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A Food Supply Chain Model Directing Food Loss and Waste to Kodomo-Shokudos

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Abstract. Food loss and waste has become a major social problem all over the world. To reduce "Food loss and waste," laws have been put in place to turn it into animal feed and fertilizers, relax delivery deadlines, and reduce serving sizes of meals. In addition, there are other activities promoted by the government, such as the use of food banks. However, even if all these activities are utilized, food loss and waste can never be reduced to zero. Another way to reduce food loss, other than these laws and activities, is to provide food materials to restaurants that provide inexpensive meals in the city, called "Kodomo-Shokudo." By using food that would otherwise be wasted at the "Kodomo-Shokudo," we can contribute to reducing food loss and lowering the operating costs of the these restaurants. Our aim is to clarify the difference between the food bank and "Kodomo-Shokudo" and create a route model that supplies food losses to the "Kodomo-Shokudo." Kodomo-Shokudo is a community place where local residents or NPOs take the initiative to provide meals to children for free or at a low cost. Consequently, Monte Carlo simulations show that the resulting transportation costs could be significantly reduced.

Keywords. Supply chain management, food loss and waste, Kodomo-Shokudo, food reuse

Introduction

Global food loss in 2015 was USD 1.2 trillion and 1.6 billion tons [1], and one-third of the flow from production to consumption was food loss or food waste. Furthermore, it is expected to increase to USD 1.5 trillion by 2030 [2]. Conversely, in Japan, food loss is 5.7 million tons per year, of which 3.09 million tons is from businesses and 2.61 million tons from households [3].

To reduce food waste and promote the formation of a recycling oriented society, the Japanese government set legal systems and targets for food loss reduction and the Food Recycling Law was enacted in 2001 as one of the measures. The Food Recycling Law places the "control of food loss" generated in food production, distribution, and

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consumption processes as the top priority for food-related businesses to address. In April 2012, “generation reduction targets” were set based on the Food Recycling Law. Currently 19 food manufacturing industries, 1 food wholesale industry, 4 food retail industries, and 7 food service industries have set generation reduction targets and efforts are being made to meet or exceed these targets[4].

In addition, as food loss in the restaurant industry accounts for one-fifth of all food loss, the government has provided guidance on the serving sizes in restaurants [5]. In addition, the government promotes the “relaxation of delivery deadlines,” “indication of the year and month of consumption deadlines,” and “extension of best-before dates.” [6]. The Japanese government encourages the use of food banks and Kodomo-Shokudos, which are food donors to food banks, as ways to reduce food loss.

However, in the attempts to use Kodomo-Shokudos, the amount of food provided to Kodomo-Shokudos is irregular and changes each time, and the food required by the Kodomo-Shokudos is not always delivered in the quantity and amount needed. In fact, even if food loss is sent to Kodomo-Shokudos, the food is not effectively utilized and may be discarded. Another issue is that Kodomo-Shokudos are operated by individuals and communities, unlike a corporate organization, thus there is no horizontal linkage. We examine and provide solutions to this issue by conducting a simulation.

Therefore, this study aims to create a food supply chain model for a Kodomo-Shokudo, and establish a Kodomo-Shokudo as a means to reduce food loss, thereby not only reducing waste but also controlling its operating costs.

During this paper, "food waste" refers to foods that are still edible and those which were originally inedible, such as meat and fish bones accumulated during food processing. Additionally, “food loss" refers to discarded foods that were originally edible, such as dented canned food or unconsumed food that was procured in large quantities at a bargain prices (untouched food).

1. Kodomo-Shokudo

According to the definition by the Ministry of Agriculture, Forestry and Fisheries of Japan, a Kodomo-Shokudo is a place where local residents and others provide nutritious meals and warm gatherings for free or at low cost, and is positioned as an initiative to provide opportunities for children who have difficulty eating together at home to share a meal[7].

The first person to organize a Kodomo-Shokudo in Japan was Ms. Kondo, the founder of the "KimagureYaoya Dan Dan Kodomo-Shokudo," which has been held at a grocery store in Ota-ku, Tokyo since 2012[8]. Ms. Kondo, a grocery store owner who was interested in mutual aid activities in the community, opened the cafeteria as a way to contribute to society when he heard from one of her customers, an elementary school teacher, that there were children who could only eat one banana outside of school lunch.

Even before the name "Kodomo-Shokudo" was used, some practices similar to the current Kodomo-Shokudo had been practiced in Japan. This is Settlement[9].

Settlement is an activity that was developed mainly in poor areas and spread to support the living conditions of the poor. This initiative started in London, England, in 1884 with the establishment of Toynbee Hall by Barnett and others, and was later developed in European countries, the U.S., and other parts of the world. In Japan, the Kingsley Hall, established in Kanda, Tokyo, in 1897 by Sen Katayama, is said to be the first settlement of this kind.

The purpose of this settlement was to target neighborhoods lacking in welfare, such as slums and areas in need of improvement, and to improve the neighborhood as a whole through human contact with residents.This spirit has been inherited by the Kodomo-Shokudo.

Currently, the poverty rate among children in Japan is the worst among OECD countries.
The rate has been on the rise since the 1980s, and today it is estimated that one in seven children live in poverty[10].

Food assistance measures for low-income people include SNAP in the U.S., which issue electronic benefits that can be used like cash directly to needy families, donations from food bank organizations, and civic activities such as "Spesa Sospesa" (hold shopping), which was created in Italy by the Corona disaster [11] [12].

In addition, for children whose families have low incomes and cannot provide enough food, the Kids Café program in cooperation with food bank organizations and the Summer meal program in cooperation with the education sector, which provides meals at school during the summer vacation when school lunches are not available, are also being developed in the U.S[13][14].

The difference between the food support provided by food banks and Kodomo-Shokudo is that Kodomo-Shokudo are not just a place to "provide meals" but also a place for children where anyone can use, regardless of age, wealth, nationality, or disability. And for this reason, many of them do not limit their visitors to those in need.

Through the operation of the cafeterias, the owners of Kodomo-Shokudo are trying to form a network that aims to protect the lives of children and their parents in the community by collaborating not only with their own facilities, but also with other institutions, facilities, and people concerned.

Yoshida lists three functions of Kodomo-Shokudos: "support through food," "a place to stay," and "emotional exchange[15].

Papers developing business analytics on the subject of food banks in a given region and previous studies exploring optimization models for distributing donated foodstuffs have been published in several countries in recent years. A study analyzing how much Foodbank in Spain contributes to food waste [16], analyzing the use of technology in the operation of Foodbank [17] and a study using foodbank data to map demand geographically and predict where additional foodbanks should be built to address food poverty in the UK [18]. Looking at the extent to which food waste minimization and food poverty relief objectives are being met in the UK from a supply chain perspective [19].

The food spillage patterns of emergency food providers (EPFs) in North Carolina, USA, and a regression analysis of these patterns shows that economic stress occurs as the number of emergency food providers (EPFs) increases [20]. Virginia food assistance service recipients have lower participation rates in food stamp programs [21]. Foodbank is able to enhance menus, etc. because donations are cost containment and that food supplies reduce waste through the food supply chain [22]. Analyzing efficient routes by calculating demand and transportation routes for the challenges of running a non-profit organization to provide equitable service [23] and minimize waste of donated items [24].

2. Reserch Approach

This study investigates the status of Kodomo-Shokudos in Japanese metropolitan areas, clarify their relationship with food suppliers, and their operational costs. By creating an

optimal supply chain model between the Kodomo-Shokudo and the food suppliers, we calculate the effectiveness of the Kodomo-Shokudo as a stable consumer of food loss and the impact of the operating costs of the Kodomo-Shokudo.

2.1. Kodomo-Shokudo Status Quo

Interviews were conducted with four Kodomo-Shokudos in the Tokyo metropolitan area of Japan to obtain data on their food supply sources and consumption. We found that these Kodomo-Shokudos do not accept donations of perishable food items due to short a shelf-life but they accept rice, retort pouch foods, and snacks. As rice is a common ingredient in each Kodomo-Shokudo that is covered by donations, we simulate the optimal solution for the rice supply chain model. Table 1 shows the amount of rice donated and consumed by the Kodomo-Shokudos, the amount paid by customers per Kodomo-Shokudo, and the cost of purchasing rice. The Kodomo-Shokudo has only one donation source and one line (Figure 1), indicating that some Kodomo-Shokudo lost rice because it was not fully consumed, and some other Kodomo-Shokudo purchased rice without rice donations.

Table 1. Kocomo-Shokudo current situation.

Kodomo-Shokudo	Frequency (/week)	Donation (kg/month)	Consumption (kg/month)	Customer (person/time)	Price (¥/person)	Purchase (¥/month)
1	2	4.8	19.2	40	200	0
2	2	0	28.8	30	200	3,600
3	2	50	14.4	30	200	0
4	2	300	62.4	130	0	0

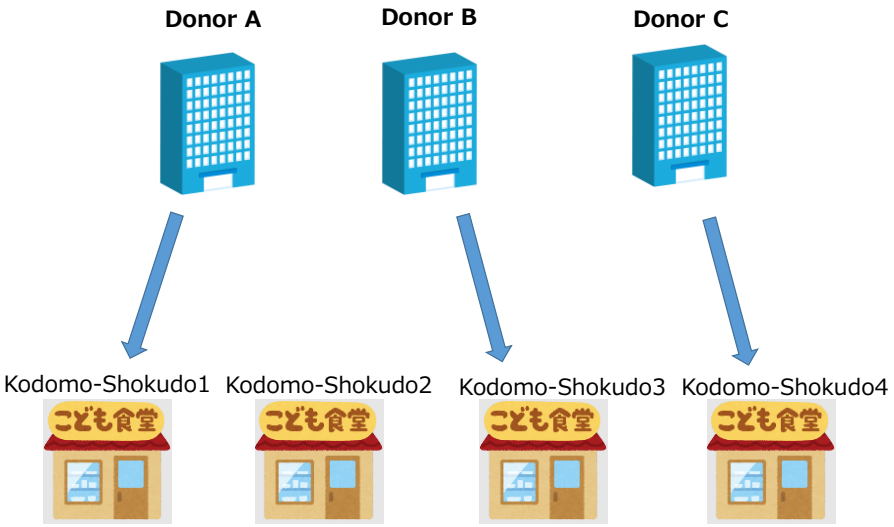

Figure 1. Current supply of rice from Kodomo-Shokudos and donors.

Next, Tables 2 and 3 show the distance between the Kodomo-Shokudo and donor and transportation fees, respectively. Rates vary by the distance per weight[25].
The income of the Children's Dining Hall, the amount of rice purchased, and the transportation fee from the supplier to the Children's Dining Hall amount to 41,325 yen.

Since it was found that some Kodomo-Shokudos receive rice donations but have a surplus, while others purchase rice due to lack of donations, the project will break this imbalance and promote cost improvement by implementing the optimal rice supply method.

Table 2. Current data on distance between Kodomo-Shokudo and donors.

Kodomo-Shokudo	Donor		
	A	B	C
1	10km	20km	20km
2	15km	15km	20km
3	20km	20km	20km
4	20km	20km	10km

Table 3. Kodomo-Shokudo transportation fee.

Kodomo-Shokudo	Donor		
	A	B	C
1	¥100/km	¥200/km	¥200/km
2	¥150/km	¥150/km	¥200/km
3	¥200/km	¥200/km	¥200/km
4	¥200/km	¥200/km	¥100/km

2.2. Simulation model

In response to the current situation described in 2.1, we consider the best means to deliver rice from the donation source to the Kodomo-Shokudo.
The prerequisites are as follows:

- Donation source can supply to any Kodomo-Shokudo
- The amount of inventory at the beginning of the month for Kodomo-Shokudos 1, 3, and 4 with a donation source is the same as the required supply for the month, and for Kodomo-Shokudo 2 without a donation source, it is set to 0.
- The required supply for each Kodomo-Shokudo is assumed to be normally distributed.
- The amount of supply from each donation source to the Kodomo-Shokudo is a discrete variable
- We assume that approximately 90% of the price per meal at the Kodomo-Shokudo is the cost of purchasing food items other than rice.

The equations for the simulation are shown below.

✓ Transportation costs from the donors to the Kodomo-Shokudos are shown in the formula below:

$$C^{trans}(i,j) = \sum_{i,j=1}^{n} \{d(i,j) \times w(i,j) \times t(i,j)\} \cdots (1)$$

C^{trans}: $Cost\ of\ Transportation\ (JPY)$
i: $Sponsor\ (1\ to\ 3)$
j: $Kodomo-Shokudo\ (1\ to\ 4)$
d: $Distance\ between\ Sponsor\ and\ Kodomo-Shokudo\ (km)$
w: $Transported\ weight\ (kg)$
t: $Transportation\ charge\ (JPY/kg \cdot km)$

✓ The cost to purchase rice is shown by the following formula:

$$C^{rice}(j) = \sum_{j=1}^{n} \{s(j) \times r(j)\} \cdots (2)$$

C^{rice}: $Cost\ of\ purchase\ rice\ (JPY)$
s: difference between standard and current inventories of rice (kg)
r: $Rice\ purchase\ unit\ price$ (JPY/kg)

✓ The following formula shows the cost obtained from participants who come to the Kodomo-Shokudos:

$$S^{meal}(j) = \sum_{j=1}^{n} \{m(j) \times g(j)\} \cdots (3)$$

S^{meal} : $Meal\ sales\ revenue\ (JPY)$
m : $Sales\ price\ per\ meal\ (JPY/meal)$
g : $Number\ of\ participants\ (people)$

✓ The optimal solution is the one where equations (1) to (3) are minimized, where the following equations hold:

$$Min.\{C^{trans} + C^{rice} - S^{meal}\} \cdots (4)$$

We simulate the optimal solution considering the above assumptions, the income of the Kodomo-Shokudo, and the transportation cost from the supplier to the Kodomo-Shokudo.

Then, we set the constraint that the amount of inventory at the beginning of the period added with the amount of supply accepted from the donation source excluding the required amount of supply (consumption) is greater than or equal to zero so that the final inventory is not negative. As there are many patterns of distribution volume and distribution destination, Monte Carlo simulations are performed to find the optimal solution.

3. Research Approach

The model in 2.2 was simulated using Crystal Ball, resulting in an optimal solution of 12,730 yen. The graph of the total amount of missing items for each Kodomo-Shokudo is shown in Figure 2. The range is 6.57 to 26.27 with a standard deviation of 0.04. The amount of supply from each source to each Kodomo-Shokudo is shown in Table 4.

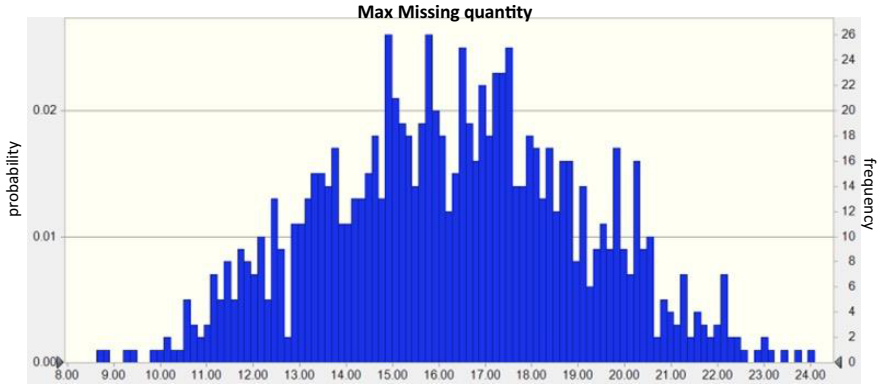

Figure 2. Max Missing quantity.

Table 4. The amount of supply from each source to each Kodomo-Shokudo.

Kodomo-Shokudo	Donor		
	A	B	C
1	4.32kg	-	18.00kg
2	-	13.50kg	27.00kg
3	-	27.00kg	-
4	-	-	180.00kg

4. Discussion and Conclusion

The results shows that the cost would be reduced by 28,595JPY from the current situation. Therefore, supplying rice to the Kodomo-Shokudo from the donation source in a well-balanced manner is effective for the operation of the Kodomo-Shokudo and transportation costs.

In the future, it is necessary to calculate the actual operation cost in the simulation of the Kodomo-Shokudo by including not only rice but also vegetables, such as root and leafy green vegetables that are purchased, with a view to supplying a balanced nutrition in the menu. In addition, we believe it is necessary to eliminate the wastage of funds and support those who work in the Kodomo-Shokudo by obtaining accurate detailed costs of operating a Kodomo-Shokudo.

Kodomo-Shokudos are run by volunteers, and the people who work there are not paid for their labor.

In order to continue the Kodomo-Shokudo in the future, we would like to consider remuneration for those who work at the Kodomo-Shokudo and consider a plan to raise that much money.

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References

[1] Boston consulting Group, 2018, *Tackling the 1.6-Billion-Ton Food Loss and Waste Crisis*, Accessed: 02.02.2022. [Online]. Available: https://www.bcg.com/publications/2018/tackling-1.6-billion-ton-food-loss-and-waste-crisis
[2] Food and Agriculture Organization of the United Nations, 2021, *Food Loss and Waste Database*, Accessed: 05.02.2022. [Online]. Available: https://www.fao.org/platform-food-loss-waste/flw-data/en/
[3] Ministry of Agriculture, Forestry and fisheries, 2021, *What is Food Loss?,* Accessed: 01.27.2022. [Online]. Available: https://www.maff.go.jp/j/shokusan/recycle/syoku_loss/161227_4.html
[4] Ministry of Agriculture, Forestry and fisheries, 2021, *Efforts to reduce the generaton of food waste,* Accessed: 01.27.2022. [Online]. Available: https://www.maff.go.jp/j/shokusan/recycle/syokuhin/hassei_yokusei.html
[5] Ministry of Agriculture, Forestry and fisheries, 2021, *The guideline of eating up deliciously when eating out,* Accessed: 01.29.2022. [Online]. Available: https://www.maff.go.jp/j/shokusan/recycle/syoku_loss/attach/pdf/170516-24.pdf
[6] Ministry of Agriculture, Forestry and fisheries, 2020, *About the Business Practices Review Campaign all over the country at once,* Accessed: 02.01.2022. [Online]. Available: https://www.maff.go.jp/j/press/shokusan/kankyoi/attach/pdf/191025-2.pdf
[7] Ministry of Agriculture, Forestry and fisheries, 2022, *Promotion of nutrition education in the community in cooperation with Kodomo-Shokudos,* Accessed: 02.04.2022. [Online]. Available: https://www.maff.go.jp/j/syokuiku/kodomosyokudo.html
[8] Agriculture and Livestock Industries Corporation, 2019, *A Kodomo-Shokudo run by a local community, utilizing the strength of a grocery store - "Whimsical Grocery Store Dandan" as a case study,* Accessed: 02.05.2022. [Online]. Available: https://vegetable.alic.go.jp/yasaijoho/senmon/1910_chosa02.html
[9] Y.Yoshida, *A discussion on the significance of children's restaurant activities and examination of their constituents – To provide spaces in the community intended for children-,* Shitennoji university Department Bulletin Paper, Vol. 62, 2016, pp. 355-368.
[10] The Nippon Foundation, 2022, *Child Poverty Measures,* Accessed: 02.08.2022. [Online]. Available: https://www.nippon-foundation.or.jp/what/projects/ending_child_poverty
[11] New York State, 2022, *Appluy for SNAP*, Accessed: 02.10.2022. [Online]. Available: https://www.ny.gov/services/apply-snap
[12] COOP Centro Italia, 2022, *La Spesa Sospesa*, Accessed: 02.13.2022. [Online]. Available: https://www.coopcentroitalia.it/spesa-sospesa
[13] Y.Tapper-Gardzina and N. Cotugna, The Kids Café: A program to reduce child hunger. *Journal of Pediatric Health Care*, Vol. 17,1, 2003, pp.18-21.
[14] Great Chicago Food, 2022, *Summer Meals For Kids*, Accessed: 02.12.2022. [Online]. Available: https://www.chicagosfoodbank.org/summer-lunch-bus/
[15] Y.Yoshida, *A discussion on the significance of children's restaurant activities and examination of their constituents – To provide spaces in the community intended for children-,* Shitennoji university Department Bulletin Paper, Vol. 62, 2016, pp. 355-368.
[16] P.L. Gonzalez-Torre, J. Coque, How is a food bank managed? Different profiles in Spain, *Agric. Human Values*, Mar 01, 2016, 33, 1, pp. 89-100
[17] R. Vidgen, A. Hamflett, G. Hindle, S. Raper and S. Duckworth, *Business analytics development in the food bank sector – Phase Two Report*, NEMODE, 2015, http://www.nemode.ac.uk/?page_id=1590, accessed June, 20 2022.
[18] G.A. Hindle, R. Vidgen, Developing a business analytics methodology: A case study in the foodbank sector, *Eur. J. Oper. Res*. Aug 01, 2018 , 268, 3, pp. 836-851.
[19] C. Alexandre, and C. Smaje. Surplus retail food redistribution: an analysis of a third sector model. *Resources, Conservation and Recycling*, 2008, 52(11), pp. 1290–1298.
[20] M. Berner, K. O' Brien, The Shifting Pattern of Food Security Support: Food Stamp and Food Bank Usage in North Carolina, *Nonprofit and Voluntary Sector Quarterly*. 2004, Vol. 33(4), pp. 655-672.
[21] M.A. Biggerstaff, P. Mcgrath Morris, Ann Nichols-Casebolt, Living on the Edge: Examination of People Attending Food Pantries and Soup Kitchens, *Soc. Work*, July 2002, Vol. 47 (3), pp. 267-277.

[22] M.E. Buisman,; Haijema, Rene; Akkerman, Renzo; Bloemhof, Jacqueline M, Donation management for menu planning at soup kitchens, Eur. J. Oper. Res, Jan 01, 2019, 272(1), pp. 324-338.
[23] O.I. Sengul, J. Ivy, R. Uzsoy, Modeling for the equitable and effective distribution of food donations under stochastic receiving capacities, *IISE Transactions*, Jun 03, 2017, 49（6), pp. 567-578.
[24] B. Balcik, S. Iravani, K. Smilowitz, Multi-vehicle sequential resource allocation for a nonprofit distribution system、*IIE Tranactions,* Dec 02, 2014, 46（12）, pp. 1279-1297.
[25] Ministry of Land, Infrastructure, Transport and Tourism, 2020, *Standard Fares,* Accessed: 02.01.2022. [Online]. Available: https://wwwtb.mlit.go.jp/tohoku/mg/kyg_14_09.pdf/