

Activity-Based Micro-pricing: Realizing Sustainable Behavior Changes through Economic Incentives

Tetsuo Yamabe¹, Vili Lehdonvirta², Hitoshi Ito¹, Hayuru Soma¹,
Hiroaki Kimura¹, and Tatsuo Nakajima¹

¹ Dept. of Computer Science, Waseda University, Tokyo, Japan
{yamabe, hitoshi_i, hayuring, hiroaki, tatsuo}@dcl.info.waseda.ac.jp

² Helsinki Institute for Information Technology, Helsinki, Finland
vili.lehdonvirta@hiit.fi

Abstract. In this paper, we further develop the idea of combining pervasive computing techniques with electronic payment systems to create activity-based micro-incentives. Economic incentives are an effective way to influence consumer behavior, and are used in e.g. marketing and resource coordination. Our approach allows marketers and regulators to induce consumers to perform particular actions in new application domains by attaching micro-prices to a wider range of behaviors. A key challenge is designing incentive mechanisms that result in desired behavior changes. We examine two basic incentive models. Based on the results of preliminary experiments, we discuss how economic incentives can affect consumer attitudes and lead to sustainable behavior changes.

Keywords: Persuasive technology, economic incentives, mobile payment, micropayments, activity-based micro-pricing, virtual currency.

1 Introduction

Economic incentives are a powerful way of shaping consumer behavior towards more commercially efficient and environmentally sustainable patterns. For example, taxation is a common strategy to dealing with the overuse of shared resources. Free resources shared by a number of people, such as a public toilet or the natural environment, tend to be overused in a process called the tragedy of the commons [1]. This happens because each individual derives a personal benefit from using the resource, while any costs are shared between all the users. An example of such behavior is the wasteful use of free plastic shopping bags that are filling landfills. In Japan, plastic bags are usually free, but in Finland shoppers have to pay for them. This provides an economic incentive for individuals to re-use plastic bags or bring own shopping bags to stores.

However, vendors and regulators are currently limited in what behaviors they can set a price on. Only a limited range of consumers' activities can be feasibly observed in a limited number of locations. In the aforementioned example, basically consumers have two options (i.e., purchase a plastic bag or bring one's

own shopping bag) and it is manually checked at the cashier in a store. However, manual observation is efficient only in cases where the consumer does not have too many options and each activity is such that it can be easily observed. Otherwise, the cost of human resources imposes a limit on this approach. If a consumer's activities could be recognized with less cost, the power of economic incentives could be applied in a far greater range of application areas.

Two emerging topics in pervasive computing and HCI research are persuasive applications and electronic payment systems. Pervasive-persuasive applications seek to alter user behavior through the means of a feedback loop between sensor-tracked user behavior and system output [2,3]. In electronic payment systems, pervasive technologies are used to implement and deploy mobile payment solutions that enable small payments in discreet and effortless manners [4,5]. In this paper, we combine these two topics, exploring the possibility of using pervasive computing technologies to create small activity-based economic incentives that discreetly steer consumer behavior towards desired patterns. Some of these applications could be aimed towards preventing overuse of environmental resources, while others would simply enable businesses to charge for their services in a more fine-grained manner, overcoming inefficiencies and stimulating commerce [5,6].

In the following sections, we describe the concept of activity-based billing systems and refer to findings in behavioral economics to discuss how economic incentives affect a consumer's decision making process. We then present an overview of a system architecture for an activity-based billing system that supports two different incentive models. Each model corresponds to a different set of transaction flows, so that services can alter consumer behavior by choosing a different model. Finally, based on lessons learned in the prototyping process, we discuss future directions. In this paper, we particularly focus on the challenge of designing incentives that have a sustainable, long-term influence on behavior [7].

2 Activity-Based Billing System

2.1 Ubiquity of Payments

The rapid growth of mobile computing has transformed mobile devices to a medium of payment. Mobile devices are used to initiate, activate and confirm payment transactions in various kinds of services, collectively known as "mobile payments" [8]. Mobile payments are not simply an extension of normal electronic payments, as they free users from physical constraints (i.e., time and place) and allow flexible decision making that adapts to the mobile use context [9]. While new features have been added to mobile user terminals, our surrounding environments are also increasingly being embedded with ambient intelligence. To support daily tasks and events, living environments are expected to become sensitive to the presence of users. For example, elder people's activities might be monitored with sensors in order to automatically detect emergency situations. Thus, computers, sensors and network connectivity have been installed into buildings, parks, trains and everyday objects [10].

The maturity of mobile payments and the increasingly prevalent ambient intelligence technology suggest the notion of *ubiquitous payments*. As argued in [5,11], sufficiently fine-grained tracking of user activity makes it possible to implement accurate pay-per-use payment models in commercial services. With sufficient context information, vendors can precisely calculate the economic cost of a consumer's action, and bill accordingly. Ubiquitous interaction techniques give consumers real-time information and control over spending. Transactions of small nominal value take place frequently, since payment is associated with the consumer actions. In ubiquitous computing environments, payments become ubiquitous, too. In this section, we introduce the idea of activity-based billing systems. Figure 1 illustrates an example scenario with two types of transaction flows, case A and case B.

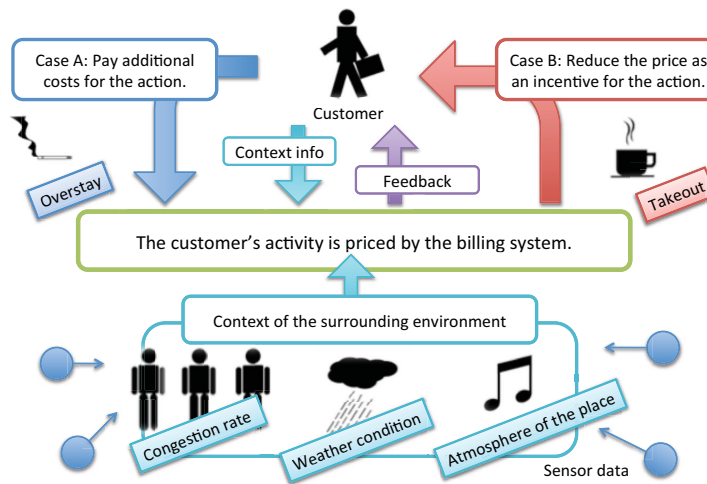


Fig. 1. Overview of the activity-based billing system with two example scenarios

2.2 Pricing Consumer Actions

A common problem for managers of busy cafes and restaurants is that customers linger in the space for a long time after their initial order without placing any additional orders, whilst taking up space from other potential customers. In Tokyo, for example, even dozens of people can be waiting for a seat outside a restaurant at lunchtime. It is difficult to keep track of how long each customer has stayed in the restaurant without making some effort to monitor them. Moreover, it would be troublesome for the staff to collect a fee for the overstay even if such customers could be identified accurately. As a result, limited seats remain occupied and from the manager's point of view, resources used inefficiently.

If the cost of customers' time spent in the cafe could be automatically priced, the situation would be different. Consider a billing system that notifies customers

how much they have to pay for spending time in the space: “an additional fee will be charged for further stay: \$0.1 for every 10 minutes”, for instance. If the customer continues to stay despite the notification, the system begins to charge the time on their mobile phone. In this way, the manager can charge an additional fee from overstaying customers, which improves the availability of seats while recouping the cost of lost business from occupied seats (case A). On the other hand, it is also possible to give rebates to customers who take actions that are beneficial to the business. For example, coffee price can be reduced if a customer orders coffee to go during lunchtime (case B).

Our key idea in this scenario is coupling economic incentives with specific actions, and implementing the resulting incentive system using ubiquitous computing technologies. Context recognition techniques provide support for tracking consumers’ actions. The payment or rebate can be carried out smoothly by mediating it with a mobile payment system. Furthermore, the vendor to determine the current price of a given action can use different pieces of context information. If the overstay charge increases as the cafe becomes increasingly packed, it will motivate customers to move on speedily. The occupancy rate of seats can be manually checked, or automatically detected with pressure sensors embedded in chairs. Methods such as discount coupons and selective taxation are sometimes used for creating economic incentives that steer consumer behavior, but compared to the approach outlined above, they are inflexible and static.

2.3 Psychological Factors and Micro-pricing Models

The prices of these actions will nevertheless be relatively small compared to the price of, for example, a cup of coffee, because the incentives are not a core part of the service. Under the notion of ubiquitous payments, transactions happen anywhere, anytime a consumer takes a relevant action. This leads to an increase in the frequency of transactions, and the price per one action will correspondingly decrease. Thus in the activity-based pricing mechanism design, we must consider how to affect consumers’ behavior with stakes of relatively low nominal value.

It is well recognized that consumers’ real economic behavior is emotional and sometimes leads to irrational decision making [12,13]. In some cases this lack of economic rationality follows quite predictable patterns. For example, people tend to avoid risk associated with uncertain gains. If there are two choices, such as (a) receive a guaranteed sum of \$10, and (b) receive \$20 with a 50% probability, choice (a) is preferred even though the expected utility is same. While risk-neutral and risk-loving attributes also exist, this preference that most people have is called risk-averse. Risk-averse decision making results from so-called loss aversion bias explained in *prospect theory* [14,15].

The practical implication of this asymmetry for economic incentive systems is that surcharges (losses) and rebates (gains) can be used to create different kinds of incentivizing effects even when their overall economic impact is the same. For example, during busy lunchtime hours, a cafe could charge patrons in the form of a small initial fee and additional time-based surcharges, encouraging short stays. During quieter hours, when the manager wants patrons to linger for as

long as possible, the equivalent sum could be charged in the form of a bigger initial fee and tiny time-based rebates. The suitable model can thus be chosen according to desired behavior.

The key challenges in implementing the activity-based billing system are designing an effective context recognition module and suitable billing policies that lead to desired incentivizing effects. In the following sections, we introduce the two basic micro-pricing models built on the earlier discussion on economic incentives, which can be used as the basis of such policies.

UbiPayment Model. As illustrated in Figure 2, the UbiPayment model is used to charge additional costs upon a consumer’s specific actions. This transaction flow corresponds to the case A in Figure 1. In the UbiPayment model, the initial cost of a service would be smaller than in the conventional case, because vendors can expect additional revenues from the micro-payments. It also has certain benefits to consumers: they obtain the possibility of leaving out unnecessary options (i.e., actions) that are normally bundled into the price of the service, and reducing costs.

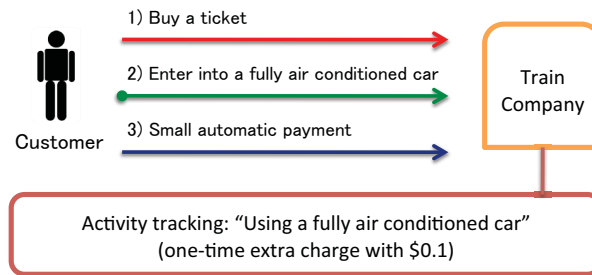


Fig. 2. Transaction flow of the UbiPayment model

UbiRebate Model. In the UbiPayment model, psychological reluctance is an important tool in influencing consumer behavior. However, sometimes it can lead to negative feelings that make customers hesitant to use the service in the first place. We therefore considered how the payment system could reduce this reluctance without changing the total volume of transactions. As illustrated in Figure 3, the idea of the UbiRebate model is to return some amount of money back to the buyer depending on the buyer’s actions. The main idea here is eliminating the “paying” process from the automatic payment system. In this approach, the initial payment is set higher than in the UbiPayment model, but rebates are paid for particular activities instead of additional payments.

The concept of this approach comes from psychological aspects of consumption behavior. In general, people resist paying from their wallet, but want to “get” something instead [4]. The UbiRebate model automatically gives micro-rebates that replace the automatic payments for opposite actions. The UbiRebate model enables vendors to implement an automatic billing system that overcomes the consumer reluctance issue. Contrary to the automatic payment case, consumers

may feel happy when they get a rebate for their actions, even though the total economic impact would be the same. Moreover, there is no satiation in the pay-as-you-do model, but the amount of maximum payment is ensured in the rebate-as-you-do model. The models consist of simplified transaction flows, and each one represents different incentive design. Thus it is possible to replace, combine, and switch the models according to a vendor's objectives.

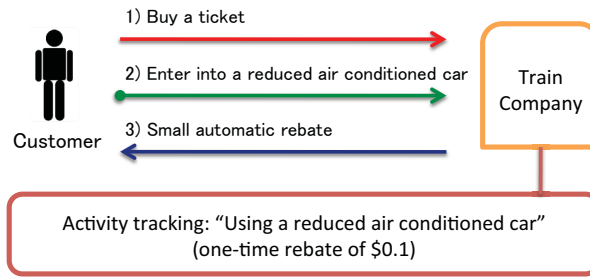


Fig. 3. Transaction flow of the UbiRebate model

3 System Architecture

In this section, we describe the system architecture of the billing system (Figure 4). The system is composed of user side modules and service side modules.

3.1 User Side

Consumers are assumed to have a mobile device for communicating with services and conducting transactions. The transaction management module handles transactions, such as payments and rebates. The module also records all transactions into a database called Log DB, which can be used for error recovery. The service discovery module detects available billing systems within range of the device's wireless connectivity (e.g., Wi-Fi, Bluetooth). The communication module establishes a connection to the detected billing system and encrypts data before transferring it to the service.

3.2 Service Side

The billing system must recognize the consumer's activities within the scope of the service in order to price and bill the behavior, and provide feedback. The context recognition module handles inputs from the consumer's devices as well as sensors that are installed in the environment. Pre-configured sensor analysis algorithms generate context information required by the billing engine. The billing engine gathers the context information and also the consumer's personal information, if necessary. The service's billing rules are pre-configured into a database called the billing policy DB; the engine calculates the applicable payment or rebate amount according to the policies set in the DB.

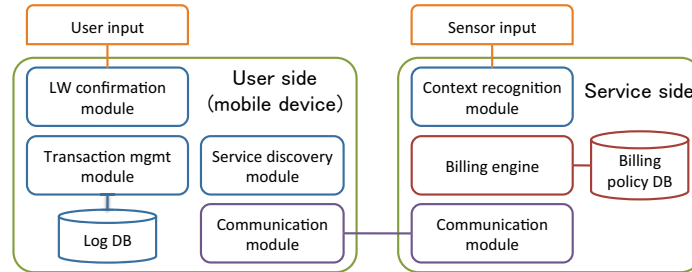


Fig. 4. System architecture of the billing system

4 Evaluation

In the above sections, we explained two basic models of activity-based micro-pricing. In order to evaluate the feasibility of these concepts, we performed an experimental study. In the sections below, we describe the methods, implementation and results of the evaluation.

4.1 Method

In order to observe how consumers might regard activity-based micro-pricing in real settings, we set up an experimental environment in our laboratory. The experimental environment was presented as a Japanese-style comic cafe (*manga kissa*), and several kinds of services were installed as shown in Figure 5. For example, participants could play a game (Nintendo Wii), read comics, browse web sites, and use a toy gadget (Chumby). A display shows a list of possible actions where participants can check which actions are priced and how much they cost. A prototype of the billing system was developed for this study.

A mobile device (iPod Touch) was handed to participants before the study started. 1,000 JPY¹ was virtually charged into the device and participants could freely enjoy the services using the money. The remaining amount is displayed on the mobile device (Figure 5), and the participant can configure feedback settings by flipping the window. Under default settings, the mobile device periodically checks whether any transactions have been conducted or not with a 10 second interval. If remaining amount is changed, sound notification is given to the participant. The participant can change the feedback interval and enable/disable the sound notification. This feature was implemented to provide insights into appropriate feedback design.

In the experiment, we prepared two scenarios: UbiPayment and UbiRebate. Table 1 shows priced actions and corresponding price in the UbiPayment scenario, and Table 2 shows the action list in the UbiRebate scenario. For example, in the UbiPayment scenario, a participant has to pay 100 JPY at the beginning.

¹ 1 JPY \simeq 0.01 USD as of 31.3.2010.

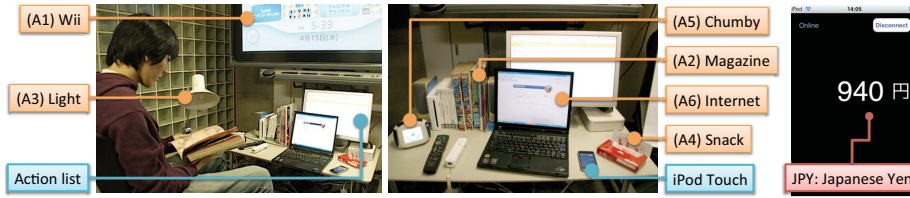


Fig. 5. A comic cafe setup and a mobile user interface for the experimental study

Table 1. Action list in the UbiPayment scenario **Table 2.** Action list in the UbiRebate scenario

ID	Action	Interval	Payment
A0	Initial cost	-	100 JPY
A1	Play Wii	1 min	10 JPY
A2	Read a comic	1 min	5 JPY
A3	Turn on a light	1 min	1 JPY
A4	Have a snack	(per 1 snack)	10 JPY
A5	Play Chumby	1 min	5 JPY
A6	Browse web sites	1 min	5 JPY

ID	Action	Interval	Rebate
A0	Initial cost	-	500 JPY
A1	NOT play Wii	1 min	10 JPY
A2	NOT read comics	1 min	5 JPY
A3	NOT turn on a light	1 min	1 JPY
A4	Have a snack	-	- JPY
A5	NOT play Chumby	1 min	5 JPY
A6	NOT browse web sites	1 min	5 JPY

Then, if the participant plays a Wii game, 10 JPY will be automatically withdrawn from their mobile device per minute. In contrast, in the UbiRebate scenario, the participant has to pay a bigger initial cost than in the UbiPayment scenario (500 JPY). However, if the participant does *not* use services, the corresponding amount of money is automatically rebated to their mobile device. For example, if they play a Wii game, the sum of all the actions' prices excluding A1 is rebated each minute.

Participants were instructed to stay in the room for 10 minutes for each scenario. While the study was performed, we monitored the room with a web camera and used the Wizard-of-Oz technique instead of using the context recognition module explained in Figure 4. In the monitor's display, a check list is shown and performed actions can be checked accordingly. Then the amount of payment/rebate is automatically calculated, and the remaining amount is updated on the mobile device's display. Six university students joined this study as participants (male: 5, female:1, age: 22-25). We recorded how they configured the feedback settings in the experiment. We also asked several questions about their impressions regarding activity-based micro-pricing at the end of the test.

4.2 Results

On average, the participants performed approximately 2.5 different types of actions in the UbiPayment scenario, and 2 kinds of actions in the UbiRebate scenario. As shown in Table 3, they felt that the test duration was not long (Q1), and the price of payments/rebates was neither expensive nor inexpensive

(Q2 and Q4). The responses to Q3 and Q5 imply that the UbiRebate model affected the participants' mental state slightly stronger than the UbiPayment model. However, due to the size of the user study, we cannot find significant differences from the results. Moreover, some of the participants pointed out that camera monitoring was one reason for their anxiety, so we cannot assert that loss-aversion effects in the UbiPayment model are the only explanation for the responses to Q3.

Table 3. Questions presented to the participants and the mean responses (5-point Likert scale)

	Question	Point
Q1	What do you think about the duration of the test? (5: too long - 0: too short)	2.5
Q2	What do you think about the size of the payments in the UbiPayment scenario? (5: too expensive - 0: too inexpensive)	3.0
Q3	Did you feel nervous or anxious in the UbiPayment scenario? (5: strongly felt - 0: did not feel)	3.1
Q4	What do you think about the size of the rebates in the UbiRebate scenario? (5: too big - 0: too small)	3.0
Q5	Did you feel happy or satisfied in the UbiRebate scenario? (5: strongly felt - 0: did not feel)	3.3

In the experiments, only two participants customized the time interval of the sound notification. In the questionnaire, they commented that frequent sound interruption was annoying. One of the participant felt that even rebating becomes annoying due to frequent notification. Alternative ideas in their comments are notifications with vibration, notifications without sound, and notification with price limitation. Almost of all participants preferred to decrease notification frequency, and 7.2 minutes was the average interval that they would set if the activity-based micro-pricing got realized. Some of the participants also commented that simple authentication or confirmation is needed in the payment transactions, but it is not necessary in the rebating transactions.

5 Discussion and Future Work

In this paper, we examined the concept of activity-based micro-pricing. Even though economic incentives could potentially be used in a persuasive way to create new business opportunities and resource conservation strategies in many areas, the cost of manual activity recognition prevents their widespread use. We proposed applying ubiquitous computing technologies to implement effective activity recognition, and examined ways of billing consumer activities in a wide variety of situations. In our vision, vendors can effectively charge for users' activities on a per-action basis. At the same time, wider choice is provided to the consumer, who can avoid unnecessary costs that are normally bundled in the price of various services. In order to bring the concept into a concrete shape, we introduced two different models and conducted a small user study. In below

sections, we discuss design issues derived from the experiments and identify future directions towards sustainable behavior change.

5.1 Conveying Information for Deeper Understanding of Actions

The activity-based micro-pricing system induces a consumer to perform particular actions by controlling the level of psychological response applied to them (i.e., anxiety in the UbiPayment model and satisfaction in the UbiRebate model). However, a key issue is how to make the behavior changes achieved through such incentives sustainable. For example, if supermarkets start to charge a fee for plastic shopping bags, consumers will stop using them in order to avoid an economic loss, but no real change is achieved in attitudes or knowledge concerning the importance of reducing plastic bag consumption and resource consumption more generally. If the supermarkets start to provide the plastic bags for free again, consumers will go back to their original mode of behavior.

This story can be explained with the *elaboration likelihood model* (ELM) [16]. The ELM postulates that people processes information in two different ways: the central route and the peripheral route. The choice of route affects people's attitude, and the central route that provides high elaboration leads to stronger attitude formulation than the peripheral route. If people processes the messages presented from a persuader (e.g., how plastic bags reduction contributes to protect the environment) in the central route, they understand the meanings of the action consciously; and thus the behavior change will become more sustainable. On the other hand, economic incentives possibly lead people to use peripheral route, since the economic value is intuitive and attractive enough to change their behavior without consciousness.

In the user study, we discovered that the way in which we communicated the pricing system or billing policy to the "customers" of the cafe was probably insufficient. We visualized the billing policy as an action list, but a more detailed explanation (e.g., how each action is defined and recognized by the system) should probably have been available. Moreover, in order to persuade consumers rather than scare them away, the overall idea of activity-based pricing probably needs to be effectively communicated. The presentation method should draw the consumers' attention, and should be lightweight so that consumers can recognize and process the message through the central route. However, the route choice and the cognitive response to the message also changes depending on a consumer's motivation and ability.

5.2 Hybrid Incentive Design for Sustainable Behavior Change

One possible solution to the problem is adding playfulness to the system design. For example, Nakajima *et al.* proposed an "ambient lifestyle feedback system" to effect changes in our daily behavior [17]. They developed several kinds of pervasive applications while considering emotional engagement. For example, if a child does not brush their teeth in the correct manner and frequency, a virtually presented aquarium becomes dirty and its virtual fish fall sick. The virtual

aquarium is installed in a bathroom, so pleasant and unpleasant feelings evoked by the application are shared among family members. Thus social pressure provides motivation for each individual to keep the aquarium clean through proper tooth brushing behavior. Providing accumulated feedbacks in the interaction loop allows a user to understand the importance of sustainable behavior change, and emotional engagement contributes to keep their attention to the service.

Affecting a consumer's normative belief is another approach. The *theory of planned behavior* (TPB) defines subjective norm as one of general constructs that guides a person's behavioral intention [18]. The subjective norm represents perceived social pressure, and it composes from normative beliefs that refer to behavioral expectation the person perceives in a social community. As aforementioned, the social pressure is expected to compensate the short comings of an economic incentive based approach. Shiraishi *et al.* developed an application called *EcoIsland*, which is a system persuading individuals to reduce CO₂ emissions [3]. In their work, economic incentives are implemented as EcoPoints, a virtual currency used in EcoIsland. Users can earn EcoPoints by reporting achieved ecological actions, and the points can be used to purchase items to decorate their virtual island in a way that visualizes each family's contributions to CO₂ reduction. In the application window, users can see other families' islands so that they can compete and improve behavior in a playful fashion.

Moreover, this social networking feature decreases dishonest behavior that is otherwise possible due to technical limitations. Since eco-friendly actions are often too complex to detect automatically, it is hard to verify users' self-reported data. The social aspect of EcoIsland allows users to monitor each other, providing peer pressure against cheating. In addition, sometimes economic incentives compel consumers to be under too much mental pressure, and services become to be uncomfortable to use in the end. Requiring too much attention also prevents consumers from enjoying the service. Thus social psychological incentives that appeals to consumers' values and ethics could relax the anxiety and reluctance.

A hybrid incentive approach could cover a wider range of users within an application. Each individual has their own preferences, and multiple types of incentives increase the chances of them developing interest in the application. For example, social psychological incentives work most effectively inside tightly linked groups or communities (e.g., families), while economic incentives operate on the individual consumer level. In a local community, users know each other and they collaborate to maximize their total benefit, instead of taking actions that are detrimental to each other. On the contrary, for bigger groups in which anonymous users are loosely coupled, economic incentives probably work better. This is because users start to make their decisions individually, and economic values become prioritized over other kinds of values. In this sense, the activity-based micro-incentive approach should thus be especially suitable for places and situations involving large numbers of general public. In addition, to avoid the tragedy of the commons with social psychological incentives, it is important to try to bring together a small community and offer a virtual space (e.g., islands in EcoIsland) to smoothen its communication and collaboration.

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