System Dynamic Model for Restaurant's Food Waste in Surabaya

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Abstract

The food service sector is the third-largest source of food waste (covering 18% of the total) after households and the food industry in terms of food input at each stage in the value-added chain. The problem of managing food waste in the foodservice sector is a complex phenomenon and includes a variety of factors and activities. By using a system dynamics method, the purpose of this study is to obtain an overview of the results of research of strategy that can be used as a consideration for making policies to reduce food waste in the foodservice sector. Food waste of restaurants in Surabaya is currently estimated at 61.23 kg per restaurant per day. Three scenarios developed in this study include increasing the frequency of purchases, implementing a fine system for customers who leave food scraps and cooperating with the food bank. Based on the simulation results, the highest percentage reduction is achieved by applying the third scenario with a reduction of food waste by 25.10% per day. Therefore, this research shows that restaurants should start to consider collaborating with food banks to donate their serving losses to those who need it. The effect of scenario simulation is uncertain and cannot be taken for granted. However, this study provides an overview of the potential impacts of the scenarios developed.

Keywords

Food Waste, Food Service, Restaurant, and System Dynamics.

1. Introduction

Food loss and waste can be interpreted as the amount of edible material that is wasted or lost in the food supply chain at various stages. Food that lost at the harvest or processing stage is called food loss, while food that lost at the consumer or retail stage is called food waste where this occurs because of the habit of buying more than we need at the supermarket, letting fruits and vegetables spoil at home or ordering more than we can eat in a restaurant. Annual global food waste is estimated to be around 1.3 billion tons, which is equivalent to about 30% of total food products intended for human consumption. This shows that the amount of food produced is far greater than what is actually consumed (Haque et al. 2016). The problem of food waste directly linked with environmental (e.g. energy, climate change, availability of resources), economic (e.g. resource efficiency, price volatility, increasing costs, consumption, waste management, commodity markets) and social (e.g. health, equality) impacts (Stenmarck et al. 2016).

The food service sector is the third-largest food waste source (covering 18% of the total) after households and the food industry in terms of food input at each stage in the value-added chain (Betz et al. 2015). Several studies have been carried out to estimate food losses after the farm level, but most studies take into account losses that occur up to the retail level, but not losses between retail purchases and consumption, such as storing, cooking, and preserving food (Engström and Carlsson 2004). The food service sector has every reason to be at the forefront of efforts to reduce food losses along supply chains and food waste caused by individuals at the point of consumption. This relates to the big impact may be achieved when addressing food waste in a food service sector where there are many individuals dining in the same way. Despite this, academic research on food waste that considers how the food service sector can effectively make meaningful reductions has been slow to emerge (Mirosa 2016).

The problem regarding food waste in recent years has become an important topic because of its large impact both on the economy, the environment, and the food security of a country. Interest in reducing food waste is also growing rapidly to ensure adequate food for a fast-growing population (De Steur et al. 2016). The target of this study is to find good potential for measures to reduce food waste in the foodservice sector, especially in the restaurant. Problem-related to food waste is not a simple problem but rather a problem that is large enough and full of complexity (FAO

2015). The problem of managing food waste in the foodservice sector is a complex phenomenon and includes various factors and activities (Martin-Rios 2018). Therefore, this study conducted the dynamic system method used in this study because the dynamic system method can be used to develop and test mathematical models and perform a computer simulation of a complex nonlinear dynamic system (Sterman 2000). The purpose of this research is to obtain an overview of the results of research on strategies that can be used as consideration for making policies to improve food waste in the restaurant.

2. Research Method

In this research, the research design including sequencing the stage of research was refer a relevant previous study in the food research with the system dynamics (Gunawan et al. 2017; Gunawan et al. 2019). In this research, the data used are primary data. Data collection is done by conducting surveys and interviews to collect facts about the system of the waste generation that occurs in food suppliers, food bank, and restaurants spread across the city of Surabaya. Furthermore, the analysis is carried out by comparing the system dynamics simulation to get the evaluation results of the simulation of the application of strategies that can be used as a consideration for making policies to reduce restaurant's food waste in Surabaya.

2.1 Preliminary Studies of Observed Area

Surabaya is the second biggest city in Indonesia which is inhabited by nearly 3,2 Million in 2013 (Barbara and Umilia 2014). Figure 1 is a map of Surabaya as case study of study.

Figure 1. Surabaya as case study of study

Surabaya has a fair good economic growth. The hotel and restaurant trade sector are one of the sectors that have the highest growth of 9.69%. According to (BPS 2018), Surabaya is the city with the highest number of restaurants in East Java. The hotel and restaurant trade sector are a sector that dominates the economic structure of Surabaya. The number of restaurants and cafes in Surabaya has increased by 15% to 20% per year (Harianto 2013).

2.2 Problem Identification

Observe the process of food waste generation that occurs in food suppliers of restaurants and restaurants to obtain some information to analyze the factors that influence the total food waste based on studies and literature studies. This research uses primary data. Primary data on the scope of waste preparation and consumption are obtained by conducting surveys and interviewing restaurant owners or managers about the information of demand, sales, planning, phasing, availability of raw food, amount of food prepared, and food consumed. Likewise, the scope of supplier waste is also obtained by conducting surveys and interviewing owners or managers of food distributors about the information of demand, sales, stock, prices, transportation modes, transportation costs, packaging costs and amount of food transported. The number of restaurants in Surabaya is shown in Table 1 below.

The restaurant population in this study is a restaurant registered in Surabaya City Government. Obtained a total of 776 restaurants registered in the Surabaya City Government.

Table 1. The number of restaurants in Surabaya (2014-2018).

Year	The Number of Restaurants
2014	383
2015	713
2016	790
2017	1083
2018	1341

The number of samples is calculated using the Slovin formula as follows (Tejada and Punzalan 2012):

$$n = \frac{N}{1+Ne^2} = \frac{776}{1+776(0.1)^2} = 88 \text{ samples} \quad (1)$$

Where N is the total population, e is the margin error while the margin error used in the calculation of the sample is 10% and n is the minimum number of samples that is 88 samples. 88 restaurant samples were selected using the random sampling method from a list of restaurants registered in Surabaya City Government.

2.3 Modelling of Restaurant's Food Waste in Surabaya Framework

In the framework of thinking about food waste problems, based on the position in the supply chain stage, food waste exists from the distribution stage of marketing to the end-user or consumer (Gustavsson et al. 2011). However, if viewed more deeply based on the cause of the occurrence, then at each stage there is still the possibility of food loss due to managerial and technical matters such as storage, transportation, cooling facilities, infrastructure, packaging, and marketing systems (FAO 2015). Thus, food loss and food waste cannot be separated completely but this study still focuses on the area or scope of the problem of food waste namely the distribution phase (at suppliers) and the preparation and consumption phase both initial consumption (at restaurants) and reuse leftover (at food banks). In this study, the mechanism of the occurrence of food waste at each stage can be explained as follows:

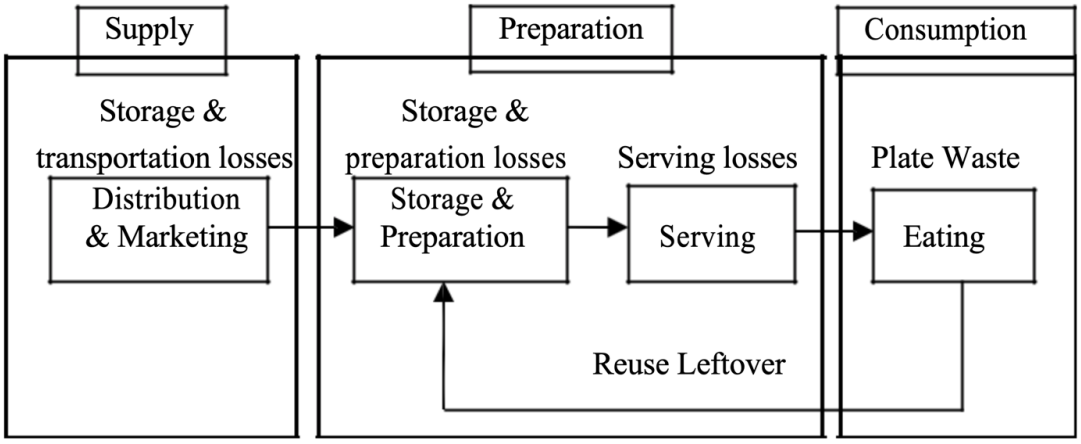

Figure 2. Modelling of restaurant's food waste in Surabaya framework.

The model in Figure 2 was obtained from the general model of the food supply chain based on (Gustavsson et al. 2011) after the processing and manufacturing stage. Modifications have been made by separating the stages of preparation and consumption and explain in more detail the processes in the preparation and consumption stages. It is done so that it is easier to classify the waste that occurs in each process. In addition, the modification was also carried out by adding an arrow indicating the reuse phase, this was done because this study also involved the food bank which reprocessed food scraps from the consumption stage.

2.3 Modelling Simulation

Modelling is done using STELLA software. The simulation model starts with evaluating the relationship between the variables in the causal-loop diagram due to the results of the survey and the literature study conducted earlier. Furthermore, the simulation model is made in the form of a stock and flow diagram that completes the mathematical equation for each variable. After that, verification and validation are performed to compare the structure of the model and interactions with the actual system.

The next step is to simulate the scenarios, increasing the frequency of purchases, implement a fine system for customers who leave leftovers and collaborate with food banks, this stage can only be done when the model has been declared valid. The purpose of the scenarios in this research is to be able to reduce the food waste produced by the foodservice sector. The simulation results will be analysed to study the potential of policies in influencing food waste.

3. Result and Discussion

3.1. Variable Identification

Most of the variables used were identified through interviews and some of them are supported by the literature. Some of the variables that become input variables in the simulation are shown in Table 2 as follows.

Table 2. Initial value of variable.

Variable	Unit	Initial Value
Food raw material cost	IDR/kg	20000
Production cost	IDR/kg	20000
Frequency of purchases	Times/month	10
Price per portion	IDR/person	53500
Number of customers	People/month	NORMAL (279;27.9)
Customer awareness	Fraction	0.75
food weight per portion	kg/person	0.6
Supplier's storage Condition	Fraction	0.7
Food quality	Fraction	0.86
Transportation mode	Fraction	0.7
Percent restaurant's storage losses	Fraction	0.02
Percent restaurant's preparation losses	Fraction	0.02
Percent amount of leftover donated	kg/person	0.02

The initial value of the variable associated with costs such as production costs and raw material prices is a dummy value due to unavailability of data, so that related output such as profit can only be seen based on the percentage increase or decrease, not the exact value. The initial values used for variables percent restaurant's storage losses and preparation losses are based on (Engström and Carlsson 2004). While the remaining variables, the initial value is obtained based on the average value of the survey results.

3.2. Causal Loop Diagram

The relationship between the variables that have been identified is illustrated in the causal loop diagram. Causal loop diagrams represent the way in which the system works. The relationship of all variables is explained in a causal loop diagram. The variables are connected by arrows which show causal influences between variables. Each arrow is given a polarity, either positive (+) or negative (-) depending on the interaction between variables. The causal loop diagram is shown in Figure 3. The causal loop diagram shows the flow of food from the supplier to the consumption stage including reuse leftover stage. Each process is associated with the possibility of waste that can be generated. Therefore, several scenarios will be simulated which are expected to reduce food waste.

In distribution phase, food waste occurs due to overstock and storage conditions, also due to the transportation process. In the preparation and consumption phase, the food waste generated is influenced by the high demand for restaurants (number of consumers). Because of the higher demand, the more food that will be stored or processed by the restaurant. This affects the amount of food waste due to storage which is termed storage losses and food waste due to the preparation process which is termed preparation losses. The rest of the food produced by the restaurant is also largely caused by the leftovers left by consumers on their plates called plate waste, of course, it also shows that the higher the demand or consumers, the more food waste are produced. In restaurants when demand is low, there can be a gap between the demand and the amount of food that has been prepared or served, which can be interpreted as the difference between food production and demand. The gap or difference is termed serving losses. However, if the request is fulfilled and its fulfilment can be maintained at all times, then a minimal amount of food waste will be achieved, this happens because there are no serving losses generated. *In* the reuse phase of food waste generated is influenced by the amount of donations received, in which the type of leftover food donated is usually in the form of serving losses because it is food waste that is still suitable for consumption. food banks receive donations from restaurants to be consumed by those who need it, but before they reach the consumption stage there is a quality control process to sort out and discard foods that are considered unsuitable for consumption. In addition, the food consumed is still possible to produce plate waste even though in very small amounts.

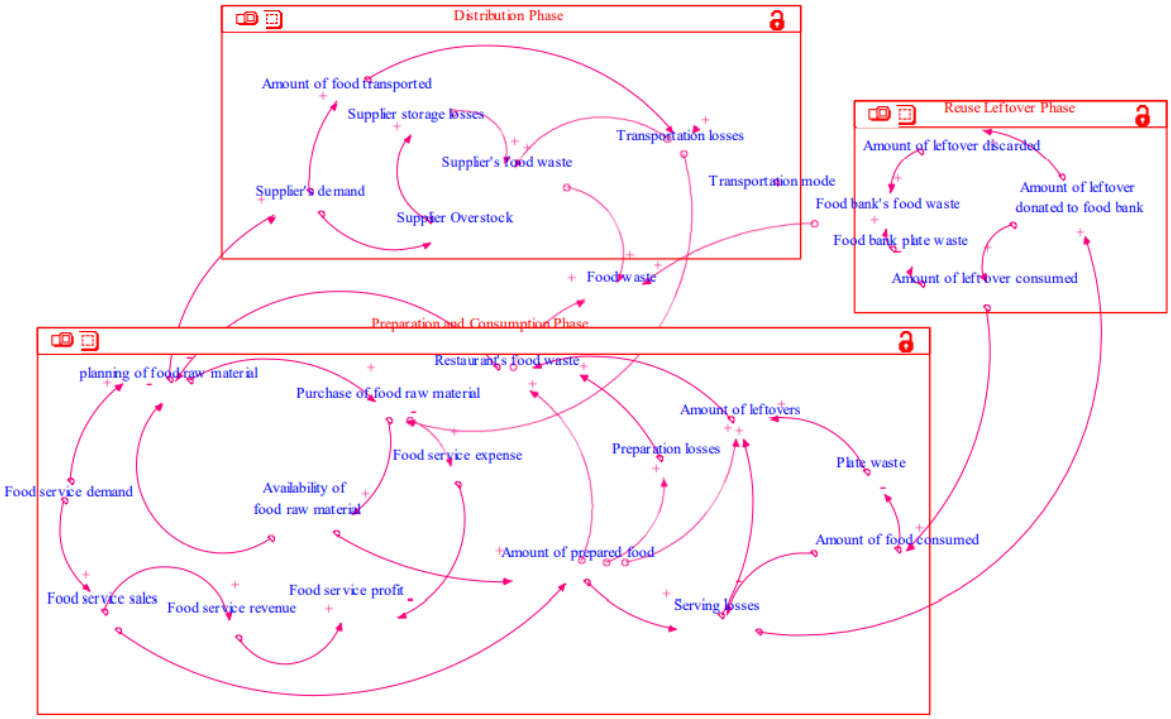

Figure 3. Causal loop diagram

3.3. Stock and Flow Diagram

Stock and flow diagrams are divided into three sub-models based on where food waste is formed. Sub-models include supplier (distribution phase), restaurant (preparation and consumption waste) and food bank (reuse leftover phase). Restaurant sub-model showed that the food waste produced by restaurants is influenced by how they do the planning, purchasing, and storage of their food ingredients, and also how they prepare and serve the food, in addition, consumer behaviour in consuming the food served also affects food waste in this sub-model. This sub-model is shown in Figure 4.

3.4. Policy Scenario Development

Policy scenarios are developed by changing the parameters that affect the model. Three scenarios were determined in this research including increasing the frequency of purchases (Scenario 1), implement a fine system for customers who leave food scraps (Scenario 2) and collaborate with food bank (Scenario 3).

3.4.1 Scenario 1

The objective of Scenario 1 is to see the effect of the frequency of purchase done by restaurants. In the stock and flow diagram, the availability of food stored by the restaurant can affect the amount of losses at the storage stage, but the amount of inventory cannot be changed directly because it is influenced by food sent from suppliers whose amounts are adjusted to the purchase plan. Based on the survey, it is known that the frequency of purchases affects the degree of oversupply, when the frequency of shopping is increased, it will affect the degree of oversupply. This might be in line with the theory that short-term forecasting is more accurate than long-term forecasting. This is because in the short-term forecasting, the factors that influence demand are relatively constant whereas the longer the forecasting period, the more likely the changes in the factors that affect the demand (Ishak 2010). Therefore, in this scenario, it will be seen the influence of the shopping frequency of the restaurant in influencing food waste. The average shopping frequency done by restaurants in Surabaya is once in 3 days. Increasing shopping frequency to once in 2 days is still possible and can be done. Therefore, in this scenario, an increase in the frequency of shopping will be simulated from once in 3 days to once in 2 days.

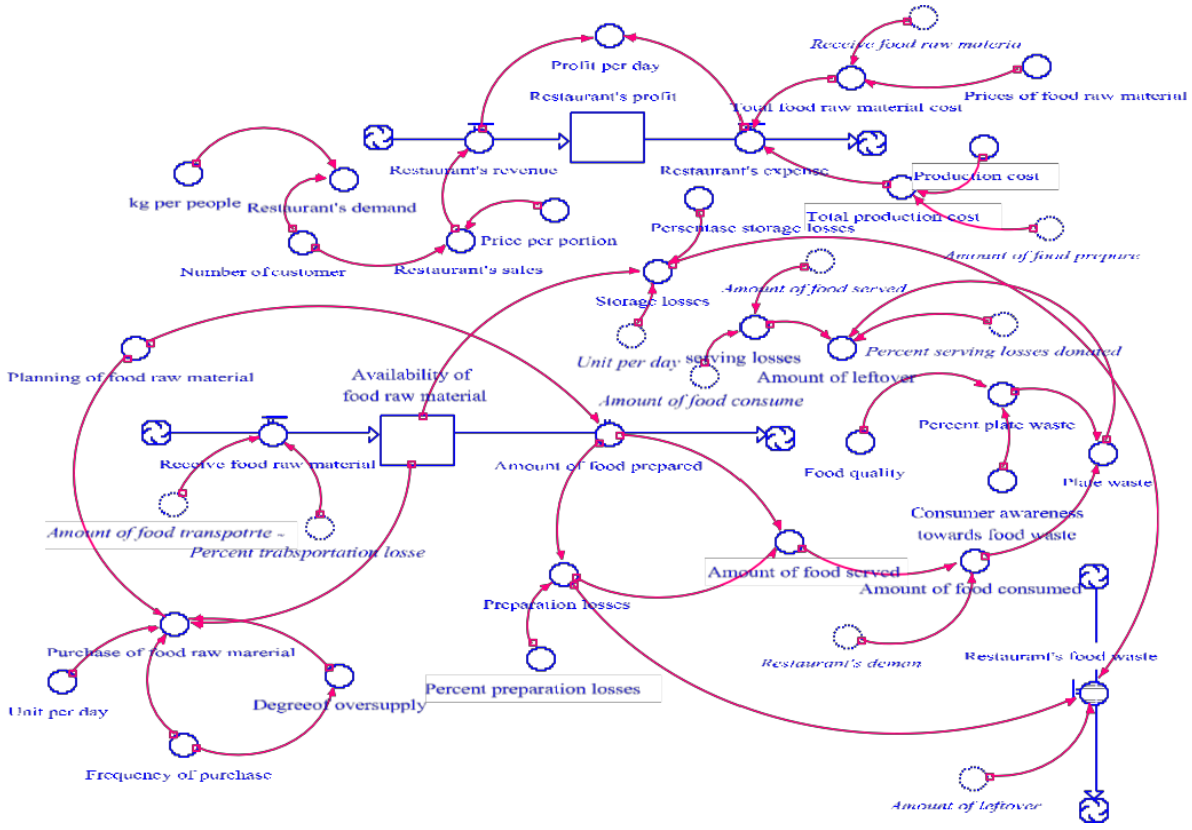

Figure 4. Stock and flow diagram of restaurant sub model

3.4.2 Scenario 20

The objective of scenario 2 is to increase consumer awareness of food waste through the implementation of a fine policy for consumers who leave food scraps. (Östergren et al. 2014) states that consumer attitudes and behaviour are closely related to the interest in reducing food waste. By imposing fines for consumers who leave food scraps, it is assumed that consumer awareness of food waste can increase because consumers will be more careful in leaving food scraps to avoid fines. In this study, data on the level of consumer awareness about food waste was obtained from a

restaurant consumer survey by asking how concerned they were with the problem of food waste from a scale of 0-1. Based on the survey, it was found that the average consumer awareness of restaurants in the city of Surabaya regarding the problem of food waste is 0.75 or 75%. By applying this scenario, it is assumed that consumer awareness of food waste can increase by at least 95%.

3.4.3 Scenario 3

The objective of scenario 3 is to collaborate with the food bank to donate their leftovers that are suitable for consumption so those who need them. When viewed from the perspective of reducing food waste, food banks appear to be socially desirable solutions to better utilize food waste. Food banks need to be considered as one of the scenarios because food banks can provide benefits to the private sector, namely reducing the cost of waste management (if any), then can benefit the charitable organizations involved and provide social benefits, namely ensuring access to food for the poor in the population (Gustavsson et al. 2011). This scenario is done by transferring serving losses to the food bank. This scenario is suitable for buffet restaurants or restaurants that apply batch cooking because the food that has been served is usually still appropriate to be given to food banks rather than plate waste, storage losses, and preparation losses.

3.5 Result Analysis

The simulation is carried out with the assumption that demand is normally distributed so that the demand value changes during the simulation. Therefore, simulation running was carried out with replication of 5 times and then calculating the average. The results of each scenario can still be compared by looking at the percentage of decrease before applying the scenario to the moment after the scenario is applied. Scenario results are presented in Table 2 which shows the value of total food waste for the existing conditions and each scenario.

Table 2. Total food waste and profit for each scenario

	Mean		Percentage of Difference	
	Total food waste	Profit	Total food waste	Profit
Existing	61.23kg	6,667,517.12		
Scenario 1	57.05kg	6,920,009.19	6.83%	3.79%
Scenario 2	59.25kg	6,769,859.29	3.23%	2.17%
Scenario 3	45.86kg	6,364,525.63	25.10%	5.99%

The results of the application of scenario 1 by increasing the frequency of purchases can reduce food waste generated, but the percentage of waste reduction generated is around 6.83%, As explained earlier, this scenario has an impact on storage losses which if the losses here can be minimized, it is seen that there will be a noticeable increase in profits. This might be caused by food ingredients that are used effectively. For scenario 2, the percentage of food waste reduction generated is quite low at only around 3.23%. In this scenario there is no significant increase in profits although there is a slight increase. This scenario has an impact on the amount of plate waste produced, so when the resulting plate waste can be minimized, this will not have too much effect on profits because even if customers leave food scraps on their plates, they have paid for the food they take, so the restaurant doesn't suffer losses. Furthermore, for scenario 3, the percentage of reduction in food waste produced is high which is 25.10%, However, the decrease in food waste does not cause an increase in profit, it is because the restaurant has incurred costs to prepare food but the food actually becomes serving losses which even though the serving losses do not become food waste but the serving losses are donated, so the restaurant remains incur economic losses but these foods can still be consumed effectively. An increase in profit might be felt by the restaurant if there is a waste processing cost that they must spend for every kg of waste they produce. So, the more food waste they produce, the more costs they have to spend. However, in this study, these costs are not included in the model.

4. Conclusions

Many factors have the potential to cause food waste, not only from infrastructure and technical factors but also caused by human behaviour. The problem of food waste must be the responsibility of all of us, not only for service providers such as restaurants or suppliers but also for us consumers who must help protect the environment. Based on the simulation results, from the perspective of reducing food waste, scenario 3 is the most effective scenario in reducing food waste. The highest percentage reduction is achieved by applying the third scenario with a reduction of food waste by 25.10% per day. Therefore, this research shows that restaurants should start to consider collaborating with food

banks to donate their serving losses to those who need it. Based on observations, almost all restaurants in the Surabaya are not aware of the food waste they produce, by applying this scenario it is expected to reduce the rate of increase of restaurant's food waste in Surabaya. The effect of the scenario simulated is uncertain and cannot be taken for granted. However, this study provides an overview of the potential impacts of the scenarios developed.

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