 | 9 |
| Improve plastic waste sorting | 13 | Follow the correct methods of waste sorting | 4 | 11 | 8 | 2 | 5 | 6 | 10 | 3 | 1 | 7 | 9 |
| | 14 | Make it easy to sort waste | 5 | 9 | 10 | 2 | 3 | 4 | 11 | 6 | 1 | 8 | 7 |
| | 15 | Cooperate with in-store collection | 4 | 10 | 5 | 7 | 3 | 1 | 11 | 7 | 2 | 6 | 9 |
| | 16 | Choose products based on ease of waste sorting | 5 | 8 | 7 | 1 | 3 | 2 | 11 | 6 | 3 | 10 | 9 |

**Fig. 2.** Matrix for ranking critical barriers by desirable behavioral change
Note. Numbers represent ranking of barrier criticality per desirable behavioral change. B1 to B11 correspond to barrier numbers in Table 2. D1 to D16 correspond to behavioral change numbers in Table 3.

The intervention measure type "I13. Goal setting and achievement tracking devices" can encourage commitment to effortful behavioral changes (OECD, 2017b). The efficacy and generality of goal setting have been well documented (Locke and Latham, 2006, 2019). Czajkowski et al. (2019) found that goal setting can help promote household recycling. We proposed measures that clarify required actions and help people understand how well they are doing (Table 4). While this attempt could be effective, it is difficult in certain circumstances, such as continuous measurement of and reporting how often plastic bags are replaced with their alternatives.

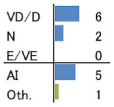
To assess the feasibility of the proposed intervention measures, we held semi-structured group interviews and a policy Delphi with key stakeholders of the measures ("Feasibility" and "Feasibility comments" in Table 4); that is, a semi-structured group interview with Kyoto City officials and a policy Delphi with retailers. The semi-structured interview with Kyoto City officials was conducted in December 2021 to assess the feasibility of the proposed measures corresponding to desirable behavioral changes D4, D13, and D14 (Table 4). The results were mixed. Preparing a checklist for devising ways to make it easy to separate plastic waste (proposed intervention measure P4) and for lifestyles without using plastic bags (desirable behavioral change D13) were rated as easy (2) and very easy (1), respectively. In contrast, informing residents of how well others in their area were separating waste was considered difficult due to a lack of information (P12). It would be possible to inform residents of the separation on average across the city, as it is analyzed annually; however, the average across the city is less connected to how an individual is performing, likely resulting in weaker motivation to improve one's behavior. This point warrants further investigation. Further, we asked the officials regarding the BBBF as a policy tool and received positive responses, as the BBBF provides useful information. However, the respondents also mentioned that a pilot test with a small number of households is required before adopting it.

**Table 4**
Proposed measures and key stakeholders for lowering barriers to desirable behavioral change.

| Policy target | Desirable behavioral change | | Barrier to behavioral change | Intervention measure type | Proposed intervention measure | | Key stakeholder | Feasibility | Feasibility comments |
|---|---|---|---|---|---|---|---|---|---|
| Reduction of plastic bag use | D1 | Reuse plastic bags repeatedly | B9 | I13 | P1 | Install informational displays to inform of possibility and extent of plastic bag reuse. | Retailers |   | "I think it is relatively easy to display posters for plastic reduction if the municipality etc. prepare them (D)." |
| | D2 | Use alternatives to plastic bags (excluding bioplastics) | B9 | I13 | P2 | Install informational displays to encourage people to stop using plastic bags and use alternative products. | Retailers |   | |
| | D3 | Use bioplastic bags | B4 | I8 | P3 | Install informational displays to facilitate selection of bioplastic bags. | Retailers |   | "Because bioplastic shopping bags are expensive, there are no plans to introduce them at present (D)." |
| | D4 | Adopt lifestyle that avoids plastic bag use | B9 | I13 | P4 | Propose specific lifestyle choices that do not use plastic bags. | Municipality | 1. Very easy | "It is easy to create a checklist. However, delivering the checklist to citizens is difficult. It is also difficult to spend money on publicity." |
| Reduction of plastic bottle waste | D5 | Do not buy or accept plastic bottles | B6 | I10 | P5 | Reduce number of plastic bottles handled to 50% of current level by 2030. | Retailers |   | "Because it is greatly influenced by customer demand and manufacturer's efforts (D)." |
| | D6 | Use alternatives to plastic bottles (excluding bioplastics) | B6 | I10 | P6 | Replace 25% of current PET bottles with alternatives by 2030. | Retailers |   | "Currently, most of the products by manufacturers are PET bottles. Additionally, it is not possible to collect glass bottles (VD)." |
| | D7 | Use plastic bottles with low environmental impact | B4 | I8 | P7 | Install informational displays to facilitate selection of PET bottles with low environmental impact. | Retailers |   | "We are thinking about not replacing it with a substitute, and to not use it in the future (Oth.)." |
| Reduction of disposable plastic waste | D8 | Do not accept or use plastic, or return plastic without using it | B6 | I10 | P8 | Reduce amount of disposable plastics handled to 50% of current level by 2030. | Retailers |   | "Because we cannot find a suitable alternative to plastic from the viewpoint of quality assurance and cost (D)." |
| | D9 | Choose non-disposable alternatives (excluding bioplastics) | B6 | I10 | P9 | Replace 25% of current disposable plastics with alternatives by 2030. | Retailers |   | "It is difficult for us to control whether plastic bags for foods and food wraps will be replaced (N)." |
| | D10 | Choose bioplastic products | B4 | I8 | P10 | Provide informational displays to facilitate selection of bioplastic products. | Retailers |   | |
| | D11 | Choose products that use less plastic packaging | B4 | I8 | P11 | Install informational displays to facilitate selection of products that use less plastic packaging. | Retailers |   | |
| | D12 | Adopt lifestyle that uses less or no disposable plastics | B6 | I10 | P8 | Reduce amount of disposable plastics handled to 50% of current level by 2030. | Retailers |   | "Because we cannot find a suitable alternative to plastic from the viewpoint of quality assurance and cost (D)." |
| Improve plastic waste sorting | D13 | Follow correct methods of waste sorting | B9 | I13 | P12 | Communicate district's actual and target plastic waste separation rate. | Municipality | 4. Very difficult | "We have not surveyed the plastic waste separation rate in the district where people live. However, as surveys are conducted at three locations every year for the whole city, it would be possible to report the separation rate for the whole city." |

(*continued on next page*)

**Table 4** (*continued*)

| Policy target | Desirable behavioral change | | Barrier to behavioral change | Intervention measure type | Proposed intervention measure | | Key stakeholder | Feasibility | Feasibility comments |
|---|---|---|---|---|---|---|---|---|---|
| | D14 | Make it easy to sort waste | B9 | I13 | P13 | Outline types of specific activities people should undertake. | Municipality | 2. Easy | "It is easy to create a checklist. However, the kind of activities that should be undertaken in the list should be further considered. Additionally, delivering the checklist to citizens is a difficult issue." |
| | D15 | Cooperate with in-store collection | B6 | I10 | P14 | Install in-store collection boxes. | Retailers |   | "Difficult to secure a place (VD)." "Because it may not match the store image (D)." |
| | D16 | Choose products based on ease of waste sorting | B4 | I8 | P15 | Install informational displays to facilitate selection of easy-to-sort products. | Retailers |   | "Because the target is too vague (D)." |

Note. VD/D: Very difficult or Difficult; N: Neutral, E/VE: Easy or Very easy; AI: Already implemented; Oth.: Other.

A policy Delphi was implemented online (Appendix E) to test the feasibility of proposed intervention measures, whose key stakeholders are retailers (Table 4). The policy Delphi comprised two rounds of questionnaires. The recruitment of the panel of participants was purposive to include targeted types of retailers, such as supermarkets and grocery stores. In addition to consultations with city officials, we used the composition analysis of disposed plastic waste by retailer types in Kyoto City to identify key retailers (Sakai et al., 2019). The panel included 15 retailers in the first round and 14 out of the 15 in the second, with a panel completion rate of 93.3%, which is considered high (de Loë et al., 2016). The panel included supermarkets (3), a convenience store (1), a drugstore (1), specialty stores (3), restaurants (3), and others (3: bookstore, souvenir shop, and large retailer). The first round was hosted online between January 13 and January 23, 2021. The second round was hosted online between February 10 and February 14, 2022.

Participants assessed the feasibility of each proposed intervention measure. We asked the participants if they would voluntarily adopt the measures, with answers rated on a 5-point scale (1 = very difficult [VD]; 5 = very easy [VE]). Additionally, we included option 6 for measures that had already been implemented (AI) and option 7 for other measures (Oth.) and comments, if any. Voluntary approaches are becoming popular, complementary to traditional legislation (European Environment Agency, 2019). Although the questionnaire in the second round asked the same questions as the first round, the results obtained from the first round, including the overall summary of all the participants' inputs and individual responses, were presented to participants to reconsider their answers from the first round.

Table 4 presents the feasibility of adopting the proposed measures voluntarily. Of the twelve proposed measures for businesses, five measures (P1, P2, P7, P10, and P11) were considered easy (E) or very easy (VE), and two measures (P5 and P14) were considered difficult (D) or very difficult (VD) to adopt. The remaining four measures (P6, P8, P9, and P15) were rated neutrally. The comments presented in Table 4 were selected to focus on barriers to adopting the proposed measures. Overall, local businesses cannot adopt certain measures without cooperating with manufacturers, the municipality, and consumers. In particular, the feasibility of the proposed measures involving reduction targets by 2030 (i.e., P5, P6, P8, and P9) is dependent on factors such as whether manufacturers will provide alternatives at a reasonable cost. Therefore, they were rated as neutral. This finding corroborates the importance of collaboration among stakeholders.

## 4. Insights from the BBBF for selecting context-specific intervention measures

We developed and tested the BBBF for selecting intervention measures to realize sustainable plastic use and disposal in Kyoto City. To effectively use the BBBF, it is crucial to articulate insights regarding the selection of context-specific intervention measures and the strengths and limitations elucidated through BBBF application.

The BBBF has four strengths. First, it can help policymakers identify suitable intervention measures from the growing number of studies and good practices (Grilli and Curtis, 2021; Löhr et al., 2017; Sterner et al., 2019). While there are typologies of intervention measures (Alpizar et al., 2020; House of Lords, 2011; ICF, 2018), they do not provide sufficient guidance for choosing context-specific measures. The Behavioural Insights Team (n.d.) provides a tool to identify critical barriers; however, it focuses on behavioral approaches.

The application of the BBBF in Kyoto City identified 15 intervention measures for lowering barriers, which were classified into three barrier types, for 16 behavioral changes that contribute to the four policy targets set by Kyoto City. Because the application intended to reflect the situation of Kyoto City, the types of critical barriers and corresponding behavioral changes may differ in other places. All barriers were categorized per behavioral approach (Table 2). Interestingly, a review reported that policies for plastic bags are dominated by bans (56%) and pricing mechanisms (32%), although some use voluntary agreements and information campaigns (Nielsen et al., 2019). Similarly, while information measures dominate in addressing plastic waste in Europe (42% of all measures), regulatory and market-based measures are relatively popular in the field of plastic waste (European Environment Agency, 2019). Second, the generic list provided in the BBBF reveals a comprehensive typology of barriers and intervention measures drawn from recent developments in behavioral economics and conventional market-based and regulatory approaches (Alpizar et al., 2020; House of Lords, 2011; ICF, 2018; Lehner et al., 2016; OECD, 2017a; Sterner et al., 2019; Sterner and Coria, 2011; World Bank, 1997). In line with the science of human behavior (House of Lords, 2011) and behavioral change approaches (Grilli and Curtis, 2021), it is important to embrace all approaches to change human behavior. This enables policymakers to identify which type of intervention measures to consider for achieving their policy targets based on critical barriers to desirable behavioral changes. Although the selection of intervention measures is undeniably context-specific, the generalization of barriers and corresponding intervention measures gathered from the literature (i.e., the list developed for the BBBF) should be universally applicable and instrumental. Some studies examined barriers and corresponding intervention

measures (Grilli and Curtis, 2021; McKenzie-Mohr, 2011). However, the BBBF, including the generic list, is comprehensive in its selection of corresponding measures and barriers and targets sustainable plastic use and disposal with explicit steps that reflect the context. Third, by involving local stakeholders during Steps 2 to 4 (Fig. 1), context-specific intervention measures were elicited (Step 4) along with desirable behavioral changes (Step 2) and their critical barriers (Step 3) for contextual policy targets (Step 1; Table 4). Fourth, the steps are simple and do not require sophisticated analytical techniques. As the generic list is readily available, the steps can be implemented without the help of highly skilled professionals.

Several limitations of the BBBF should be noted. First, the BBBF should be tested in other contexts to validate its usefulness. Second, it focuses on intervention measures that can be implemented by local stakeholders; however, resolving plastic problems should involve a wider range of stakeholders, including manufacturers (Alpizar et al., 2020). For example, a national beverage company developed plastic bottles made with 100% plant-derived materials (Suntory, 2021), giving retailers an important option for reducing the amount of fossil-based plastic bottles. Further studies including multiple level stakeholders are required. Third, while the BBBF evaluates the feasibility of each measure, it does not guarantee implementation, which involves additional processes. Furthermore, some proposed intervention measures may not be easy to implement. Although the BBBF was tested and developed in consultation with policymakers, the effectiveness of proposed measures using the BBBF was not tested. Nonetheless, the evaluation provides references or starting points for considering the possibilities. Fourth, the BBBF does not examine synergies and trade-offs between intervention measures, although they are important (Fogt Jacobsen et al., 2022; Sterner and Coria, 2011).

## 5. Conclusions

The BBBF helps identify suitable intervention measures from infinite possibilities. However, it does not primarily intend to contrive innovative measures. The BBBF assumes that an intervention measure that lowers critical barriers to desirable behavioral change is effective for attaining sustainable plastic use and disposal. To expedite the identification of barriers and corresponding intervention measures, we developed a generic list of barriers corresponding to and derived from existing intervention measure types. Among the proliferation of barriers and intervention measures, as well as their combinations, the generic list helps policymakers identify critical barriers and derive corresponding intervention measures, guided by the identified intervention measure types linked to the listed barriers. By applying the BBBF in Kyoto City, this study revealed 15 potential desirable behavioral changes, three types of critical barriers to these changes, and 16 corresponding intervention measures to attain four policy targets (Table 4). As the BBBF, including the generic list, is based on broad literature and not restricted to plastic use and disposal, it could be applied to other waste-related problems requiring interventions to lower barriers to desirable behavioral change.

## CRediT authorship contribution statement

**Takuro Uehara:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Misuzu Asari:** Data curation, Formal analysis, Funding acquisition, Resources, Validation. **Ryo Sakurai:** Data curation, Formal analysis, Validation, Writing – review & editing. **Mateo Cordier:** Validation, Writing – review & editing. **Maheshwari Kalyanasundaram:** Data curation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Our research data are provided as supplementary material.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2022.135609.

## References

Akbulut-Yuksel, M., Boulatoff, C., 2021. The effects of a green nudge on municipal solid waste: evidence from a clear bag policy. J. Environ. Econ. Manag. 106, 102404 https://doi.org/10.1016/j.jeem.2020.102404.

Alpizar, F., Carlsson, F., Lanza, G., Carney, B., Daniels, R.C., Jaime, M., Ho, T., Nie, Z., Salazar, C., Tibesigwa, B., Wahdera, S., 2020. A framework for selecting and designing policies to reduce marine plastic pollution in developing countries. Environ. Sci. Pol. 109, 25–35. https://doi.org/10.1016/j.envsci.2020.04.007.

Beaumont, N.J., Austen, M.C., Atkins, J.P., Burdon, D., Degraer, S., Dentinho, T.P., Derous, S., Holm, P., Horton, T., Van Ierland, E., 2007. Identification, definition and quantification of goods and services provided by marine biodiversity: implications for the ecosystem approach. Mar. Pollut. Bull. 54, 253–265. https://doi.org/10.1016/j.marpolbul.2006.12.003.

Beshears, J., Kosowsky, H., 2020. Nudging: progress to date and future directions. Organ. Behav. Hum. Decis. Process. 161, 3–19. https://doi.org/10.1016/j.obhdp.2020.09.001.

Borrelle, S.B., Ringma, J., Law, K.L., Monnahan, C.C., Lebreton, L., McGivern, A., Murphy, E., Jambeck, J., Leonard, G.H., Hilleary, M.A., Eriksen, M., Possingham, H. P., De Frond, H., Gerber, L.R., Polidoro, B., Tahir, A., Bernard, M., Mallos, N., Barnes, M., Rochman, C.M., 2020. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science 369, 1515–1518. https://doi.org/10.1126/science.aba3656.

Brouwer, R., Hadzhiyska, D., Ioakeimidis, C., Ouderdorp, H., 2017. The social costs of marine litter along European coasts. Ocean Coast Manag. 138, 38–49. https://doi.org/10.1016/j.ocecoaman.2017.01.011.

Carlsson, F., Gravert, C., Johansson-Stenman, O., Kurz, V., 2019. The Use of Green Nudges as an Environmental Policy Instrument. Department of Economics, Göteborg University, Gothenburg.

Chenillat, F., Huck, T., Maes, C., Grima, N., Blanke, B., 2021. Fate of floating plastic debris released along the coasts in a global ocean model. Mar. Pollut. Bull. 165, 112116 https://doi.org/10.1016/j.marpolbul.2021.112116.

Cordier, M., Uehara, T., 2019. How much innovation is needed to protect the ocean from plastic contamination? Sci. Total Environ. 670, 789–799. https://doi.org/10.1016/j.scitotenv.2019.03.258.

Cordier, M., Uehara, T., Baztan, J., Jorgensen, B., Yan, H., 2021. Plastic pollution and economic growth: the influence of corruption and lack of education. Ecol. Econ. 182 https://doi.org/10.1016/j.ecolecon.2020.106930.

Czajkowski, M., Zagórska, K., Hanley, N., 2019. Social norm nudging and preferences for household recycling. Resour. Energy Econ. 58 https://doi.org/10.1016/j.reseneeco.2019.07.004.

de Loë, R.C., Melnychuk, N., Murray, D., Plummer, R., 2016. Advancing the state of policy Delphi practice: a systematic review evaluating methodological evolution, innovation, and opportunities. Technol. Forecast. Soc. Change 104, 78–88. https://doi.org/10.1016/j.techfore.2015.12.009.

Derraik, J.G.B., 2002. The pollution of the marine environment by plastic debris: a review. Mar. Pollut. Bull. 44, 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5.

Emadian, S.M., Onay, T.T., Demirel, B., 2017. Biodegradation of bioplastics in natural environments. Waste Manag. 59, 526–536. https://doi.org/10.1016/j.wasman.2016.10.006.

Preventing plastic waste in Europe. https://doi.org/10.2800/096909, 2019.

Fogt Jacobsen, L., Pedersen, S., Thøgersen, J., 2022. Drivers of and barriers to consumers' plastic packaging waste avoidance and recycling – a systematic literature review. Waste Manag. 141, 63–78. https://doi.org/10.1016/j.wasman.2022.01.021.

Geyer, R., Jambeck, J.R., Law, K.L., 2017. Production, use, and fate of all plastics ever made. Sci. Adv. 3 https://doi.org/10.1126/sciadv.1700782.

Grilli, G., Curtis, J., 2021. Encouraging pro-environmental behaviours: a review of methods and approaches. Renew. Sustain. Energy Rev. 135, 110039 https://doi.org/10.1016/j.rser.2020.110039.
Hohn, S., Acevedo-Trejos, E., Abrams, J.F., Fulgencio de Moura, J., Spranz, R., Merico, A., 2020. The long-term legacy of plastic mass production. Sci. Total Environ. 746, 141115 https://doi.org/10.1016/j.scitotenv.2020.141115.
House of Lords, 2011. Behaviour Change (London).
ICF, Eunomia, 2018. Assessment of Measures to Reduce Marine Litter from Single Use Plastics (London).
Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771. https://doi.org/10.1126/science.1260352.
n.d. Japan Soft Drink Association. Can PET bottles be reused as a container? [WWW Document]. URL. http://www.j-sda.or.jp/ippan/qa_view.php?id=161&cat=2, 9. November.21.
Johnson, E.J., Goldstein, D., 2003. Do defaults save lives? Science 302, 1338–1339. https://doi.org/10.1126/science.1091721.
Kahneman, D., 2003. A perspective on judgment and choice: mapping bounded rationality. Am. Psychol. 58, 697–720. https://doi.org/10.1037/0003-066X.58.9.697.
Kühn, S., Bravo Rebolledo, E.L., van Franeker, J.A., 2015. Deleterious effects of litter on marine life. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), Marine Anthropogenic Litter. Springer International Publishing, Cham, pp. 75–116. https://doi.org/10.1007/978-3-319-16510-3_4.
Kyoto City, 2021. Kyoto City Basic Plan for the Promotion of Recycle-Based Society 2021-2030.
Landrigan, P.J., Stegeman, J.J., Fleming, L.E., Allemand, D., Anderson, D.M., Backer, L. C., Brucker-Davis, F., Chevalier, N., Corra, L., Czerucka, D., Bottein, M.Y.D., Demeneix, B., Depledge, M., Deheyn, D.D., Dorman, C.J., Fénichel, P., Fisher, S., Gaill, F., Galgani, F., Gaze, W.H., Giuliano, L., Grandjean, P., Hahn, M.E., Hamdoun, A., Hess, P., Judson, B., Laborde, A., McGlade, J., Mu, J., Mustapha, A., Neira, M., Noble, R.T., Pedrotti, M.L., Reddy, C., Rocklöv, J., Scharler, U.M., Shanmugam, H., Taghian, G., Van De Water, J.A.J.M., Vezzulli, L., Weihe, P., Zeka, A., Raps, H., Rampal, P., 2020. Human health and ocean pollution. Annals of Global Health 86, 1–64. https://doi.org/10.5334/aogh.2831.
Lau, W.W.Y., Shiran, Y., Bailey, R.M., Cook, E., Stuchtey, M.R., Koskella, J., Velis, C.A., Godfrey, L., Boucher, J., Murphy, M.B., Thompson, R.C., Jankowska, E., Castillo, A., Pilditch, T.D., Dixon, B., Koerselman, L., Kosior, E., Favoino, E., Gutberlet, J., Baulch, S., Atreya, M.E., Fischer, D., He, K.K., Petit, M.M., Sumaila, U.R., Neil, E., Bernhofen, M.V., Lawrence, K., Palardy, J.E., 2020. Evaluating scenarios toward zero plastic pollution. Science. https://doi.org/10.1126/science.aba9475.
Lebreton, L., Egger, M., Slat, B., 2019. A global mass budget for positively buoyant macroplastic debris in the ocean. Sci. Rep. 9, 1–10. https://doi.org/10.1038/s41598-019-49413-5.
Lebreton, L.C.M., Van Der Zwet, J., Damsteeg, J.W., Slat, B., Andrady, A., Reisser, J., 2017. River plastic emissions to the world's oceans. Nat. Commun. 8, 1–10. https://doi.org/10.1038/ncomms15611.
Lehner, M., Mont, O., Heiskanen, E., 2016. Nudging – a promising tool for sustainable consumption behaviour? J. Clean. Prod. 134, 166–177. https://doi.org/10.1016/j.jclepro.2015.11.086.
Locke, E., Latham, G.P., 2019. The development of goal setting theory: a half century retrospective. Motivation Science 5, 93–105. https://doi.org/10.1037/mot0000145.
Locke, E.A., Latham, G.P., 2006. New directions in goal-setting theory new directions in goal-setting theory. Psychol. Sci. 15, 265–268. https://doi.org/10.1111/j.1467-8721.2006.00449.x.
Loewenstein, G., Chater, N., 2017. Putting nudges in perspective. Behavioural Public Policy 1, 26–53. https://doi.org/10.1017/bpp.2016.7.
Löhr, A., Savelli, H., Beunen, R., Kalz, M., Ragas, A., Van Belleghem, F., 2017. Solutions for global marine litter pollution. Curr. Opin. Environ. Sustain. 28, 90–99. https://doi.org/10.1016/j.cosust.2017.08.009.
McKenzie-Mohr, D., 2011. Fostering Sustainable Behavior: an Introduction to Community-Based Social Marketing. New society publishers.
Ministry of the Environment Japan, 2021. Roadmap for Bioplastic Introduction: for the Sustainable Use of Plastics (Tokyo).
Mullainathan, S., Thaler, R.H., 2015. Behavioral economics. In: International Encyclopedia of the Social & Behavioral Sciences, second ed. 3, pp. 437–442. https://doi.org/10.1016/B978-0-08-097086-8.71007-5.
Mundt, D., Carl, S., Harhoff, N., 2020. A field experiment on reducing drinking straw consumption by default. Front. Psychol. 11, 1–6. https://doi.org/10.3389/fpsyg.2020.565537.
Nielsen, T.D., Holmberg, K., Stripple, J., 2019. Need a bag? A review of public policies on plastic carrier bags – where, how and to what effect? Waste Manag. 87, 428–440. https://doi.org/10.1016/j.wasman.2019.02.025.
OECD, 2017a. Tackling environmental problems with the help of behavioural insights. https://doi.org/10.1787/9789264273887-en.
OECD, 2017b. Tackling Environmental Problems with the Help of Behavioral Insights (Paris).
Ono, K., Kon, S., Mori, N., Ohta, S., 2004. Study of the Drink with the PET Bottle. Bulletin of the Faculty of Education. Hirosaki University 133–145.
Persson, L., Carney Almroth, B.M., Collins, C.D., Cornell, S., de Wit, C.A., Diamond, M.L., Fantke, P., Hassellöv, M., MacLeod, M., Ryberg, M.W., Søgaard Jørgensen, P., Villarrubia-Gómez, P., Wang, Z., Hauschild, M.Z., 2022. Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. Environmental Science & Technology acs. https://doi.org/10.1021/acs.est.1c04158 est.1c04158.
Prieto-Sandoval, V., Alfaro, J.A., Mejía-Villa, A., Ormazabal, M., 2016. ECO-labels as a multidimensional research topic: trends and opportunities. J. Clean. Prod. 135, 806–818. https://doi.org/10.1016/j.jclepro.2016.06.167.
Punch, K.F., 2013. Introduction to Social Research: Quantitative and Qualitative Approaches. sage.
Sakai, S., Yano, J., Tomita, Y., Asari, M., Yashiro, Y., 2019. The state and policy of use and dispal of plastic bags (shopping bags). Kankyo Kanri 55, 30–35.
Smith, S.D., Beran, T.N., 2012. A comparison of empirical ranking methods of frequency and severity ratings of clinical presentations. Eval. Health Prof. 35, 383–395. https://doi.org/10.1177/0163278711425041.
Statistics Bureau of Japan, 2021. Population Census [WWW Document]. URL. https://www.stat.go.jp/english/data/kokusei/index.html, 10.JanuaryJune.21.
Sterner, T., Barbier, E.B., Bateman, I., van den Bijgaart, I., Crépin, A.S., Edenhofer, O., Fischer, C., Habla, W., Hassler, J., Johansson-Stenman, O., Lange, A., Polasky, S., Rockström, J., Smith, H.G., Steffen, W., Wagner, G., Wilen, J.E., Alpízar, F., Azar, C., Carless, D., Chávez, C., Coria, J., Engström, G., Jagers, S.C., Köhlin, G., Löfgren, Å., Pleijel, H., Robinson, A., 2019. Policy design for the anthropocene. Nat. Sustain. 2, 14–21. https://doi.org/10.1038/s41893-018-0194-x.
Sterner, T., Coria, J., 2011. Natural resource management: challenges and policy options. Annual review of resource economics 3, 203–230. https://doi.org/10.4324/9781315780894.
Stutsky, B.J., Singer, M., Renaud, R., 2012. Determining the weighting and relative importance of CanMEDS roles and competencies. BMC Res. Notes 5, 1–7. https://doi.org/10.1186/1756-0500-5-354.
Sunstein, C.R., 2014. Why Nudge?: the Politics of Libertarian Paternalism. Yale University Press.
Suntory, 2021. Succeeded in Developing a PET Bottle that Uses 100% Plant-Derived Materials (Tokyo).
Thaler, R.H., Sunstein, C.R., 2008. Nudge: improving decisions about health, wealth, and happiness, nudge: improving decisions about health, wealth, and happiness. doi.org/10.1016/s1477-3880(15)30073-6.
The Behavioural Insights Team. n.d. Barrier Identification Tool [WWW Document]. URL. https://www.bitbarriertool.com/, 3.March0.21.
Tietenberg, T., 2005. Tradable permits in principle and practice. Penn St. Envtl. L. Rev. 14, 251.
Uehara, T., 2020. Can young generations recognize marine plastic waste as a systemic issue? Sustainability 12. https://doi.org/10.3390/su12072586.
Uehara, T., Sono, M., Tsuge, T., Onuma, A., 2021. Can prior informed consent create virtuous cycle between biodiversity conservation and genetic resources utilization? J. Environ. Manag. 300, 113767 https://doi.org/10.1016/j.jenvman.2021.113767.
UNEP, 2014. Valuing Plastics: the Business Case for Measuring, Managing and Disclosing Plastic Use in the Consumer Goods Industry (Nairobi, Kenya).
van der Ven, H., Rothacker, C., Cashore, B., 2018. Do eco-labels prevent deforestation? Lessons from non-state market driven governance in the soy, palm oil, and cocoa sectors. Global Environ. Change 52, 141–151. https://doi.org/10.1016/j.gloenvcha.2018.07.002.
van Wijnen, J., Ragas, A.M.J., Kroeze, C., 2019. Modelling global river export of microplastics to the marine environment: sources and future trends. Sci. Total Environ. 673, 392–401. https://doi.org/10.1016/j.scitotenv.2019.04.078.
Vethaak, A.D., Leslie, H.A., 2016. Plastic debris is a human health issue. Environ. Sci. Technol. 50, 6825–6826. https://doi.org/10.1021/acs.est.6b02569.
Villarrubia-Gómez, P., Cornell, S.E., Fabres, J., 2018. Marine plastic pollution as a planetary boundary threat – the drifting piece in the sustainability puzzle. Mar. Pol. 96, 213–220. https://doi.org/10.1016/j.marpol.2017.11.035.
Wensing, J., Caputo, V., Carraresi, L., Bröring, S., 2020. The effects of green nudges on consumer valuation of bio-based plastic packaging. Ecol. Econ. 178, 106783 https://doi.org/10.1016/j.ecolecon.2020.106783.
Wilcox, C., Mallos, N.J., Leonard, G.H., Rodriguez, A., Hardesty, B.D., 2016. Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife. Mar. Pol. 65, 107–114. https://doi.org/10.1016/j.marpol.2015.10.014.
World Bank, 1997. Five Years after Rio: Innovations in Environmental Policy (Washington, DC).