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Analysis of an Indonesian food bank sustainability using system dynamics simulation

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Abstract
Foodbank is an organization that obtains food from donor organizations and individuals, proceeds the donated food products at storage facilities and distributes them to the end users, either directly or indirectly via charitable institutions. Foodbanks have been developed in several countries to tackle food waste and hunger problems. This research uses the case of FoodCycle Indonesia (FCI) as one of the food banks in Indonesia that has been in operation since 2017. The purpose of this study is to analyze the sustainability of FCI using system dynamics simulation to identify the factors that influence its sustainability. We develop the initial model based on literature and modify it according to interview results with representatives from FCI and its two partners (charitable organizations that redistribute the donated food to beneficiaries). The model consists of partners, wedding partners, food redistribution, transportation cost, community, volunteers, beneficiaries, and food balance subsystems. Based on the simulation results it can be concluded that FCI will be sustainable as long as the growth of the food supply is constant, and the organization has the financial ability to support the distribution of donated food to the beneficiaries.
Keywords: food bank; food redistribution; sustainability; system dynamics

1. Introduction

Research conducted by the Food and Agriculture Organization of the United Nations (FAO) in 2019 shows that 14% of the food produced in the world (or $400 billion per year) is not distributed to the consumers and becomes waste (FAO, 2019). This phenomenon occurs globally, both in developed and developing countries, and can have a significant negative impact on food security, the economy, and the environment (Rezaei and Liu, 2017). From an economic perspective, the decreasing availability of food in the market can increase food prices and reduce consumers' ability to access food. Conversely, sufficient or excess availability of food with substandard quality will cause food prices to fall and harm producers and farmers (Rezaei and Liu, 2017). In an environmental perspective, food waste also has a negative impact due to the exploitation of natural resources and gas emissions (Jeswani et al., 2021). The exploitation of natural resources occurs because of the required resources to produce food come from limited natural resources, which is eventually wasted. Food waste also contributes to gas emissions; about 8 to 10% of the total gas emissions produced in the world comes from food waste (UNEP, 2021). By reducing food waste, 1.4 billion hectares of land can be saved, which constitutes about 30% of the total agricultural land (Barilla CFN, 2012).

Figure 1 shows the percentage of waste and leftover food produced in each stage of the supply chain in developed and developing countries. It can be seen that, in the developing countries, food waste is higher at the upstream part of the supply chain, while in the developed countries, food waste is higher at the downstream part of the supply chain.

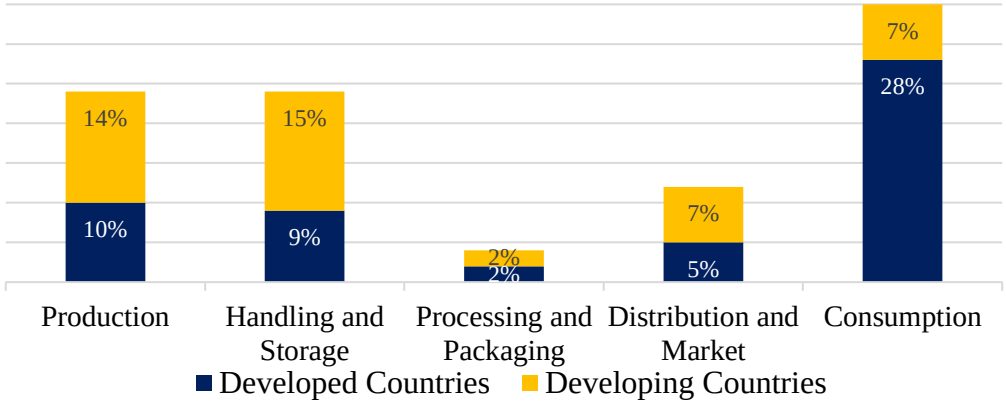

Figure 1. Percentage of Waste and Leftover Food Produced in Each Stage of Supply Chain (100% = 1.5 quadrillion kcal) (Hanson et al., 2015)

While the food loss and waste phenomenon continue to happen, food insecurity, hunger, and malnutrition still occur throughout the world. FAO estimated that in 2020 there were about 811 million people experiencing chronic malnutrition, and most of them were living in middle-low-income countries. The number has been continually increasing, showing the urgency of this issue (FAO, 2020). Food insecurity and hunger are caused by limited access to food. The group of people that are affected the most by food insecurity are low income and homeless people, children, pregnant and/or lactating women, and the elderly (Timmer et al., 1983). In addition to that, the global phenomenon in recent years contributes to the risk. Due to COVID-19 disruption, climate changes, and war, agriculture-related growth will be at risk. If no prior action was taken, it could stimulate the global food crisis which predicted will happen in 2023 (World Bank, 2022), making food security an urgent issue (WFP, 2022).

Even though the food producers have produced enough food to satisfy the needs of the entire world population (FAO, 2015), food insecurity, hunger and malnutrition are still happening, indicating a "missing link" between food supply and demand. According to FAO (2017), there are three main causes of the imbalance. First, it is caused by income inequality. Second, limited access to food due to lack of food and clean water storage facilities, especially for poor households. Third, there is an increase in the amount of food in the market (such as meat, vegetables, and fruits) which are not accompanied by a healthy consumption lifestyle due to the increased consumption of processed foods. Processed foods can cause increased consumption of sugar, salt, and preservatives which in turn cause an increased prevalence of micronutrient deficiencies and overweight.

Based on the Food Sustainability Index in 2021, Indonesia ranks at 44 out of 78 countries, in the food loss and waste indicator with a score of 55 on a scale of 100, with the world average score of 59. This score decreased from 2018 score of 61.4 (the average is 74), also showing globally declining food loss score all over the world (The Economist Intelligence Unit, 2021; The Economist Intelligence Unit & Barilla CFN, 2018). This score also indicates that Indonesia is still not effective in managing food waste compared to other countries. In terms of the policy response to food loss sub-indicator, Indonesia only gets a score of 50 out of 100, whereas from the policy response to food waste sub-indicator, Indonesia only gets a score of 41 out of 100. This rank shows the lack of government regulations regarding food waste. There is only one paragraph in the legislation that specifically regulates food waste in Indonesia, which is the Act No. 18 concerning Waste

Management Article 13 Paragraph 4. The lack of regulation and public awareness of the importance of waste and food waste causing Indonesia to be ranked low in waste and food waste management and is one of the largest food wastes producing countries in the world. It is estimated that every Indonesian produces about 300 kg of food waste every year. Bappenas studies also found that Indonesia waste 23 – 48 million tons of food annually from 2000 – 2019 (Bappenas, 2021) and the root cause of this problem is ineffective supply chain system (Bisara, 2017). Often food can no longer be consumed when it reaches retailers and consumers due to a long distribution process. Limited cooling facilities also causes food to spoil faster before finally reaching the consumers. To make matter worse, the end consumers also waste food, for instance 50% of household waste in Jakarta (the capital city of Indonesia) is classified as kitchen waste, whereas at the same time 7.6% of the entire population in Jakarta is malnourished, and more than 36% of children under five years old in Indonesia experience stunting (Bisara, 2017).

With stunting affecting one-third of children under five in Indonesia, Indonesia government has begun to prioritize hunger reduction and improve food security through the establishment of a study from Ministry of National Development Planning (Bappenas, 2021), and set target on food waste reduction by 2025. Yet, no legislation or national plan to prevent food loss and waste has been established (The Global FoodBanking Network, 2022; Faishal and Suprapto, 2022). Indonesia is still dependent on food donation through various of food redistribution organizations or non-profit organizations in reducing their food waste.

In Indonesia, food waste management in household level is still dependent on donation or giving leftover food to people in need (Alamsyah, 2023; Soma, 2017). However, retailers face risks of damaging their business reputations through contamination or bad quality of the leftovers or expired products so they prefer to throw the leftovers away (Kusumowardani et al., 2022).

One of the alternatives to manage food waste is by donating and redistributing unwanted or unsold food to low-income populations (Hanson et al., 2015). Food redistribution is often carried out voluntarily by food redistribution organizations called food banks. Food banks play a role as the link between parties who have excess food and those in need of food. With this role, these institutions have contributed to the environment and the communities, both in increasing access to food for disadvantaged people, and reducing food waste. One of the food banks in U.S., namely Feeding America West Michigan has managed to distribute about 14,450 tons of food in 2016 (FeedWM, 2017). In 2022 alone, Feeding America distributed 5.2 billion meals to millions of people in need (Feeding America, 2023). Various food banks in the world such as food banks in Guatemala, Chile, Ghana, and Eta'am in Saudi Arabia have also contributed to reducing potentially wasted food to those in need.

However, a study by Daradzeika et al. (2018) shows that food banks face various challenges in order to be sustainable, such as limited availability of food because of the limited potential of food donors near the food banks' locations. The study also shows that food bank operations depend on resources that are limited, both in the amount of donations and the number of volunteers. Furthermore, Dubey and Tanksale (2022) find that lack of planning and coordination is the most significant barrier of food banks growth and sustainability.

In Indonesia, food banks play an important role as it offers solution to this food waste problem by providing a bridge that connects the excess supply from retailers and households with the food demand of the people in need. Institutions and communities in Indonesia that redistribute food wastes started to operate since 2016 with the establishment of Foodbank of Indonesia in 2016 and Foodcycle Indonesia in 2017 in Jakarta, Indonesia Foodbank in Banten in 2016 and Food Guards in Surabaya in 2017. These non-profit organizations redistribute the food excess to those in need. These organizations collect food from end consumers such as from weddings, corporate events, and hotels. The food will then be redistributed to the elderly, children in orphanages, homeless children,

and other people in need. Like food banks in other countries, food banks in Indonesia may face the same challenges to be sustainable.

Kaplinsky and Morris (2000) define sustainable food value chain as an overall activity carried out by farmers and companies as well as coordinating both producing agricultural raw materials and converting them into food products that are sold to end consumers, then discarded after use. The whole activity aims to gain profit, provide benefits to the community, and but not permanently deplete the natural resources. Literature in sustainable food supply chain or food value chain has been growing in the past year, expected to provide solutions to food waste and loss problems as well as food insecurity. Sustainable FSC is a new mode of food supply chain (FSC) that develops a sustainable balance through the triple bottom line by simultaneously considering economic, environmental, and social issues (Jarzębowski et al., 2020).

One of the problems that occurs in the food supply chain is the amount of food that does not reach the consumer and becomes waste, which is called food loss and waste (FAO, 2011). According to Lipinski (2015), food loss and waste are parts of plants and animals that can be eaten, then produced or harvested for human consumption but not immediately consumed by the community. Specifically, food loss and waste mean the reduction in mass, calories, or nutrients in food consumed by humans at each stage of the value chain (Hanson et al., 2015).

Food waste is classified into three types, namely, unavoidable (which is food waste that is usually not eaten such as banana peels, eggshells, chicken bones, etc.), possibly avoidable (which is food that can be eaten or not, like the bread and potato skins), and avoidable (which is edible food but ends up not being eaten or discarded) (WRAP, 2015).

Wilson and Steinman (2000) state that a non-profit organization called "food bank" has existed since the 1980s in Canada. This program began as a response to the recession in the early 1980s. In its development, the demand for charitable food has continued to grow, and according to Riches (2002), food bank has become an important part of the revenue security system as well as an employment insurance program provided by the government in Canada (Tarasuk & Eakin, 2005). Specifically, Middleton et al. (2018) define food banks as non-profit organizations that collect, store and distribute surplus food to hungry people, either directly or through social welfare institutions (Middleton et al., 2018).

Research on foodbanks have been done by researchers. Daradzeika et al. (2018) investigate the sustainability of the food redistribution system of a food bank in Lisbon using a system dynamics approach. The results indicate that food banks face various challenges in order to be sustainable. These challenges include limited availability of food because of the limited potential food donors around the location of the food banks. Although food banks provide food for hungry people, there is no research that shows that a system of food redistribution with charitable donors can reduce the demand for charitable food. This shows that food banks cannot be a solution to food insecurity problems. However, for the problem of food waste, the study shows that food banks can be regarded as a solution to the problem because of the learning effects felt by the food donors, it means the donors become more efficient in their operations and produce less food waste.

Galli et al. (2019) study the food redistribution of food banks in Italy by using system dynamics. This study analyzes the reduction of food waste and poverty alleviation and finds that increasing the awareness of the issues will strengthen the redistribution of food surplus and the awareness of volunteering. Strengthening food surplus redistribution will lead to the establishment of standards for preventive systems suppliers to reduce the food waste.
Lafrati (2016) studies the sustainability of a food bank in Black Country (West Midlands) by examining the balance between demand and supply. It is found that with limited economic growth, low welfare, and service cuts, the demand for food banks will not be declining. However, food banks also have limitations to be able to fulfill the existing demand. It is also found that food banks need to make plans to increase their capacity, in terms of food supplies, volunteers, and space.

Research on food banks is also conducted by Martins et al. (2016). They use a mixed-integer linear programming model to redesign food bank's supply chain network.

Specifically, the model can be used to make logistical decisions, including opening of new food bank warehouses, and determining the storage and transportation capacity by considering the limited food donations and investment costs.

On the other hand, there are studies that examine food bank donors, such as the study by Vlaholias et al. (2015). The research discussed the motivation of companies to donate food excessively in terms of values, attitudes, and motives of food donors. The analysis is carried out using theoretical and conceptual reviews through related environmental and social literature.

Dubey and Tanksale (2022), study the barriers of food bank adoption and growth in India using hybrid Dematel and Analytical Network Process (ANP), and find that lack of planning and coordination is the most significant barrier, while lack of infrastructure and human resources are the most significant effects of the other barriers.

Finally, a study by Capodistrias et al. (2022) finds that food banks need innovation to be resilient in the time of crises, such as by implementing new strategies and establishing new types of external relations with other organizations.

The above literature has discussed different aspects of food bank operations, as solution to food waste, mostly in the developed countries, such as the US and EU. Although many studies concerning food bank has been growing, studies regarding food bank sustainability in emerging countries, like Indonesia, has yet to be explored. Indonesia is facing a significant economic loss (at 213 – 551 trillion rupiah per year) and environmental damage (produced the average of 7.29% of GHG emission) from food waste (Bappenas, 2021), showing the importance of studies in the area. Food bank in Indonesia, as one of the pillars to food security and to end the food waste, need further analysis and study to improve the operations and can continuously redistribute excess food. In the case of food bank sustainability, it is important to consider all aspects and dynamics of the whole system to understand the nature of food banks. Furthermore, it is also important to understand which aspects are important for the sustainability of food banks, especially in the emerging countries. This paper addresses the food bank as a supply chain and how it interacts with its important internal and external stakeholders, and how it can sustain and redistribute food in the long term.

This study is focusing on one of the food banks in Indonesia, named FoodCycle Indonesia (FCI). FCI collects excess food from wedding parties, bakeries, and corporates lunches, and redistributes the food to those in need. The objective of the research is to identify factors that affect the sustainability of FCI and propose ways to ensure its sustainability. This paper contributes by providing insights on foodbanks in developing countries (such as Indonesia) and the challenges to be operationally sustainable.

The remainder of the paper is organized as follows. Relevant literature is discussed in Section 2, followed by explanations of the research stage and system dynamic models in Section 3, findings in Section 4, and conclusions in Section 5.

2. Methods

2.1. Research stages

This is an exploratory study and begins with the identification of problems faced by food banks in Indonesia. In this study two models are developed, namely the model of food banks in Indonesia in general, and the model of the research object. As previously mentioned, the purpose this research is to investigate the sustainability of food banks in Indonesia using system dynamics simulation. The method is chosen as it allows the use of computer simulation to study a complex system and investigate alternatives of policies (Sterman, 2000). We use the P'HAPI framework (Problem, Hypothesis, Analysis, Policy, and Implementation) based on Moxnes (2009).

The study is conducted as follows. First, literature review and in-depth interviews (IDIs) with representatives from institutions which are actively involved in the food banks In Indonesia. Specifically, our informants are one (Social Program Officer) from Foodbank of Indonesia (FOI), three (Chief Executive Officer/Co-Founder, In Charge in Operations, Volunteer) from FCI, and two from FCI's partners (the recipient communities). IDIs are

carried out to identify problems that are generally faced by food banks in Indonesia and identify variables as well as causal relationships between variables. In the next stage, the qualitative model for FCI is developed in the form of a causal loop diagram (CLD). The model is modified from Daradzeika et al. (2018) based on IDIs results. A quantitative model in the form of stock and flow diagram (SFD) is then developed based on the CLD. We then simulate the SFD model and compare its structure and behavior to the actual conditions to ensure the validity of the model. Lastly, we simulate the model for a period of five years to analyze the operational sustainability of FCI.

2.2. Model development

The CLD is developed based on literature and IDIs. The model is created to understand the whole system and each party that plays an important role in the operation of FCI. In general, the food banks in Indonesia are as follows (see Figure 2):

1. Food banks only collect avoidable food waste. However, to maintain the quality of these foods, food banks only accept foods that have not been touched, so they are deliberately set aside before being eaten.
2. Three parties are involved in food bank activities, namely the food bank itself, donors who donate the surplus food, and the recipients consisting of disadvantaged people.
3. Resources needed in food bank operations are transportation to redistribute the surplus food, volunteers to arrange and coordinate the redistribution, and storage (or cold storage) to store the highly perishable food.
4. Food bank donors are individuals, groups of individuals, and institutions.

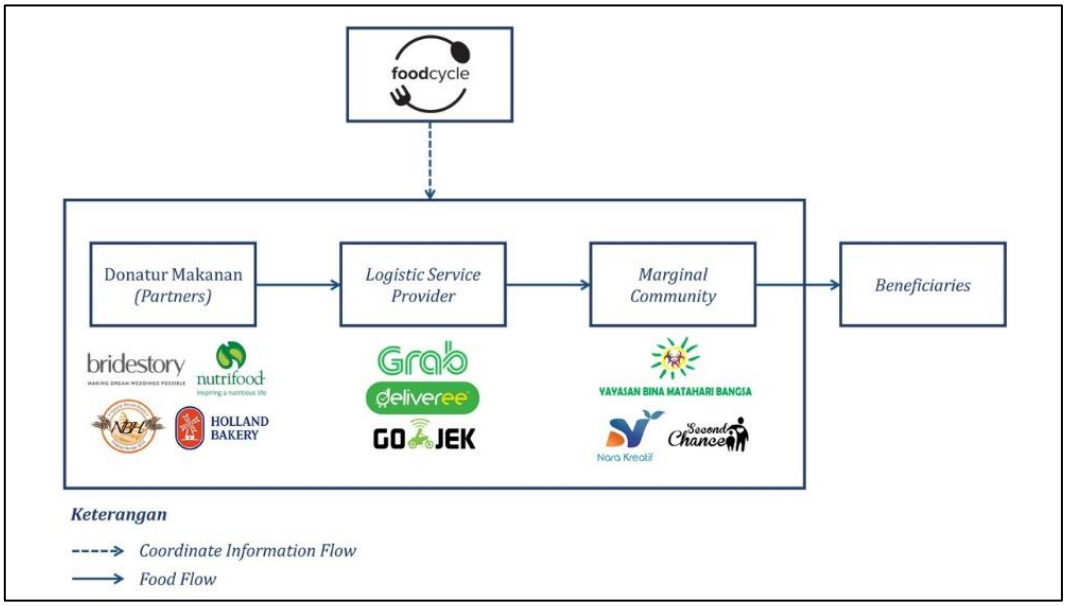

Figure 2. FCI's supply chain

Specifically, for FCI, this food bank distributes food in Jakarta and Bekasi (the satellite city of Jakarta) areas, and in its operations, the cooperation with food donors is in the form of a partnership with contracts that are renewed every three months. FCI's current source of food are weddings, bakeries, and office lunches. The beneficiaries of FCI are disadvantaged people under foundations or institutions, and FCI connects donors and beneficiaries, thus it does not store the food. The quality inspection of the food is conducted by the beneficiaries, however FCI provides the necessary training and conducts quality control and audits. FCI has the vision of "zero food waste, zero hunger", but currently it is still focusing on reducing food waste. Therefore, its emphasis is on collecting surplus food from donors, and then, it will look for additional beneficiaries. Informant from FCI states that publication in a well-known media usually has a significant impact in increased number

of donors and volunteers. Lastly, volunteers help to coordinate daily food redistribution and finding potential new beneficiaries.

Based on the above explanations, the CLD is developed (see Figure 3), The CLD consists of 30 variables with seven main loops, namely, food balance (B1), volunteer recruitment (B2), beneficiaries (B3), locations (B4), media (B5), distribution (R1), and resources (R2). The food balance loop explains the balance between supply and demand. The variables involved include Number of regular donors, Available surplus food produced by donors, Food available at the food bank, Food supply/demand balance (supply minus demand), Pressure to contact new donors, and Number of potential contacted donors.

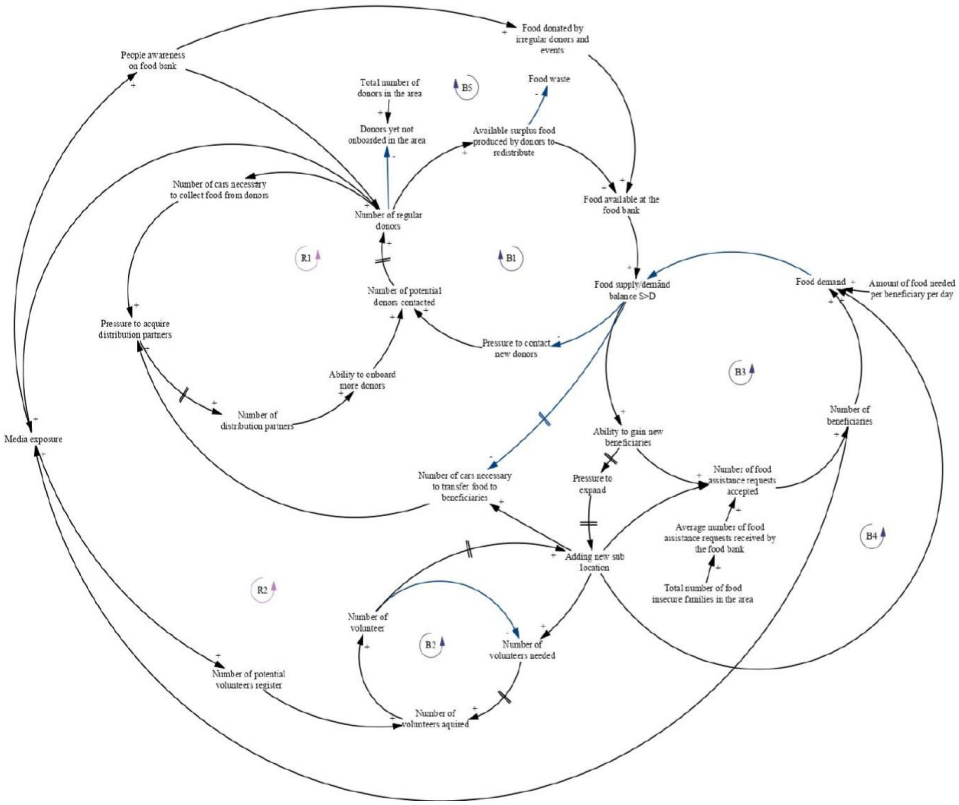

Figure 3. The causal loop diagram of FCI

Volunteers recruitment loop explains how the number of volunteers returns to their original condition with an increase or decrease in the Number of volunteers, Number of volunteers needed, and Number of acquired volunteers. The beneficiaries loop, on the other hand, explains how the number of beneficiaries returns to their original state with an increase or decrease in the variables (Food supply/demand balance, Ability to gain new beneficiaries, Pressure to expand, Add new sub location, Number of food assistance, accepted requests, Number of beneficiaries, and Food demand).

The location Loop explains how the increase in the number of locations (of beneficiaries) returns to its original state with an increase or decrease in the variables (Food supply/demand balance, Ability to gain new beneficiaries, Pressure to expand, Adding new sub location, and food demand), while the media loop describes the media exposure and the cycle returns to its original state with an increase or decrease in the related variables (Number of regular donors, Media exposure, People awareness on food banks, Food donated by irregular donors and events, Food is available at the food bank, Food supply/demand balance, Pressure to contact new donors, and Number of potential contacted donors).

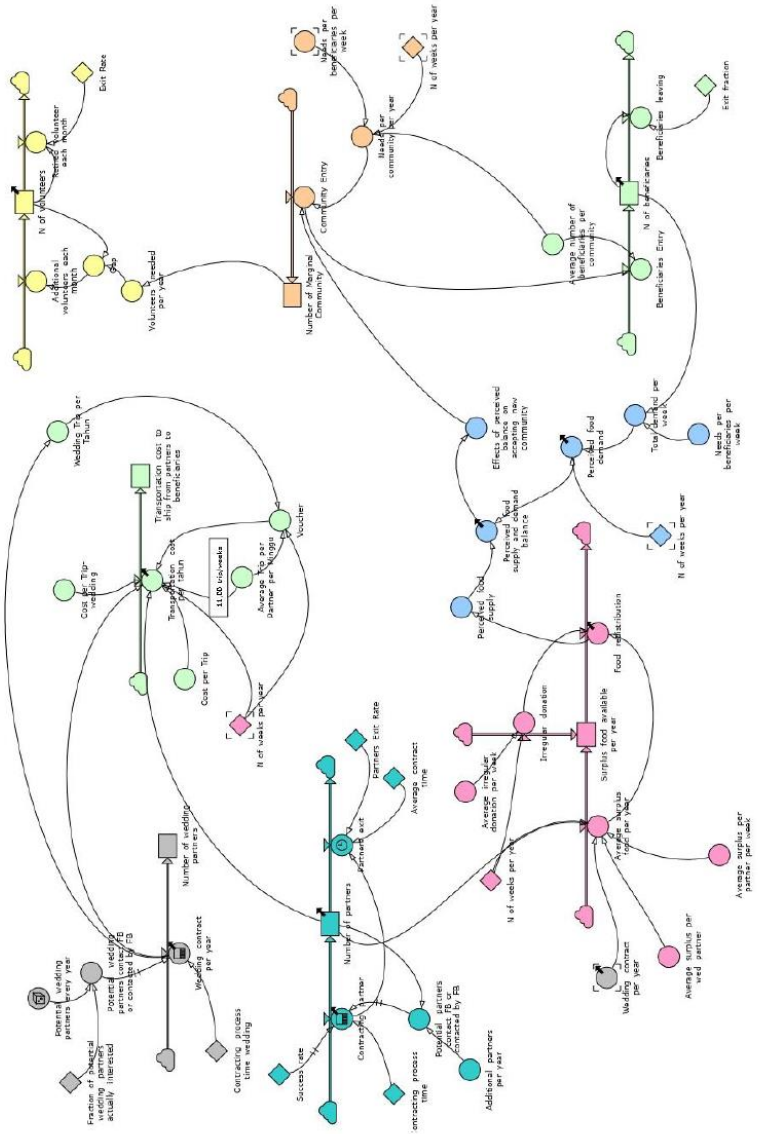

Figure 4. The stock and flow diagram of FCI

The distribution loop explains the distribution cycle. The influence of the number of distribution partners becomes stronger with an increase in other variables, and vice versa. The variables are the Number of regular donors, the pressure to obtain distribution partners, the number of distribution partners, the number of distribution partners, the ability to onboard more donors, and the number of potential donors contacted. Lastly, the resources loop involves all resources, namely, media, volunteers, and transportation for distribution. This loop explains how the influence of these variables gets stronger with an increase in the related variables, and vice versa. The variables include Number of regular donors, Media exposure, Number of potential volunteers, Number of volunteers acquired, Number of volunteers, Adding new location, Number of cars needed to transfer food to beneficiaries, Pressure to acquire distribution partners, Number of distribution partners, Ability to onboard more donors, and Number of potential donors contacted.

Based on the CLD, we develop the SFD model using Powersim software (see Figure 4). The model consists of partners, wedding partners, redistribution supply, transportation cost, community, volunteers, beneficiaries, and food balance subsystems.

We then perform several tests to ensure the validity of the models, namely direct structure test, structure-oriented behavior test, and behavior pattern test, and the results show that the model is valid.

2.3. Validity tests

We perform several tests to ensure the validity of the models, namely direct structure test, structure-oriented behavior test, and behavior pattern test. Direct structure test can be done either empirically or theoretically (Schwaninger and Groesser, 2011).

3. Results and Discussion

The simulation is conducted based on actual data (January 2017 – April 2019) for a period of five years (2017-2022). The results can be seen in Figure 5.

The number of potential wedding partners every year is obtained from the interviews, and in the simulation, we use a random number between 104 to 208 wedding partners in one year. We also set the number of partnerships with wedding parties per year to 60% of the number of potential wedding parties based on the results of interviews. Therefore, the number of wedding contracts per year is less than potential weddings as shown in Figure 5(1).

On the partners subsystem, the Number of partners, Contracting partners (the number of donors who are in the process of working together with FCI), and Partners exit (the number of donors who stop cooperate with food banks) following the exponential growth pattern, where growth has increased every year as shown in Figure 5(2). This is because in the base case scenario, there are no partners that stop supplying food to FCI. The simulation results are in accordance with the results of interviews whereas in the first two years, the growth of the number of partners tends to be slow, while there is a significant increase in the third year.

With the increasing number of partners and wedding partners, the amount of food that must be distributed also increases. In this simulation, it is assumed that the cost per redistribution (trip) and the average trip for each partner in a year is fixed. Therefore, the behavior pattern of transportation costs follows the behavior pattern of the number of donors, namely exponential growth. It can be seen in Figure 5(3) that over time, the transportation costs borne by FCI will be higher. If FCI increases the number of donors continuously, then it needs to have sufficient resources to support the distribution process due to higher costs.

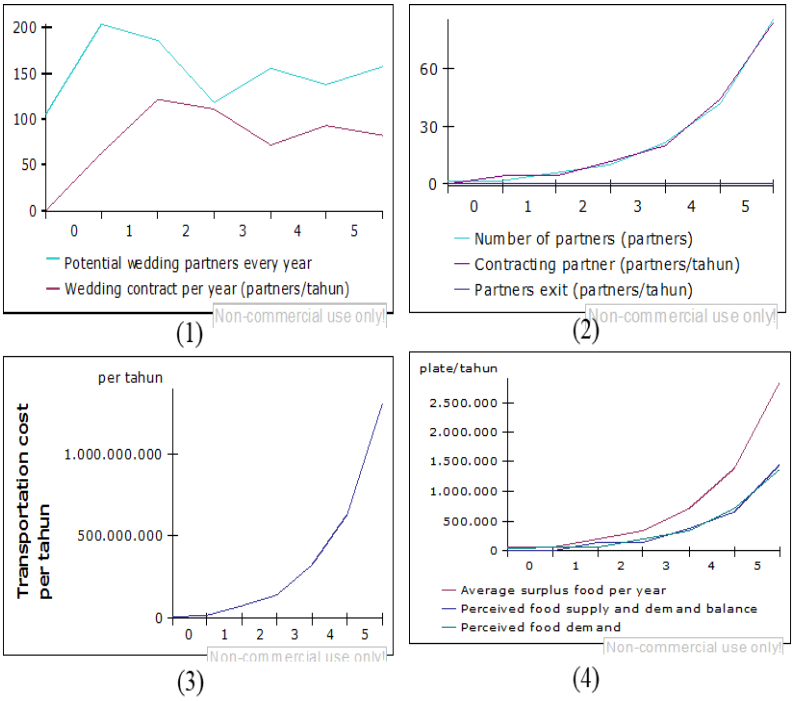

Figure 5. Simulation Results part 1

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In the food balance subsystem, on the other hand, shows the balance between the surplus food prepared for redistribution and the food needed by beneficiaries (see Figure 5(4)). It can be seen that the increase in food donors (partners) will increase the balance between the surplus food and the food demand. If the balance is positive (or there is surplus food in the food bank), then the food bank will look for new marginal community as the recipients. Increasing the number of marginal communities will result in an increased number of beneficiaries, and thus it will increase the food demand as well.

Therefore, the food bank experiences a positive balance because even though in the first year the balance is almost close to zero, but the increase in surplus food from donors will cause an increase in food demand because food banks will add the number of marginal communities as recipients of the donated food. Food banks will add a number of beneficiaries (or marginal communities) only when there is an increase in the number of partners and the amount of surplus food. This is because it requires more effort and a longer time to obtain partners than beneficiaries. Simulation is performed by assuming that the beneficiaries receive one donation of food per week, and there are 100 people in each receiving marginal community.

When FCI experiences a surplus in the amount of balance of food, it is responsible to deliver the food to those in need so that the collected food is not wasted. In the SFD model, it is assumed that the beneficiaries can receive a maximum of one serving per person per week. This assumption is made based on the interviews results; the recipients of donations experience burnout when they receive the same food repeatedly and have the potential to waste the food at the community site.

The simulation results in Figure 6(1) show that the increasing amount of surplus food results in an increase in the number of additional food that must be donated annually. In the first and the second years, the amount of surplus food is close to zero, indicating that the food can be distributed to the community so that no food is wasted. But in the third year and thereafter, the number is increasing, indicating that that the waste exists because FCI cannot distribute the surplus food.

The growth rate of marginal communities that receive food donations depends on the food balance at FCI. As seen in Figure 6(2), the increase in the food supply/demand balance from the first until the fifth years results in the increased number of new recipient communities (community entry) that in turn will increase the number of beneficiaries. Therefore, the behavior of the number of beneficiaries is not much different than the

behavior of the number of marginal communities (Figure 6(3)). In addition, based on the interview results, it is also assumed that there are no beneficiaries leaving the service so that the number of beneficiaries leaving the service is constant at zero.

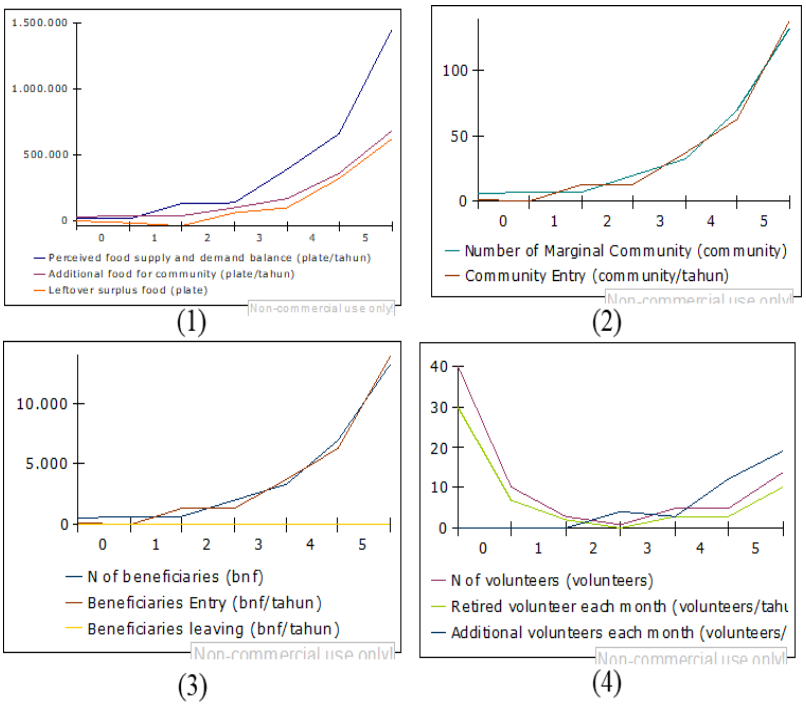

Figure 6. Simulation Results part 2

Concerning the volunteers, the results reveal that the number of volunteers keeps decreasing until it reaches the minimum point at the end of the second year and then it bounces back and keeps increasing until the fifth year (See Figure 6(4)). This is because volunteers do not have the obligation to have a long-term commitment with FCI, and thus, they don't last very long. Interview results reveal that in a year only 25% of the entire volunteers remain to commit to FCI, or there is a high turnover of volunteers at FCI. The results also show that in the third year there is an addition of volunteers due to the addition in the number of marginal communities served by FCI (See Figure 7).

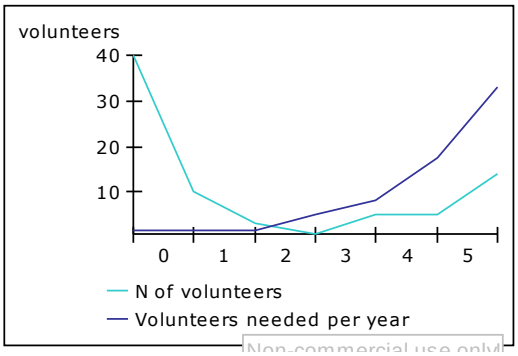

Figure 7. Number of volunteers & Volunteers needed per year

The need for volunteers is due to the lack of resources that can contribute to the management of distribution and beneficiaries. Therefore, when the number of marginal communities increases significantly in the second year, there is also an increase in the number of volunteers needed per year, and its pattern is like the pattern of the number of community entry. In the simulation, it is assumed that the number of volunteers needed is one person per four communities.

Based on the analysis of the entire system and the results of IDIs, it can be concluded that if the growth of partners, wedding partners, and food supply balance are similar to the current condition, and therefore, FCI will be sustainable in its operations. However, these three subsystems are influenced by the financial condition of FCI (that must cover the transportation costs). At this situation, the total transportation costs of FCI is about IDR 300 million (or USD20,700) within four years. If FCI does not have sufficient financial resources or cooperate with transportation and logistics providers or obtain sponsors, then the organization's growth tends to be stagnant.

The simulation results also reveal that when the number of partners and the amount of food for redistribution are greater, FCI must attract new marginal communities so that there is no surplus of food donation. Therefore, in terms of beneficiaries, it can be concluded that FCI is sustainable. In addition, it should also be noted that FCI must prioritize serving marginal communities located around the partners' locations to minimize the transportation costs. In other words, similar to Dubey and Tanksale (2022), FCI must better plan the redistribution of food to be sustainable.

In the Volunteers subsystem, there are fewer volunteers than the number of volunteers needed in the five-year simulation. However, food bank operations depend on the number of volunteers (Daradzeika et al., 2018). Hence, the results indicate that if in the next three years the volunteer management system is still like today, FCI may not be sustainable. The more food to redistribute, the more human resources is needed to conduct the quality control of donated food and coordinate with the recipient foundations (or communities), and logistics service provider. Therefore, FCI must have good management of volunteers by providing training and increasing volunteers' involvement in food bank activities.

Based on the above analysis, we can say that FCI is sustainable in its efforts to redistribute food to achieve its mission of 'zero food waste and zero hunger'. However, just like in Daradzeika et al. (2018), there are several challenges to FCI's sustainability in the long term and must be addressed properly, namely, its financial condition, ability to plan the food redistribution, and ability to manage its volunteers.

4. Conclusions

This study uses system dynamics simulations to determine the operational sustainability of an Indonesian food bank, called FoodCycle of Indonesia (FCI). The data is obtained by conducting in-depth interviews with informants from FCI and other food bank (FOI).

Based on literature and IDIs results, it is found that food bank sustainability is influenced by various factors including the existence of food donors, beneficiaries, transportation, media, number of volunteers, and financial capabilities of the food bank. The absence of one of these resources will have an impact on the food bank's redistribution capability.

Based on the base case scenario (the actual condition), it is found that FCI will be sustainable in the next five years assuming that the growth is constant. However, the organization's growth will be stagnant, if it does not have enough financial resources to fund the transportation costs. Therefore, cooperation with logistics providers and corporate through corporate social responsibility (CSR) is recommended to help FCI to fund the transportation of donated food to the beneficiaries. In addition, FCI must also have a better way to manage volunteers to lower its turnover rate and ensure sufficient human resources are available to support the organization's growth.

This paper has several limitations. At the time of the simulation in 2019, FCI has been in operation only for about two years, thus the collected data may not be enough to capture the dynamics of food banks. A longer period of historical data may contribute to a better mental model of the food banks. Secondly, the focus of this research is on the sustainability of the food bank. However, food banks are established with two objectives in mind, reducing food waste, and achieving zero-hunger. Future research may include investigating the effect of food banks on both objectives by estimating the food waste reduction and impacts of the welfare of the beneficiaries. Furthermore, instead of collecting

data from one food bank, data from multiple food banks could result in more comprehensive research on food banks in Indonesia. In addition, a further analysis of food banks at the time of COVID-19 could also give more insights on food bank operations under disruptions since food security also been disrupted at the time of pandemic.

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Author Contribution
Conceptualization, S.I. Syalianda and R.D. Kusumastuti.; Methodology, S.I. Syalianda; Software, S.I. Syalianda; Validation, S.I. Syalianda; Formal Analysis, S.I. Syalianda and R.D. Kusumastuti.; Data Curation, S.I. Syalianda.; Writing – Original Draft Preparation, S.I. Syalianda; Writing – Review & Editing, R.D. Kusumastuti.

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Ethical review and approval were waived for this study due to no personal data was collected in this study. The number of informants is six, and the interviews are mainly to gain insights on how food bank operates in Indonesia, no personal information is collected.

Informed Consent Statement
Informed consent was obtained from all subjects involved in the study.

Data Availability Statement
The data is available upon request.

Conflicts of Interest
The authors declare no conflict of interest.

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