Delivering Value of Composting and Recycling in Household Waste Management System: An Agent-Based Modeling Approach

Noorhan Firdaus Pambudi and Akbar Adhiutama

Abstract Community and government have different perspectives and roles in conducting household waste management system. On one hand, the government generates a policy to decrease waste to be sent to final disposal; on the other hand, the community will accept that, and without community involvement, sometimes the policy will not run well. Household waste management system policies focus on delivering value of composting and recycling in community. One of the policies is waste bank which lets the community turn their waste into money in the form of savings like in a bank. Efforts from different household waste supply chain parties such as government and communities must be coordinated. This research aims to find the exact coordination between government and communities in order to adopt household waste policies especially waste bank. This research considers possibilities to produce policies by determining community needs previously (bottom-up technologies). Agent-based modeling presents three kinds of community: the careless community (not willing to adopt waste management technologies/policies even it is profitable for them), arguing community (not willing to adopt waste management technologies/policies when it is not profitable for them), and adapting community (willing to adopt waste management technologies/policies whether it is profitable or not for them). The simulation shows that the number of adapting communities is increasing; meanwhile the number of arguing communities is decreasing. However, the number of careless communities is increasing in the first half of simulation and starts decreasing in the second half of simulation. According to this result, communities socially interact with and influence each other because in the first half, the number of arguing communities was larger than that of adapting communities, which affects the increasing number of careless communities, and then in the second half, the number of adapting communities was larger than that of arguing communities, which influence the decreasing number of

N.F. Pambudi (✉)
Graduate student in School of Business and Management Institut Teknologi Bandung, Bandung, Indonesia
e-mail: noorhan.firdaus@sbm-itb.ac.id

A. Adhiutama (✉)
Lecturer in School of Business and Management Institut Teknologi Bandung, Bandung, Indonesia
e-mail: akbar@sbm-itb.ac.id

U.S. Putro et al. (eds.), *Agent-Based Approaches in Economics and Social Complex Systems IX*, Agent-Based Social Systems 15, DOI 10.1007/978-981-10-3662-0_16

careless communities. It also shows that the role of government to maintain policies profitable for community is important.

Keywords Agent-based modeling • Community • Government • Household waste management system • Participatory action research • Waste bank

1 Introduction

Increasing population in Indonesia has led to increasing amount of waste generated by the community. Indonesian government starts to find a way in order to decrease the amount of waste which are sent to sanitary landfill. It is because sanitary landfill usage will decrease the amount of land area in one district (we consider it as district since waste management policy is conducted by district government, not national government). One way to do that is by increasing the number of waste recycled, reduced, reused, and composted in a household level.

Indonesian government through Environmental Ministry had introduced waste bank to increase recycle, reduce, and reuse activities in community. Waste bank is one policy from the government which lets the community turn their waste into money in the form of savings like in a commercial bank. But to conduct this policy, the government needs community involvement, support, and willingness to exchange their waste. This policy already showed the impact into waste tonnage which was sent to landfill in Surabaya city. Previous research in Surabaya indicated that the reduction of waste tonnage up to 7.14 tons per week was supported by the increasing number of waste bank in Surabaya by more than 50 and 30% in 2012 and 2013 [16].

The processes which are involved in this research include the waste collecting phase in the community where wastes are sold to specific/contracted small and medium enterprises or remanufacturing enterprises. There are several actors which will be observed in this research such as the community, government, waste bank administrators, and remanufacturing industries. This research aims to define behavior in each actors and its impact to performance of household waste management system.

Agent-based modeling is chosen to describe interaction among communities and government in order to gain community involvement in household waste management system. Influencing factors will also be added to the model to see how these factors will impact the dynamic of community and influence it to change its behavior, from not caring too much about their environment, especially waste, to caring about environment and adopting the policy given by government.

2 Literature Review

2.1 *Closed-Loop Supply Chain in Household Waste Management System*

Reverse logistic is the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal [11]. A forward supply chain is a network of facilities and distribution options that performs the function of procurement of materials, the transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers [8]. Composting and recycling system often occurred in reverse logistic of supply chain management. But the processes of producing packaging material in several kinds of products are involved in forward logistic and also the processes to recycling waste material to a better value of products. Closed-loop supply chain is a combination of reverse logistic and forward logistic [8].

Although collection, recycling, and disposal procedures for used and obsolete products are important components of corporate responsibility [5], collection, recycling, and disposal processes are also conducted by a third party such as scavengers in developing countries such as Indonesia. Indonesian government through regulation [10] has introduced a recycling system in household level through waste bank policies. Waste bank is a place for community to exchange their waste into money in the form of savings like in a bank. Waste bank is considered to be involved in closed-loop supply chain in household waste management system. It can be seen in Fig. 1.

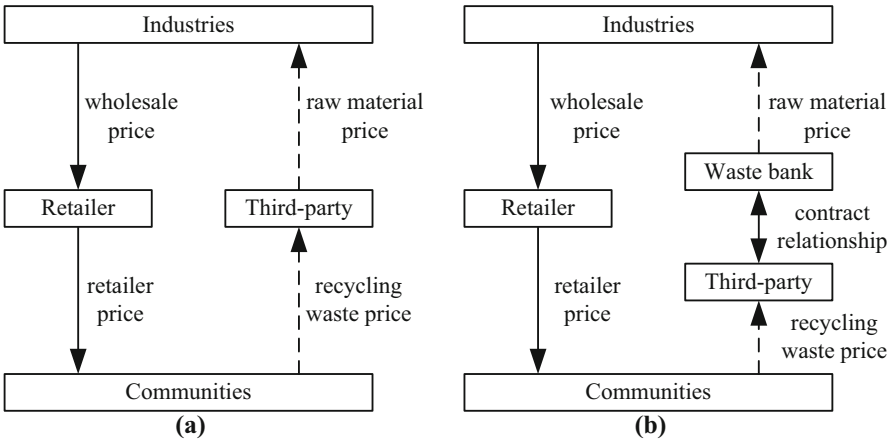

Fig. 1 Closed-loop supply chain without waste bank (**a**) and with waste bank (**b**)

In several researches, closed-loop supply chain problem was solved by several types of method. Retailer and non-retailer models of closed-loop supply chain in electronic industries are solved by defining constraints in retailer and non-retailer model [5]. A genetic algorithm approach also used in previous research for solving a closed-loop supply chain in battery recycling industry [8]. But the problem in firms' environmental behavior (dynamic of environmental behavior in Chinese firms) is solved by agent-based modeling approach [9]. The behavior in each part of closed-loop supply chain can be approximated by agent-based modeling; however, the closed-loop supply chain pricing and costing should be approximated by mathematical modeling or heuristic method such as genetic algorithm.

2.2 Waste Management System in Indonesia

Problems faced in waste management system [1]:

- Equipment capacity is not suitable.
- Equipment are less maintained.
- Development for operational personnel especially for daily worker is weak.
- Operational method suitable for each area condition is limited.
- Operational cycle in waste management is not completed because of different persons who are responsible.
- Coordination among departments in government is usually weak.
- Operational management is more focused on implementation, but in the controlling aspect, it is weak.
- Operational planning is often only used for short-term period.

In Indonesia, through Peraturan Menteri Lingkungan Hidup No. 13 Tahun 2012 about guidelines for implementation in reduce, reuse, and recycle with bank sampah (waste bank), activities for decreasing nonorganic waste are done with waste bank system. In that regulation, waste bank system that dedicated a place for separating and collecting wastes which can be recycled and have economic values had been introduced. With waste bank, societies are able to exchange their waste for a specific type which can be recycled and/or reused with money in savings that can be used in specified term. Price of waste in this regulation considered environmental cost from production processes for recycling waste into specified product until it have no economic value at all.

Current problems that happened in waste bank implementation is there are scavengers or other parties outside waste bank that doing similar activities and couldn't be controlled by government in several areas. Otherwise, the number of waste banks can't accept needs for recycling and reusing activities in some place. This regulation explained that market price is fluctuating, which affects the change in price according to market needs and also influences customers to sell their waste to buyers who offer higher price.

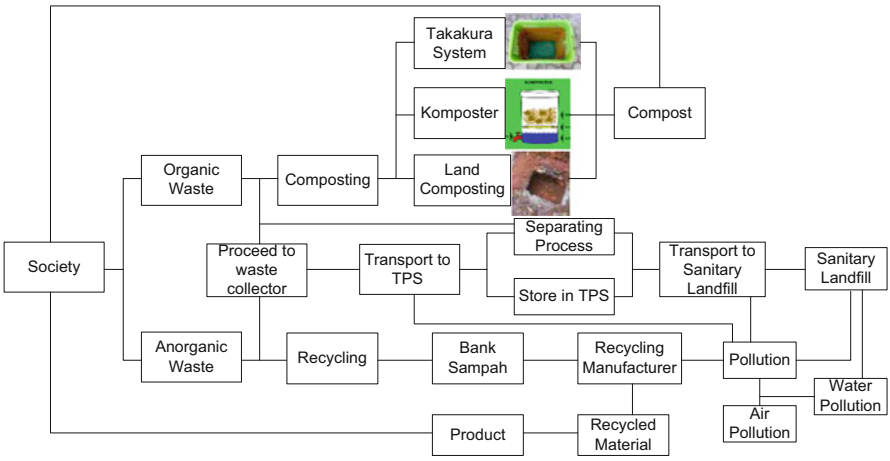

Fig. 2 Waste management system that considers waste bank and three ways of composting

This difference among the prices will affect the competition between waste bank and scavengers. Savings system that has a goal of decreasing consumptive behavior of societies can't be achieved if customers sell their waste to scavengers rather than waste bank. For that reason, societies have a decisive role in this situation for giving more integrated and sustainable system for reduce, reuse, and recycle implementation in household waste management.

Besides implementation of waste bank, government also introduced several systems that are able to support composting activities at a household level. There are three systems that are introduced by the Ministry of Environment, including Takakura system, simple composter, and composting activities, that use empty space or land in the household (this system can be done if household has an empty space). Unfortunately, those three systems can only be implemented well if there is no active participation from societies. Figure 2 illustrates the process of waste management system if all systems introduced by government that support reuse, reduce, and recycle activities can be run well.

In several researches, waste management problems were solved by several types of method. Problem in waste paper procurement optimization is solved by agent-based simulation approach [12].

3 State of the Art

Several researches have been studied about agent-based modeling in environmental aspect, such as the firms' environmental behavior [9], taxonomy of agent-based modeling in environmental management [4], modeling personality and power as evidence is brokered to support decisions on environmental risk [2], waste paper

Table 1 State of the art of this research

Author	Object	ABM	Waste management	Environmental aspect	Closed-loop supply chain	Heuristic method (LP)
[3]	Landfill construction in Hong Kong	X	X	X		
[4]	Taxonomy of ABM in environmental management	X		X		
[9]	Firms' environmental behavior in China	X		X		
[2]	Several case studies about regulation	X		X		
[12]	Waste paper procurement	X	X			X
[13]	Solid waste management in Florida, USA	X	X	X		
[5]	Electronic industries		X	X	X	X
[8]	Battery recycling		X	X	X	X
SOTA	Recycling system (waste bank) in household waste management system	X	X	X	X	Participatory action research

procurement optimization [12], single-stream recycling programs [13], and backfill in construction waste management (Gan and Cheng). Each research develops different agents and behaviors. Firms' behavior when facing environmental regulation [9] is focused on, as well as regulators or government that controls environmental risk [2]. Recycled product industries also become an agent of waste paper procurement optimization [12], as presented in Table 1.

4 Method

4.1 Participatory Action Research

In this subchapter we talk about participatory design and participatory action research. Several studies talked about participatory design and participatory action research separately. It is actually already common sense to use the terminology [15]. Designers and final users will learn from each other through feedback. Designers will lead the designing process in the initial step, giving a clear instruction and explanation on the objectives from interaction between designers and users. Clear objectives will lead the designers to focus on results, a pattern which can be formed

as alternatives of solution for problems that occurred. In PD, users and designers should be in the same position, and interventions are not allowed in generating idea process.

A lot of constraints associated with human aspects; social, culture, and religious aspects; financial and time frame aspects; and organizational aspects are faced when using PD for designing an exact product for societies (6). Most research that employs PD as its methodology discusses about discrimination issues in societies which affect opinions or unrecognized needs of several elements of societies. Discriminations on people with disabilities in developing country like Cambodia (6) and disparities in health status because of their economic class and the racial differences between white and nonwhite in the USA exist [7, 14].

Participatory design that was used in that condition is caused by this methodology giving freedom in argument for several parties who are not given an opportunity in giving their aspiration. Wanyama and Zheng [15] called it as "democracy in the workplace." PD not only gives an opportunity to marginalize or discriminate community but also can be used to give an opportunity to several parties who are not capable to develop a product but have an influence in deciding available needs in societies. Those parties are consumers of the products. Previously, PD also was used for developing digital products in an information system. Developers of IT products are well educated in computer system, but they have a limitation for making an understandable system for its consumers. PD appeared to give a description of IT products that can be used by its consumers easily [15].

Hussain et al. [6] repaired tradition system of PD by changing it into an integrated methodology as seen in Fig. 2. Previously, PD conducted with only solved designers and users in one term without any specific division of role for avoiding designer's intervention to users' idea and vice versa. Especially with the appearance of stakeholders as one part that should be needed to be involved, the previous form of PD is not strong enough to produce a solution. Detailed explanation about what kind of necessary interaction happened between designers, end users, and stakeholders is needed.

4.2 Agent-Based Modeling and Simulation

4.2.1 Purpose

The purpose of this model is to explore community involvement regarding their behavior in adopting composting and recycling systems (waste bank) which are proposed by the government. The model also examines the dynamic of different perspectives from community and government to adopt and publish policies in household waste management.

Table 2 Overview of state variables and scales

Variables	Description
Numbers of common community (agents)	The amount of common community
Numbers of careless community	The amount of careless community which will be rejected from the system
Numbers of arguing community	The amount of community which always argues about policy
Numbers of adapting community	The amount of community which adapts the policy
Rate of careless community	Ratio between numbers of careless community and numbers of common community
Rate of arguing community	Ratio between numbers of arguing community and numbers of common community
Rate of adapting community	Ratio between numbers of adapting community and numbers of common community
Careless community	Community or agents who are not willing to adapt the household waste system (waste bank)
Arguing community	Community or agents who are still arguing price and cost comparison; they are willing to adapt the household waste system if there is "cheaper" condition
Adapting community	Community or agents who are willing to adapt whether price and cost condition is not "cheaper"

4.2.2 Variable and Overview of the Model

A community and government are characterized by state variables. The variables selected are substantiated by the literature or a field survey during participatory design. Variables included in this research are listed in Table 2, with two considerations on simulation to decide which transformation will be taken by the community. The first consideration is *price and cost comparison*, i.e., whether the price is higher or lesser than the cost. If the price is higher than the cost, this condition is referred to as the "cheaper" condition. The second consideration is *willingness of community* to adopt waste bank (household waste system). If the community is willing to adopt waste bank, then the condition is termed the "willing" condition.

Initial condition of the community is called the common community. Numbers of common community or agents are 100 which will be transformed to adapting community, arguing community, or careless community. Its transformation depends on the condition of each consideration (price and cost comparison and willingness of community). If the iteration has a "willing" condition whether it has a "cheaper" condition or not, then the community will be transformed to adapting community. If the iteration has no "willing" condition because it has no "cheaper" condition, then the community will be transformed to arguing community. If the iteration has no "willing" condition but it has "cheaper" condition, then the community will be transformed to careless community. It was described in Fig. 3. Price is represented by letter "p" in the figure, cost is represented by letter "c," and threshold "p>c" means whether the condition is "cheaper" or not.

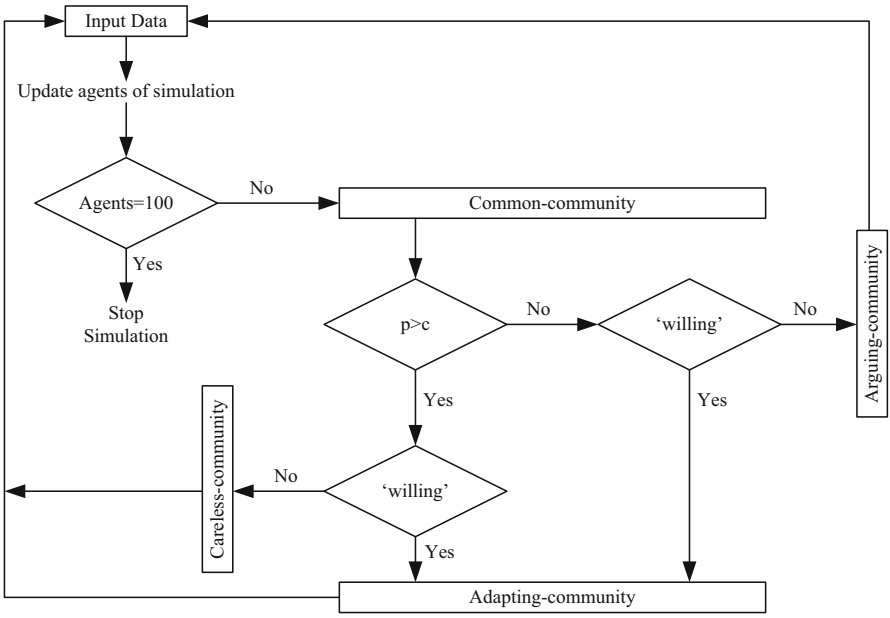

Fig. 3 Flowcharts of the model's processes

4.2.3 Model Description

This research scope is household waste management system which consists of interaction between communities and government (policy maker). Communities will accept the policy in shape of system in recycling and composting strategies in household level. Waste bank will be considered as one policy introduced by government in this model. The interaction will be dependent on type of tool provider (government or communities itself provide the composting tool), waste bank development (number and location of waste bank built in district), third-party involvement (availability of third party that maintains waste collection in household, i.e., scavengers or cleaning service paid by communities), community pressure (pressure from community to other community and government to repair their way of thinking or policies that will be made), policy pressure (pressure from policy that makes communities obey it in order to avoid sanction), the number of autocracy policy (whether a lot of policy did not consider communities' needs), and the number of democracy policy (whether a lot of policy have been considering communities' needs).

The model wants to capturing a changing behavior of communities and government in order to maintain their own perspective about the policy or household waste management system. Community can be moved from common communities (who just know the information about the policy) to adapting communities (who are already willing to adopt the policy) or to arguing communities (who will think

about the impact of policy once again before deciding) or to be rejected from the model and become a careless community who doesn't care about the policy at all. The government can change their way to produce policy by increasing or decreasing autocracy policies or increasing or decreasing democracy policies. It will be the impact to communities' perspective, and this is actually the interaction among communities and government.

4.2.3.1 Collection Phase in Household

There are several options in conducting collection phase in household waste management system. There is hiring third party (i.e., scavengers or cleaning services) who will be paid periodically by communities or no hiring third party which means communities will send the waste to waste bank or temporary final disposal site by themselves. But if waste bank is developed very well until the number of waste bank increases and the location of waste bank is possible to hiring waste bank administrators to collect our waste periodically, then there will be another option to hiring waste bank administrator in collection phase. If communities hire third party, then they will not accept the advantages of using waste bank, and in this option, communities still have an opportunity to make savings in waste bank; however, exchange value must be subtracted by collection cost previously. This will be influencing to cost in collection waste and will be considered as situation in changing behavior of communities.

4.2.3.2 Exchange Phase from Household to Waste Bank

There are several types of conducting exchange phase from household to waste bank. It will be connected to collection phase. If in the collection phase communities use third party to collecting waste, then there is no advantage that can be achieved by using waste bank. If in the collection phase communities exchange their waste independently, then they will receive advantages of savings in waste bank. If in the collection phase communities use waste bank administrator to collect their waste and exchange it, then communities will receive advantages minus their responsibility to pay waste bank administrator (collection cost using waste bank administrator services).

4.2.3.3 Collection Phase in Waste Bank

Waste bank administrators must differ waste into specific waste in their own characteristic such as plastic waste, metal waste, paper waste, etc. These activities can be conducted when waste bank administrator collects waste in household (it happened if household uses waste bank administrator services to collect their waste)

and in waste bank site. This activity will give production lead time until waste is ready to be sent to industries (small medium enterprise or recycling industries).

4.2.3.4 Selling to Industries

After the collecting phase in waste bank, waste bank administrator will sell waste to industries. Specific price will be taken for a specific type of waste. This activity will give profit and ability to pay communities for waste bank. The profit can be used as developing ability of waste bank to build another waste bank. However, building another waste bank in other location will also be government's responsibility.

4.2.3.5 Inspection from the Government About Waste Bank

Waste bank will be inspected by the government periodically, not only waste bank performance but also whole of supply chain performances in composting and recycling system in household waste management system. It is because performance of each part of supply chain such as communities, third parties, recycling and small medium enterprise industries, local government, and waste bank administrators will impact other part of supply chain. It will impact waste bank development in other local areas if there is some success story resulted from waste bank system in another local area. This experience also will be adopted by other waste bank in other local area. It is similar with technology commercialization scheme. That's the reason why agent-based modeling is appropriate for this study.

5 Results and Discussions

The model will be simulated and compared with different situation of the system. Types of situations are considered waste bank in household waste management system, household waste management system without waste bank, increasing number of waste bank and location of waste bank, and different types of variables mentioned in Sect. 4. From that comparison, this research offered several actions that must be taken in different situation, what should government do to maintain household waste management system and how the relationship between government and communities in household waste management system.

Further research can be considered about other policy besides waste bank or adopting the model with different policies based on different countries or governments. Schematic of agent-based modeling can be combined with other methods in simulation such as system dynamics or linear programming to determining cost or price which has become data input in agent-based simulation.

In this model we assumed that there are two considerations in adapting waste bank by households. There are price and cost comparison and willingness from

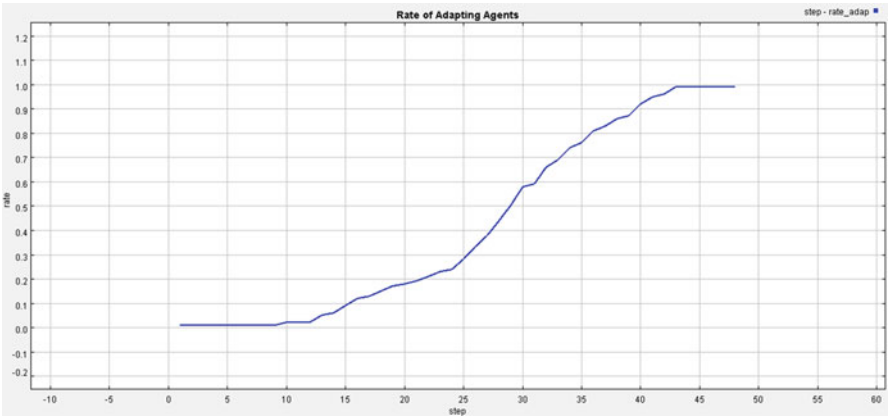

Fig. 4 Results of the simulation and rate of adapting community

community. If the price (selling price of waste exchange) is higher than cost (transportation and collection cost), then we called it as "cheaper" condition in the simulation. If there is willingness from household to use waste bank, then we called it as household "willing" to use waste bank whatever condition from price and cost comparison. The simulation used SOARS 4.1.1 to describe the result of the simulation. We want to know the rate of common community who transforms to become adapting community.

Figure 4 showed the rate of adapting community from the result of the simulation. It described that the rate of adapting community is increasing. In the beginning of simulation, the rate of adapting community is zero which means that there is no community adapting the household waste system (waste bank). Then in the end of simulation, the rate becomes one which means that all members of community or all agents have adopted the system. This increase happened because there is changing in price and cost which influences changing in "cheaper" condition.

Figure 5 showed the rate of arguing community from the result of the simulation. It described that the rate of arguing community is decreasing. In the beginning of simulation, the rate of arguing community is one which means that all members of community or all agents are arguing about the system. Then in the end of simulation, the rate becomes zero which means that there are no members of community or agents who are arguing about the system. This decrease happened because of the impact from increasing pattern for the rate of adapting community.

Figure 6 showed the rate of careless community from the result of the simulation. It described that the rate of careless community is increasing in the first half of iterations and then decreasing in the second half of iterations. This pattern happened because careless community is the transformation when the community has no "willing" in the "cheaper" condition. For "willing" condition represented by condition in the rate of adapting community because adapting community is community who always "willing" whether there is no "cheaper" condition. For

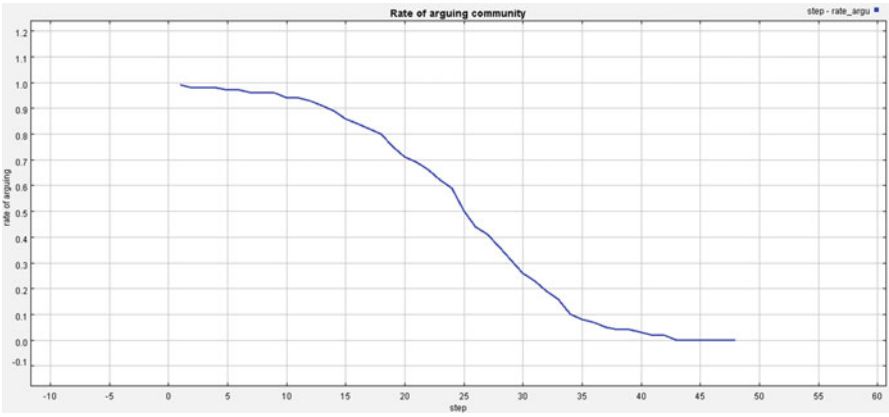

Fig. 5 Results of the simulation and rate of arguing community

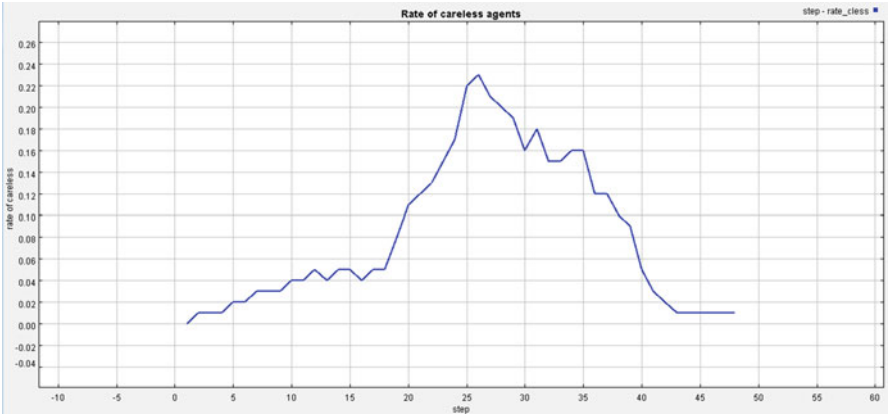

Fig. 6 Results of the simulation and rate of careless community

"cheaper" condition represented by condition in rate of arguing community because arguing community is community who has no "cheaper" condition and decide to have no "willing" before there is "cheaper" condition. In the first half of iterations, the numbers of arguing community are higher than the numbers of adapting community which made the increase in the numbers of careless community. In the second half of iterations, the number of adapting community is higher than arguing community which made the decrease in the numbers of careless community. It was shown in Fig. 7.

Figure 7 showed that when the rate of adapting community is increasing but the number of adapting community is less than the numbers of arguing community, then rate of careless community will be increasing. It is because "willing" condition is still dominated by no ("willing" = "no") value. But when the graphs are much closest to equilibrium point between the rate of arguing community and

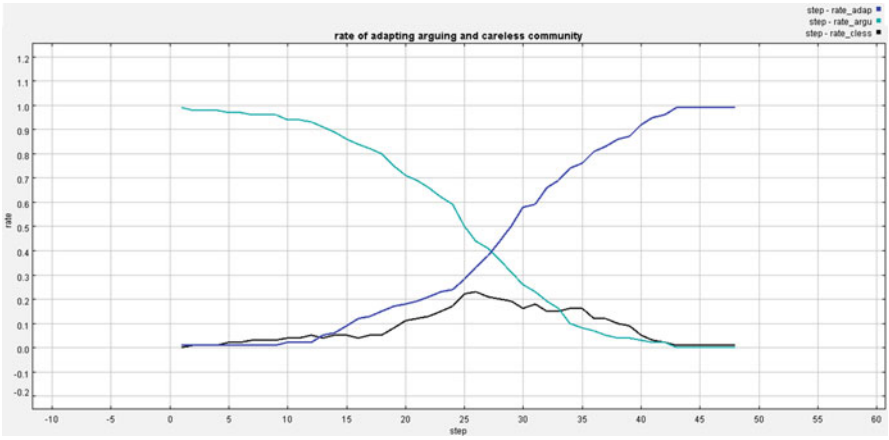

Fig. 7 Comparison between the rate of adapting community (*blue*), arguing community (*green*), and careless community (*black*)

rate of adapting community, there is a decreasing pattern from the rate of careless community although the numbers of adapting community are less than the numbers of arguing community. It means that "willing" condition is no longer dominated by no ("willing" = "no") value. The decrease becomes tight when the numbers of adapting community are much higher than the numbers of arguing community.

6 Conclusions

Price and cost which are represented by "cheaper" condition became an influencing factor besides the willingness of community to adopt the system (waste bank). Decreasing cost can be maintained by developing several policies which can eliminate transportation cost and collection cost. The role of government to provide the tools in household level to make an ease in the collecting process can eliminate collection cost. Policy to provide service which delivers waste from household to waste bank will eliminate transportation cost. This kind of policy can make cost near to zero that affects the increase of "cheaper" condition. It can be developed with the willingness of community to use waste bank rapidly, but willingness of community also must be our concern to apply waste bank in community. It is happened because there are conditions that community will transform to careless community who will have no "willing" whether the condition of price and cost comparison is "cheaper" (price is higher than cost). Further research can be considered about other policy besides waste bank or adopting the model with different policies based on different countries or governments. Schematic of agent-based modeling can be combined with other methods in simulation such as system dynamics or linear programming to determine cost or price which has become data input in agent-based simulation.

Other qualitative approach also can be considered to combine with modeling to give an insight about decision based on emotional and psychological aspect of human being. Unfortunately, this research more focuses on simulation rather than discusses about the result from participatory design or participatory action research.

From the result itself, this research proposes to maintain the number of adapting community larger than the number of arguing community. To maintain the number of arguing community, it will need more contribution from government to pay much attention in order to give more profitable condition for community when they try to adopt eco-friendly policies. This condition shows that collaboration between government and community will be needed and necessary for the future. It also gives the idea to get the research which will accommodate government and community conflict of interest. It means combination of two approaches, bottom-up approaches where ideas are generated by the community and top-down approaches where ideas are generated by the government. Combination of agent-based modeling and system dynamic is appropriate for this kind of research. Government also can use participatory action research to design new policies and technologies which are appropriate for community. Combination of design thinking and system thinking will be necessary to this idea.

References

1. Damanhuri, E., & Padmi, T. (2000, October). Reuse and recycling as a solution to urban solid waste problems in Indonesia. In *Proceeding of the international symposium and exhibition on waste management in Asian Cities*, Hong Kong.
2. Davies, G. J., Kendall, G., Soane, E., Li, J., Rocks, S. A., Jude, S. R., & Pollard, S. J. (2014). Regulators as agents: Modelling personality and power as evidence is brokered to support decisions on environmental risk. *Science of the Total Environment, 466*, 74–83.
3. Gan, V. J., & Cheng, J. C. (2015). Formulation and analysis of dynamic supply chain of backfill in construction waste management using agent-based modeling. *Advanced Engineering Informatics, 29*, 878–888.
4. Hare, M., & Deadman, P. (2004). Further towards a taxonomy of agent-based simulation models in environmental management. *Mathematics and Computers in Simulation, 64*(1), 25–40.
5. Hong, I. H., & Yeh, J. S. (2012). Modeling closed-loop supply chains in the electronics industry: A retailer collection application. *Transportation Research Part E: Logistics and Transportation Review, 48*(4), 817–829.
6. Hussain, S., Sanders, E. B. N., & Steinert, M. (2012). Participatory design with marginalized people in developing countries: Challenges and opportunities experienced in a field study in Cambodia. *International Journal of Design, 6*(2), 91–109.
7. Israel, B. A., Coombe, C. M., Cheezum, R. R., Schulz, A. J., McGranaghan, R. J., Lichtenstein, R., ... & Burris, A. (2010). Community-based participatory research: A capacity-building approach for policy advocacy aimed at eliminating health disparities. *American Journal of Public Health*, *100*(11), 2094–2102.
8. Kannan, G., Sasikumar, P., & Devika, K. (2010). A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling. *Applied Mathematical Modelling, 34*(3), 655–670.

9. Liu, Y., & Ye, H. (2012). The dynamic study on firm's environmental behavior and influencing factors: An adaptive agent-based modeling approach. *Journal of Cleaner Production, 37*, 278–287.
10. Republik, P. M. N. L. H. (2012) Indonesia Nomor 13 Tahun 2012 TentangPedomanPelaksanaan Reduce. *Reuse, dan Recycle melalui Bank Sampah*.
11. Rogers, D. S., & Tibben-Lembke, R. S. (1999). *Going backwards: Reverse logistics trends and practices*. Pittsburgh: RLEC Press.
12. Sauvageau, G., & Frayret, J. M. (2015). Waste paper procurement optimization: An agent-based simulation approach. *European Journal of Operational Research, 242*(3), 987–998.
13. Shi, X., Thanos, A. E., & Celik, N. (2014). Multi-objective agent-based modeling of single-stream recycling programs. *Resources, Conservation and Recycling, 92*, 190–205.
14. Wallerstein, N., & Duran, B. (2010). Community-based participatory research contributions to intervention research: The intersection of science and practice to improve health equity. *American Journal of Public Health, 100*(S1), S40–S46.
15. Wanyama, I., & Zheng, Q. I. N. (2010). Augmenting the participatory design concept in systems development. *Management Science and Engineering, 4*(2), 69–81.
16. Wijayanti, D. R., & Suryani, S. (2015). Waste bank as community-based environmental governance: A lesson learned from Surabaya. *Procedia – Social and Behavioral Sciences, 184*, 171–179.