

## Stimulating Green Growth in Bandung's Food Sector: An Agent Based Simulation on Food Waste Problem

Ahmeed Arya Widino<sup>1</sup>, Khrisna Ariyanto<sup>2</sup>, Utomo Sarjono Putro<sup>3</sup>

<sup>1,2,3</sup> School of Business and Management, Institut Teknologi Bandung, Bandung, Indonesia

**ABSTRACT:** Food waste is one of the primary contributors to environmental change in Indonesia, posing a significant threat to global sustainability. Food waste in landfills contributes to more methane emissions than any other landfilled material due to its quick decay rate. One of these problems is occurring in the Bandung area, where a humanitarian tragedy caused by a garbage explosion and landslide took place 20 years, leading to a severe waste problem. A similar issue is now happening again. The latest data shows that the final waste disposal site in Bandung area has reached 1200% of its capacity, with around 45% of total waste being dominated by food waste. As a response to this situation, this study simulated the food waste problem in Bandung area, especially in a buffet restaurant to identify the mechanisms beyond the waste problem and find a solution. This study proposes an Agent-Based Modelling as a tool to explain the food waste problem in Bandung, Indonesia and how to reduce it, as shaped by different scenarios. Our simulations indicate that introducing the new policy can reduce the amount of food waste generated by the restaurant. The most effective one is the mixed instrument of rewards and fines policy.

**KEYWORDS:** Agent-Based Model, Buffet, Food Waste, Policy Implementation, Simulation.

### INTRODUCTION

Worldwide waste quantity continues to increase, leading to the escalation of environmental problems. Waste is one of main contributor of greenhouse gas (GHG) emissions, contributing 1,580 billion tones CO<sub>2</sub>e (Carbon Dioxide equivalent). It's equivalent to 3.2% of the total CO<sub>2</sub> emission worldwide.

Indonesia has also been encountering pressing problems with regards to the management of solid waste. Along with the increasing urbanization, major urban centers in Indonesia produce a high number of wasted per day. Greenhouse gas emission from those wasted make Indonesia place as the world's third-largest emitter in the waste sector (Aprilia, 2021).

One of the main components of waste is the food waste. Food waste is a food that is ready for consumption by humans but is simply thrown away and ends up piling up in the landfill. When food is discarded, all inputs used in producing, processing, transporting, preparing, and storing discarded food are also wasted. Production, transportation, and handling of food generate significant Carbon Dioxide (CO<sub>2</sub>) emissions and when food ends up in landfills, it generates methane, an even more potent greenhouse gas. Due to its quick decay rate, food waste in landfills is contributing to more methane emissions than any other landfilled materials (Krause et al., 2023).

Indonesia is one of the countries with the highest rates of food loss and waste. The report by the Food Sustainability Index (FSI) in 2016 places Indonesia as the second largest producer of food waste in the world. Bappenas' research in 2021 also accumulated the economic losses over the last 20 years due to food waste, which are equivalent to 4-5% of GDP, or around IDR 213 trillion – IDR 551 trillion per year. In 2024, Indonesia ranks first in Southeast Asia as a food waste producer with a volume of 14.73 million tons/year, according to the United Nations Food Waste Index Report. The big contribution to wasted food comes from hotels, restaurants, catering services, supermarkets and the behavior of people who like to leave the food behind.

The high volume of food waste leads to an irony. Indonesia, as a developing country, still faces two conflicting food problems. On the one hand, there is a large amount of food that was not used as it should be, while on the other hand, there are still a lot of people who have not fulfilled their food needs yet. Reducing food waste presents an opportunity to lower costs and address some of the most significant environmental and social challenges of our time: combating climate change and alleviating food insecurity.



Bandung, as one of the most populous cities in Indonesia, has been experiencing a continuous waste problem that has not stopped for decades, even though governments have come and gone. This city has already experienced a waste crisis several times, starting in 2005 because of the explosion at the Leuwigajah final disposal site, and it has happened again in 2023 until now at the Sarimukti final disposal site (the replacement for the Leuwigajah final disposal site).

According to Badan Pusat Statistik (BPS), waste in Bandung is primarily composed of food waste and leaves (44%), followed by plastic (18%) and paper (13%). The food waste and leaves almost made up to half of the total waste in Bandung, and if we can reduce it, it will decrease the total waste significantly. The data about the waste type in Bandung can be seen in Table I.

**Table I. Waste type in Bandung**

Waste Type	Waste (M <sup>3</sup> /Days)	Percentage
Food Waste and Leaves	772,69	44,51%
Woods and Twigs	69,09	3,98%
Paper	227,76	13,12%
Plastic	324,28	18,68%
Metal	15,62	0,90%
Clothes	82,46	4,75%
Rubber and Leather	41,32	2,38%
Hazardous Waste	131,42	7,57%
Others	71,35	4,11%
<b>Total</b>	<b>1.735,99</b>	<b>100%</b>

To minimize the waste crisis, the government of Bandung has made a program, namely Kang Pisman (Kurangi, Pisahkan, dan Manfaatkan) or in English, to reduce, separate, and utilize the waste. This program started in 2018. It's a socialization program that cooperates with the leader in every district to help people sort their trash, whether it is organic, inorganic, or toxic. The objective of this program is to reduce the pile of trash in the landfill, because when people can sort out their own trash, the waste problem will be addressed in the household, so it cannot overburden the landfill. The problem is, 50 per cent of the waste that is thrown away is organic waste. In fact, if we can sort the waste at home, there will be no more organic waste thrown away at the landfill, it can be used for other things like fertilizer, animal feed, or donated to an organization that can recycle that waste. There is also a Kang Pisman school where you can get educated on how to reduce, separate, and utilize the waste at home.

But as of August 2024, Sarimukti landfill (the final disposal site), which should only accommodate 2 million cubic meters of waste, has now recorded the achievement of accommodating as much as 24 million cubic meters. It means that the final disposal site is already overloaded by 1000%. Before June, the overload capacity was more than 800% and in November 2024, the overload was even crazier, up to 1200%. This also means that the "Kang Pisman" program is not effective enough to reduce the waste problem in Bandung. The waste is not reduced but goes up instead, up to 200% every two months. Not only that, the increase in waste was already happening in the last three years in Bandung (Figure I).

There are several reasons why the government program is not effective enough to reduce the waste in Bandung, like poor handling practices in the food retail (poor storage), or how the retail or market structure works in Bandung (unsold products just go to waste), but the most important thing is the consumer behavior. With the "Kang Pisman" program, the government is too focused on the household problem by providing education on how to utilize the waste as the final product. It doesn't have a significant impact on consumer behavior, as people often eat oversized portions or overorder. Some consumers take more than they can eat and don't bring the leftovers home.

This study tries to see why the food waste has a high number in Bandung, even after the introduction of "Kang Pisman" (Kurangi, Pisahkan, Manfaatkan) in Bahasa term or the reduce, separate, and utilize program in English. The objective of this research is to see the mechanism that can explain the high amount of food waste in Bandung and what is the best policy scenario that can effectively reduce this food waste. This study focused on the reduction (Kang) in the "Kang Pisman" program.

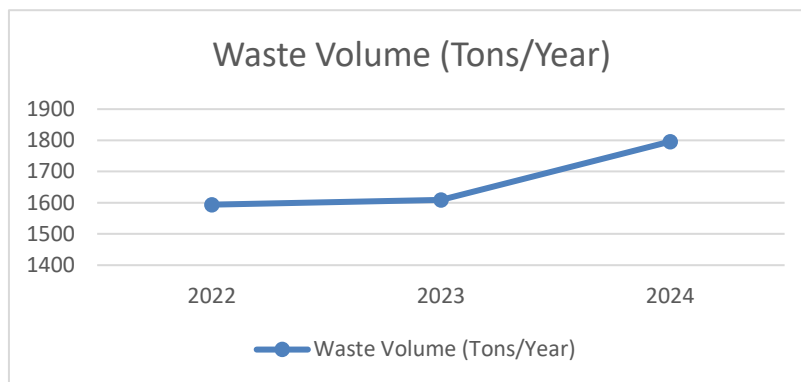


Figure I. Waste Volume

Earlier studies have noted that climate change education and communication have evolved beyond the challenge of convincing people that human agency is responsible for creating climate change (Toivonen, 2022). People in general were so self-centered, driven by habit and money, and consumption-oriented that only strict regulations, drastic price changes and technological innovation could possibly achieve widespread behavioral change (Neebe et al., 2011). Because of that, this study tries to learn what regulations can reduce the amount of food waste.

Based on the research objective, this research will be conducted to answer those research questions: (1) What kind of mechanism can explain the increase of food waste in the Bandung food sector, and (2) What kind of policy can reduce the food waste in the Bandung food sector?

## THEORETICAL REVIEW

### Food Waste

Food waste is a serious global problem. Efforts to reduce food waste are closely linked to the concepts of circular economy and sustainability. In a circular economy, products and materials are kept in circulation through processes such as maintenance, reuse, refurbishment, remanufacturing, recycling, and composting.

Food waste is a societal challenge drawing a burgeoning amount of attention in the agendas of public and private actors. In developed countries, consumers are responsible for the largest share of waste throughout the value chain. This implies the waste of valuable resources, such as soil, energy, and water, as well as the unnecessary emission of huge amounts of CO<sub>2</sub>, contributing to climate change. There has thus been an increasing focus on interventions aimed at reducing food waste at the consumption stage (Piras, Righi, et al., 2021).

In the restaurant industry, the concept of plate waste generally refers to the quantity of served food uneaten by customers. Although plate waste is unlikely to be completely eliminated, high plate waste often indicates operational deficiencies, such as undesirable food quality, incorrect portion sizes, or menu ineffectiveness (C. Kuo & Shih, 2016).

Waste behaviour is intrinsically social because of its economic, environmental, and ethical implications (Piras, Pancotto, et al., 2021). First, the visibility of one's waste behaviour is limited to the members of a restricted group, such as one's family, so it cannot be subject to social monitoring. Second, wasting is a repetitive choice resulting from well-established habits. Third, waste is the outcome of a decision-making process focused on the individual consumption of resources.

When referring to food, individual opinions and behaviour, and the influence that social norms exert on them, show a unique complexity. The literature on consumer psychology has recognized that food choices result from a wide range of factors, including moods, distraction, sensory cues, and psychology (Bublitz et al. 2010), as well as from social influence (McFerran et al. 2010).

### Operant conditioning

Operant conditioning is a theory of learning where behaviour is influenced by its consequences. Behaviour that is reinforced (rewarded) will likely be repeated, and behaviour that is punished will occur less frequently (Skinner, 1938).



The research by Skinner, as the father of Operant Conditioning, was based on Thorndike's (1898) Law of Effect. According to this principle, behaviour that is followed by pleasant consequences is likely to be repeated, and behaviour followed by unpleasant consequences is less likely to be repeated. Skinner introduced a new term into the Law of Effect: reinforcement. Behaviour that is reinforced tends to be repeated (strengthened); behaviour that is not reinforced tends to die out or be extinguished (weakened).

Skinner studied operant conditioning by conducting experiments using animals, which he placed in a "Skinner Box", that is, a device used to objectively record an animal's behaviour in a compressed time frame. An animal can be rewarded or punished for engaging in certain behaviours, such as lever pressing (for rats) or key pecking (for pigeons). Skinner identified three types of responses, or operant, that can follow behaviour.

- Neutral operant: Responses from the environment that neither increase nor decrease the probability of a behaviour being repeated.
- Reinforcers: Responses from the environment that increase the probability of a behaviour being repeated. Reinforcers can be either positive or negative.
- Punishers: Responses from the environment that decrease the likelihood of a behaviour being repeated. Punishment weakens behaviour.

B.F. Skinner's theory of operant conditioning describes positive and negative reinforcement. In positive reinforcement, a response or behaviour is strengthened by rewards, leading to the repetition of the desired behaviour. The reward is a reinforcing stimulus. Negative reinforcement is the termination of an unpleasant state following a response which is 'rewarding' to the animal or person. Negative reinforcement strengthens behaviour because it stops or removes an unpleasant experience.

Skinner demonstrated the effectiveness of positive reinforcement by placing a hungry rat in his Skinner box. The box contained a lever on the side, and as the rat moved in the box, it would accidentally knock the lever. Immediately, a food pellet would drop into a container next to the lever. After being placed in the box a few times, the rats quickly learned to press the lever directly. The consequence of receiving food if they pressed the lever ensured that they would repeat the action again and again.

Skinner showed how negative reinforcement worked by placing a rat in his Skinner box and then subjecting it to an unpleasant electric current, which caused it some discomfort. As the rat moved in the box, it would accidentally knock the lever again. Immediately, the electric current would be switched off. The rats quickly learned to press the lever directly after being placed in the box a few times. The consequence of escaping the electric current ensured that they would repeat the action. In fact, Skinner even taught the rats to avoid the electric current by turning on a light just before the current was applied. The rats soon learned to press the lever when the light came on because they knew that this would stop the electric current from being switched on.

### *Agent-Based Modelling*

Simulation is a significant methodological approach to theory development in the literature focused on strategy and organizations (Davis et al., 2016). Through developing theories and exploring their consequences, simulation is well-suited for the study of complex behavioural systems because it shows the greatest utility for gaining theoretical insight (Harrison et al., 2016).

One of the simulations is an Agent-Based Model (ABM). ABM focus on modelling the behaviours of adaptive actors who make up a social system and who influence one another through their interactions, where the behaviour of the system is an emergent property of the interaction of the agents.

This study used Agent-Based Modelling (ABM) as a method to answer the research question in the Introduction section. We believe that this is the appropriate method to see how the agent's behaviour can affect their choice to waste the food or not. We use the term "reinforce" from the operant conditioning theory in the form of reward (reinforce positive) and fine (reinforce negative) to see if the guests in the restaurant industry can form a new norm to minimize the food waste. The originality of this research lies in the simulation models, which can test the effectiveness of various interventions in the simulation on how to reduce food waste. The research is expected to contribute to the existing body of knowledge on the Agent-Based Modelling method in the context of food waste.



**METHODOLOGY**

This research uses Agent-Based Modelling (ABM) as a method. ABM is the computational study of systems of interacting autonomous entities, each with dynamic behaviour and heterogeneous characteristics (Heckbert et al., 2010). The agents interact with each other and their environment, resulting in emergent outcomes.

A fundamental approach to creating ABMs is called explanatory modelling. In this approach, we first define a set of agents and rules, and then we explore the emergent patterns that arise from the agents' interactions by varying the model's parameters. ABMs can be relied upon to examine how a system will respond to developments such as the introduction of a new policy.

We observe an all-you-can-eat food-service facility or a buffet as a complex system. These systems are characterized as being constituted of many individual agents that follow certain simple rules without a leader or a coordinator (Mitchell, 2009). We introduce our model by discussing the main steps involved in designing an ABM, as outlined in Table II.

**Table II. Designing Agent-Based Modelling**

Step	Details
1. Establish the conceptual design and motivation	Establish the reasons to utilize agent-based modelling and study the phenomena of interest.
2. Define the agents and their properties	Define the agents and use attributes and time-varying variables to encode the properties and characteristics of the agents in the model.
3. Formalize the governing dynamics of interactions	Formalize how agents interact with each other within the spatial and temporal boundaries.
4. Define objective functions and implement the model	Design objective functions to quantify the emergent behavior of agents.
5. Introduce scenarios and justify the initial values	Specify the scenarios of interest to launch simulations. Provide the logic behind the selection of the initial values.
6. Explore the behavior space of the scenarios	Perform numerical analysis to explore the behavior space of the model and derive intuitions.

*Agent Properties and Global Variable*

We capture the structure of an all-you-can-eat food service or buffet  $B = \langle F, G \rangle$ , where  $F$  is the set of food station agents, and  $G$  is the set of guest agents. Food stations have the following attributes and state variables:

- Each food station has two attributes: food type (e.g., meat, fruit, rice, etc) and a wait time necessary to make a single serve.
- Each food station agent has a state time-varying variable that is the available number of food items, and the queue in front of the station. The initial available number of food items is a fixed number for all stations.

The set  $G$  represents agents who visit the food-service facility to consume food. Guests have the following attributes and state variables:

- Each guest has an  $m$ -dimensional attribute  $E_j = [e_1, e_2, \dots, e_m]$  capturing her preference for each type of food provided in the food service facility, where  $m$  is the number of food items provided in the facility. The preferences are real non-negative numbers that are randomly generated (using a Uniform distribution), and then normalized so that their sum is equal to 1.
- Each guest agent  $j$  has an appetite level and hunger intensity as the state variable. The initial values of hunger-intensity and appetite-level are randomly generated using a Uniform distribution such that  $1.0 \leq h_j \leq 1.2$  and  $1.05 \leq a_j \leq 1.3$ . Hunger is a complex physical sensation triggered by the body's nutrient deficiencies. And appetite is an affective state that can be triggered by stimuli such as the smell of food and the anticipation of its taste (Lowe and Butryn, 2007; Grossman, 1955). Hence, we refer to appetite as a "desire to eat", and hunger as a "need to eat".



We summarize the structure of our model in Table III for an all-you-can-eat food or buffet service facility (S, G).

**Table III. Attribute and State Variable**

Agents		Description	Domain
Global Settings		Number of Food Types	{3,4,5,6}
		Total Food Quota	2200 (Normal) & 3900 (Busy)
Food Stations	Attribute	Food Type	{1,2,3,4}
		Wait time	1 tick (30 seconds)
	State Variable	Available Food Item	Initially equal for all food stations
		Queue	Subset of Agent G
Guest	Attribute	Preference for each Food Type	$0 < e < 1$
	State Variable	Appetite Level	$1.05 \leq a_j \leq 1.3$
		Hunger Intensity	$1.0 \leq h_j \leq 1.2$

*Food Consumption Process*

In our model, guests choose food according to their food-type preferences, hunger-intensity, and appetite-level. The primary objective of guests is to satisfy their hunger and appetite by taking food that best matches their preferences.

Upon arrival at the food-service facility, guests will select a station and wait in the queue for the selected station to take their food. When they reached the front of her selected station's queue, for each empty spot on her plate, they would choose to take a food item or leave the spot empty. Next, they will decide to start eating her food, take additional food from her current station, or move to the queue of another station. When the guest finishes consuming food (eating or wasting), they will decide to leave the food service or go for the next plate. Throughout the food consumption process, the appetite-level and hunger-intensity of guests gradually decrease. The food consumption process can be seen at Figure II.

Through the simulations, agents make decisions to take and consume food. Those decisions are governed by the agent's internal factors, such as hunger-intensity, appetite-level, and food-type preferences, and external factors. Since guests' decisions are binary (e.g., take food or not and stay or leave), we use Bernoulli distributions to design and implement the process of decision-making in the following steps.

Step 1 – Upon arrival of a guest agent at the food service facility, the first decision to make is selecting a station to take food. A guest  $g_j \in G$  ranks each station  $s_i \in S$  using Eq. (1), where  $E_j[f_i]$  denotes the guest's preference for the type of food  $s_i$  provides. The exponent factor  $w_i | Q_i |$  decreases the rank of stations in the presence of long queues.

$$rank = E_j[f_i] * e^{-w_i | Q_i |} \dots (1)$$

Step 2 – Guest  $g_j$  decides to take food for each empty spot in her plate according to Eq. (2) when she arrives at the head of her selected station's queue.

$$take\ food = Bernaulli \{ \min(a_j * e^{-(1-h_i)}, 1) \} \dots (2)$$

Step 3 – If the guest's plate is not full, they will decide to start eating (go to step 4), take more food from their current station (go to step 2), or move into the queue of another station (go to step 1). This decision is made in the same manner as the previous step, using Eq. (2).

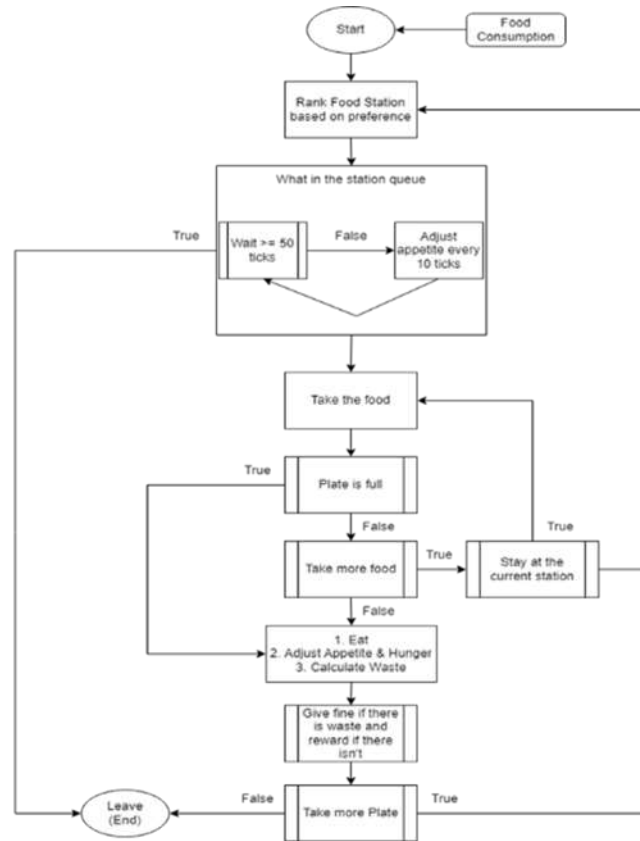


Figure II Food Consumption Process

Step 4 – When the guest decides to start eating, they will decide whether to eat or waste each food-item using the success probability presented in Eq. (3). We include the guest's serving satisfaction by measuring the distance between the guest's preferences  $E_j$  and the types of food items taken. Function (4) (PrefD) defines the mentioned measurement.

$$eat = Bernaulli \{ \min (h_j a_j e^{-0.1 * PrefD(E_j, P_j)}, 1) \} \quad \dots (3)$$

$$PrefD(E_j, P_j) = \sqrt{\sum_{type=1}^f (E_j[type] - ((\sum_{p \in P} 1)/f))^2} \quad \dots (4)$$

Step 5 – After consuming (eating or wasting) the food-items on the plate, the guest decides whether to go for another plate or to leave the food-service facility. This decision is made by Eq. (5) with the hunger intensity as its dominant factor.

$$next\ food = Bernaulli \{ \max (0, h_j - e^{-a_j}) \} \quad \dots (5)$$

Moreover, during Step 4 (decision to consume food), the hunger intensity and appetite level of guests decrease in the following way: for each food-item taken, the appetite-level decreases by 0.05, and for every item eaten (not wasted), the hunger-intensity decreases by 0.07. Additionally, agents lose their appetite by waiting too long to eat. For every 10 ticks of waiting in a line, an agent's appetite decreases by 0.02. However, if an agent waits more than 50 ticks, the guest will leave the food service facility without taking any food.

Also, the policy for rewards and fines happened during Step 4. If the guest gets a reward, the probability of wasting the food is decreased, while not affecting hunger intensity and appetite level. And if the guest gets a fine, the probability of wasting the food is also decreased, but it reduces the appetite level.



## *Objective Function*

We provide three objective functions to study the collective behavior of the agents.

- Food Surplus is the proportion of food that is not taken from the food station.
- Food waste refers to the amount of food wasted by each guest.
- Unsatisfied Guest is the proportion of guests who have left the food-service facility without satisfying their hunger.

## *Model Parameter*

We describe six parameters to configure the settings under which a food-service facility operates. Furthermore, we use these parameters to design scenarios and launch simulations.

- Food-types is the number of food types served by all food stations (each station only serves a single food type, i.e. rice, meat, fish, vegetables, desert, etc).
- Food-station refers to the number of food-station agents.
- Operation-duration refer to the hours of operation.
- Arrival Period refer to the periods (ticks) at which new guests come to the food service facility.
- Flow-rate refer to the number of new guests on every arrival-period (randomly generated between 1 and flow-rate).
- Expected-food-quota is the total number of food-items available for consumption

## *Scenario and Implementation*

To explore the emergent behaviour of agents, we begin by introducing four scenarios: normal, rewards, fines, and a mix of rewards and fines. Normal scenarios refer to situations where there is no established policy regarding food waste. Rewards happen when you don't waste any food. Fines were given to people who waste their food. And finally, the mixed instrument of rewards and fines policy. For each of these scenarios, there is also normal traffic (during the normal season) and high traffic (during the busy season).

The space of combinations of all dynamic parameters is referred as behaviour space of an ABM. Our focus is on exploring the behaviour space of the proposed model to find a combination of parameters' values that corresponds to a minimal amount of food waste and a high quality of service. We implemented our model using NetLogo software which is a declarative multi-agent programming language and modelling environment for studying the emergent behaviour of multi-agent systems.

## **RESULTS**

### *Normal Traffic*

Normal traffic scenario represents a regular facility where up to 4 guests (flow-rate parameter) arrive at the facility at each arrival period, and 2200 food-items are prepared to be served (food quota parameter). We begin analysing the model by observing the objective function, which is food waste, food surplus, and unsatisfied hunger.

In a normal traffic scenario with a 17% food surplus, the restaurant generated up to 18% food waste. There is more leftover food surplus both in the reward scenario and the fine scenario, that is, around 23%. But the food waste can be reduced in both of those scenarios. In the reward scenario, the food waste can be reduced by 5% to become 12%, while in the fine scenario, the restaurant produced 15% food waste. The mixed instrument of reward and fine policy reduces both food surplus and food waste. The leftover food surplus decreased to 7%, while food waste decreased to 8%. There are no unsatisfied guests in the rewards scenario, whereas the other scenarios had around 2% of unsatisfied guests.



Figure III. Normal Traffic on Four Scenarios

*High Traffic*

High traffic scenario represents a regular facility where up to 8 guests (flow-rate parameter) arrive at the facility at each arrival period, and 3900 food items are prepared to be served (food quota parameter).

In a high-traffic scenario with around 24% food surplus, the restaurant produced up to 17% food waste. There is less leftover food surplus both in the rewards scenario and the fines scenario, that is, around 16%. This is different from the normal traffic when food surplus is increasing in both scenarios. The food waste can be reduced in both of those scenarios, which is around 13%. The mixed instrument of rewards and fines policy reduces both food surplus and food waste. The leftover food surplus decreased to 9%, while food waste decreased to 8%. There is no unsatisfied guest in the normal scenario and rewards scenario, while the other scenarios had around 1% of unsatisfied guests.



Figure IV. High Traffic on Four Scenarios

**DISCUSSION**

This research developed a mechanism for why there is a lot of food waste in the Bandung food sector, especially in buffet restaurants. Based on that, we tried a different scenario to reduce the food waste. Traditional models have provided insights into the problem of food waste, but often lack the granularity to understand the behaviour that drive the food waste. This research use an Agent-Based



Modelling (ABM) as a method. We use the term "reinforce" from the operant conditioning theory in the form of reward and fine to see if the guests in the restaurant industry can form a new norm to minimize the food waste. The originality of this research lies in the simulation models, which can test the effectiveness of various interventions policy in the simulation on how to reduce food waste.

The problem of reducing food waste in food-service facilities involves minimizing food waste both in terms of the food-waste and food-surplus and ensuring the quality of service (in terms of maintaining low wait-time, unsatisfied-hunger, and walk-out percentages). Our objective is to illustrate the behaviour of all proposed objective functions by exploring the behaviour space of the proposed model. This could help all-you-can-eat facilities to plan an operation setting that reduces food waste while ensuring both consumers and food-service operations feel satisfied.

There are already several studies that address the food waste problem, but these studies typically employ quantitative data analysis or case studies. For example, the research by C. F. Kuo & Shih (2016) tries to see how gender affects the reduction of "plate waste" via education and coercion in a buffet restaurant. The research was conducted over a 3-week period, encompassing six dining sessions, and measured the average plate waste in a university buffet. After an initial control week, the education strategy was used in the second week, and the coercion strategy was used in the third. The average plate waste was slightly reduced in the education week, but it was reduced dramatically in the coercion week. Just like this research, the implementation of the new policy can reduce the total of food waste. The result also stated that the female average plate waste was greater than that of male plate waste for all 3 weeks.

Apart from the gender differentiation, there are also studies to see how the differences in generational attitudes affect the food waste problem. Attitude positively and significantly affects intention and behaviour to cut down on food waste among Generation X (Purwanto et al., 2023). Among Generation Z, the responses showed that only half of the respondents were aware of food waste issues (Lemy et al., 2020). This means that without the strict regulations or the drastic measures changes, people will still oblivious to the food waste problem.

This study is inspired by the research of Ravandi & Jovanovic (2020) that has employed Agent-Based Modelling to address the food waste problem, focusing on how changes in plate size can affect the food waste produced by guests in an "all-you-can-it" restaurant. This research, on the other hand, tries to see what the amount of food waste would be if the restaurant were to apply a new rule, such as rewards for people who finish their food without waste and a fine for people who waste their food. This idea comes from the research by Kamath, Sun, & Hermans (2022), who attempt to see how green innovation will develop in a scenario with fines, incentives, and grants in the context of pollution. The results align with this research when the reward is more effective than the fine policy, where in the previous research, the fines is the least effective instrument.

The research by Desmarchelier, Djellal, & Gallouj (2013) who try to evaluate the sensitivity of the eco-innovation to environmental policies by comparing the effectiveness of two such policies: the environmental tax and consumer information gives a different result. The results suggest that the eco-tax is more effective compared to a consumer information policy, quite different with this research and the research by Kamath, Sun, & Hermans (2022).

## CONCLUSION

Our study aims to identify potential strategies for reducing waste in all-you-can-eat food service operations. We calculate the food waste as the ratio of the number of food items left on the plate and the number of food items taken on the plate. Our simulations indicate that introducing the new policy can reduce the amount of food waste generated by the restaurant. The most effective one is the mixed instrument of rewards and fines policy, followed by the rewards policy and fines policy. The mixed instrument policy can reduce up to 10% food waste if compared with the normal scenario, where there is no policy regarding food waste in both normal traffic and high traffic. But if we separate those mixed instruments, the rewards policy is more effective than the fines policy for reducing food waste. It is stated that people can be encouraged more if we give positive stimuli rather than negative ones.

An important contributor to food waste in all-you-can-eat facilities is food surplus. However, there are very few studies that quantify food surplus and its relationship with food waste. Our simulations show food surplus accounts for an average of 20% over the



normal traffic and high traffic. There is more leftover food surplus in normal traffic for the rewards scenario and fines scenario, while in high traffic, the leftover food surplus becomes less after the introduction of the new policy.

Our study also wants to ensure guest satisfaction despite the introduction of the new policy. The rewards policy can ensure guest satisfaction, while the fines policy and mix instrument policy still have unsatisfied guests.

To conclude, the mentioned relationship between food waste and food surplus suggests that further research and a rethink of priorities in food reduction strategies are needed while ensuring guest satisfaction. The simulation data from this research can be used to see the relationship between food waste, food surplus, and the unsatisfied guest, or maybe even to the extended of food preference, hunger, and appetite level. The idea from the previous research can be also applied in the future research like the differentiate gender or the generation (generation x, y, and z).

Some all-you-can-eat restaurants already charge a fine to customers if they don't finish their food. However, there is no policy yet for the rewards scenario if they do not waste any food. The rewards can be economic or social and can be immediate or delayed. The best approach for rewards is to give them a coupon every time there is no food waste by the customer to be exchanged later for a prize, and also give them a satisfaction thank you from the staff for not wasting any food. The punishment that the restaurant imposes on the all-you-can-eat buffet is usually in an economic form. It's also good to see how the difference form of reward and punishment can affect the food waste and guest satisfaction in further research.

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