NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

BC2410 Prescriptive Analytics: From Data to Decisions

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Members	Ng Chi Hui	U1922243C
	Sui Lulu	U1921987A
	Lim Yan Di	U2010984H
	Goh Ray Sam	U2010503A
	Tan Jin Xian Cyrus	U2010867K
Seminar Number	1	
Group Number	3	
Instructor	Asst Prof Tang Qinshen	
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1 Background and Introduction

Food Bank Singapore (FBSG) is a non-profit organisation working to end hunger in Singapore by 2025. FBSG receives donated food and food collected is then distributed to those in need through a network of member beneficiaries (FBSG, 2020).

Annually, FBSG sources and rescues more than 800,000kg of food. These come from a variety of sources - food suppliers, F&B establishments, schools that run donation drives, companies, and individuals that donate through the Food Bank boxes available for shopping malls, Shell petrol stations, or adopted by companies for staff to donate (FBSG, 2020).

Food is then distributed to their member beneficiaries including Family Service Centres (FSCs), Soup Kitchens, Voluntary Welfare Organisations (VWOs), Religious Establishments, Schools with children from low-income families, or various homes (FBSG, 2021). Many of these beneficiaries rely on these donated dry rations from FBSG to survive.

With limited funding, and reliance on volunteers, it is important that FBSG optimises the use of its resources and logistics so that they can efficiently meet the food needs of our underprivileged.

2 Business Problem Analysis

2.1 Current Operations

Typically, FBSG donates non-perishable foods in two ways - in boxes to beneficiary centres like boys or girls homes and senior care centres, or in bags to individual homes (FBSG, 2020). We will focus on the Joy In Every Bundle Campaign, which distributes standardised bundles of food items to the underprivileged that live in rental units. Two types of bundles are packed - the standard food bundle and the healthier food bundle. The standard bundle includes non-perishables like rice, oil, canned food, snacks, noodles, and beverages, while the healthier food bundle contains fresh fruits and vegetables. Both bundles contain enough food items to supplement an individual for a week (FBSG, 2018).

In order to get the food bundles out to the beneficiaries, FBSG first sorts the food donations into different categories then checks the expiry dates to make sure that they have at least 1 month of shelf life. After this, volunteers then take inventory using an online system and donations are then packed by volunteers and transported to the different locations around Singapore with the use of the two FBSG vans (depending on the amount being sent) (FBSG, 2020).

When packing the bundles, volunteers only make sure that the basic staples are covered and that each bundle will typically contain the same things. Nutritional content is not considered, and volunteers simply ensure that things like rice or bread, and some form of protein like canned tuna, sardines or luncheon meat, is included. While whether the beneficiary consumes Halal food is considered, other food or dietary preferences are not considered, for example whether the beneficiaries are diabetic or have high cholesterol (FBSG, 2021).

This often translates to many underprivileged families not having the necessary nutrients that they need from these packs to lead a healthy lifestyle (CNA, 2020). The lack of consideration for nutritional content is largely attributed to the fact that the Food Bank has limited inventory in their warehouse and the quantity of products donated varies. The standard packs that the beneficiaries receive from Joy In A Bundle tend to contain an excess of sugar, sodium, and fat, while they lack important nutrients like fibre or vitamins.

Interviews with some beneficiaries have also shown that there was often no variety for the food they received which leaves them with too much of the same food (CNA, 2020). This can sometimes mean that they end up not consuming the repeated items and so these end up being hoarded instead of eaten.

Despite Singapore being the most food secure nation in the world, 1 in 10 Singaporeans suffer from food insecurity (Toh, 2021). While the FBSG does their best to identify and meet the needs of these Singaporeans, many of the beneficiaries that receive food still end up going hungry as their needs are not being effectively met.

With feedback on the amount of food donated occasionally being too much, it is also important that the FBSG sends only what is necessary each time, so that excess can be redistributed to help more people.

2.2 Objective/Problem Statement

FBSG is a charity that relies on food and monetary donations for its operations. Therefore, it is important that the costs of operating and logistics are minimised so that they can make the most out of their donations to provide food for their beneficiaries and reach more people.

This means that while the necessary food is sent to the beneficiaries, FBSG should also consider ways to optimise their transport costs. One of the factors that affect the cost it takes to run their 2 transportation vans is the weight that the van carries since this has an impact on the amount of petrol used. The heavier the weight being carried on the van, the more petrol is used.

At the same time, FBSG has to send enough food to meet the needs of the beneficiaries effectively, by taking into account their nutritional and caloric requirements, as well as their dietary preferences. They also have to match what is available in their inventory based on what has been donated to them.

Therefore, our project's aim is to find a way where we can minimise the weight of the amount of food sent to each household, while making sure that all their nutritional and caloric needs are met, and the FBSG's inventory is accounted for.

We have chosen not to look at factoring the cost of the food itself into consideration as FBSG mostly receives its food through donations and not through purchasing. Therefore, the cost of the food purchased is not a consideration in this project.

2.3 Assumptions

<u>Nutritional Needs</u>
In reality, different households with different types of people will have different nutritional needs. For example, the nutritional needs for a household containing someone with diabetes, will be different from the nutritional needs for a household containing someone undergoing kidney dialysis, and that could also be different from the nutritional needs for another household containing someone with hypertension. However, for our project we assumed that the household nutritional needs of all the households follow the average and fixed nutritional needs of the population.

Inventory

The actual distribution and number of the items in the FBSG inventory is unknown, but for our project, we introduced simulated data for the inventory with the assumption that it follows a discrete uniform distribution. Since the type and amount of food donated from the different sources are random, uniform distribution is the best fit.

Number of Households and Number of Members

In reality, the number of households and the number of members in each household could be constantly changing. Since these deliveries are done week to week, some weeks there could be more households that need food, and some weeks there could be less. However, for our project, we assumed that the number of members in the household and the number of households will remain constant.

As the household information for the FBSG's beneficiaries are not publicly revealed, we introduced simulated data for the number of people in each household by assuming that it follows a discrete uniform distribution.

3 Our Solution

There are three key steps to our data analysis approach. They are: (1) Data Preparation and Cleaning, (2) Exploratory Analysis, and (3) Model Application.

The sample dataset which we used to perform our analysis on was obtained from openfoodfacts, an online open source food database. The dataset comprises 1889 rows and 289 columns and the dataset was largely uncleaned. Upon the completion of cleaning this dataset 'nutrition.csv' was generated. We also generated another dataset 'household.csv' which will be further explained below.

3.1 Data Cleaning

Part A - C are data cleaning steps used in the generation of the nutrition data and part D is used for both household and nutrition data.

A. Removing Redundant Columns

Nutritional values that applied to our problem statement were selected and copied to another data frame. We selected nutritional values that were considered important by the FDA such as *fat, salt, energy, carbohydrates, sugars, protein* and *saturated fat* values and their corresponding units columns. Nutritional content information for things like cholesterol or fibre were left out because there were large amounts of missing data in our data set and were of a lower significance. We also selected and copied the *product name, quantity, categories_tag, labels_tag and serving_size* columns.

B. Standardising Responses

The nutrition columns came in a variety of units. For example, there was an *energy_unit* column and an *energy_value* column whereby the energy values were in different units such as kilojoules and kilocalories. We standardised the units to kilocalories(kcal). Similarly, for the other nutrition columns such as *fat, salt, carbohydrates, sugars, protein and saturated fat*, the values were standardised to grams.

The *quantity* column also contained values in a variety of units such as mg, kg, grs, mL, L. There were also some special and non conventional units such as 24 ml x 330, lit/Bottle, etc. These were cleaned using substring matching and regex formulas to grams.

The *product_name_en* column which represents the product name had many missing values. We replaced the missing values with the names of the products in other languages such as from the *product_name_de* (German) column or the *product_name_fi* (Finland) column.

C. Subsetting of Data for replacing NAs and Dropping NAs

For the column *categories_tag*, we replaced the long strings of categories into reasonably derived categories from the original categories. They were broadly classified into snacks, beverages, staples, supplements, etc. We also replaced the NA values in the *categories_tag* columns with their product name so that we could use it to derive the product categories based on the name of the product. For example, Straight Red Tea was classified into the beverages category and Cadbury Milk Chocolate was classified as a snack.

Finally, the NAs from the nutritional values columns and quantity columns were dropped as they were difficult to substitute to replace their values. This is because each food had very different nutritional values. Nutritional values can also be vastly different within food in the same category so we were unable to do a substitution through estimation or by finding mean or median.

D. Data Generation

For the first dataset, containing all the nutritional data of the foods, we randomly generated the inventory column using the randInt function from the numpy module to get random integers between 0 and 44 (inclusive) as we did not have the actual inventory of food items from Food Bank Singapore. As mentioned earlier, we did this under the assumption that the food in the inventory had a discrete uniform distribution.

Since we required data for the number of members in each household, we generated a *'members'* column using the randInt function we used for generating the inventory. We set a range of 1 to 5 (inclusive) and the number generated had to be an integer. This resulted in a list of households and the number of members in each of these households.

In the same dataset we then generated the nutritional requirement columns (*fat, salt, energy, carbohydrates, sugars, protein and saturated fat*) for each household. This was calculated by taking the average nutritional value for one person of each nutrition type (values can be found in the Appendix 7.1) and multiplying it by the number of members in the household.

After all the data cleaning and the addition of the necessary columns, we exported the 2 cleaned datasets into csv files called 'nutrition.csv' and 'household.csv' respectively. These were then used subsequently for data visualisation and model building.

3.2 Data Visualisation

To have a better understanding of our dataset 'nutrition.csv', we performed some data visualisation on the cleaned data.

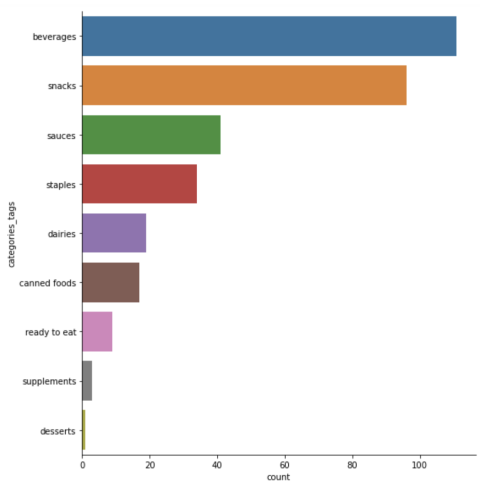

Figure 1: Unique Category Count for Food Items

We counted the number of unique food items in each category (defined by the *categories_tag* column) and sorted them in decreasing order. From this, we identified that the top 3 categories with the most number of unique products are beverages, snacks and sauces. For the categories with the least number of unique products, we have desserts, supplements and ready to eat food. This suggests that the model may end up with a selection of foods that is more biased to particular food categories (e.g. beverages or snacks) since there are more unique items in these categories. This could also not be reflective of the distribution of food in the different food categories that the FBSG currently has in their inventory.

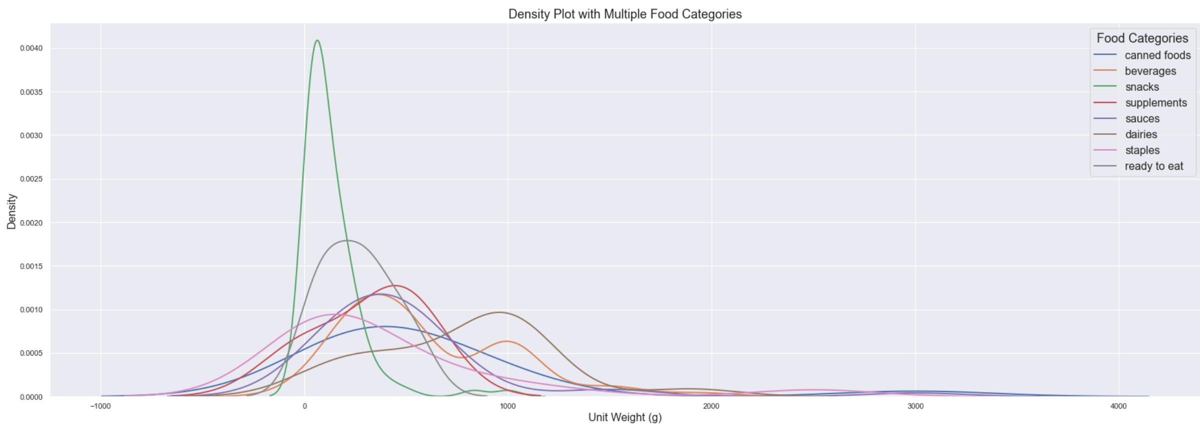

Figure 2: Density Plot of Food Items across Food Categories

From Figure 2, we can conclude that across the various categories of food, their weight distribution differs rather greatly. Generally, snacks and ready to eat food have lighter weight while dairy products and beverages tend to be on the heavier side. This suggests that things like snacks are most likely to be chosen by our model, since our objective is to minimise the weight of the food carried by the vans.

3.3 Model Formulation

The model that we generated for this project is a proof of concept. We tested the model a few times on the cleaned dataset with different numbers of households and types of food. We ended up taking 331 types of food from the list of food we had in the 'nutrition.csv' and assumed that there were 12 households in total that FBSG needed to deliver the food.

Our model aims to find the optimal total weight of inventory to pack and carry. Broadly, the objective for this model was to minimise the weight of food given to each household, while still meeting all their nutritional needs, also taking into consideration the amount of food in the inventory. The reasons for the formulation are as mentioned in Section 2.2.

We formulated the model as such:

Sets:

P : set of food items

R : set of households

U : set of nutritional values for food items

Decision Variables	**Meaning**	**Sources**
x_{ij}	Number of units of food *i* delivered to household *j*, $i \in P$, $j \in R$	-
Parameters		
a_{mi}	Amount of nutrition type *m* in food *i*, $i \in P$, $m \in U$	From 'nutrition.csv' dataset
w_i	Unit weight of food *i*, $i \in P$	From 'nutrition.csv' dataset
N_{jm}	Amount of nutrition type *m* needed for household *j*, $m \in U$, $j \in R$	From 'household.csv' dataset
Q_i	Total weight of food *i* in inventory, $i \in P$	From 'nutrition.csv' dataset

Formulation:

$$(1)\quad min \sum_{i\in P}\sum_{j\in R} w_i x_{ij}$$

$$(2)\quad s.t \sum_{i\in P} a_{mi}\, x_{ij} \geq N_{jm} \qquad \forall m \in U, \forall j \in R$$

$$(3)\quad \sum_{j\in R} w_i x_{ij} \leq Q_i \qquad \forall i \in P$$

$$(4)\quad 0 \leq x_{ij} \leq 3 \qquad \forall i \in P, \forall j \in R$$

(1) The objective of our model is to minimise the weight of food sent to all the households. This is calculated by multiplying the number of units of food *i* sent to each household (x_{ij}) multiplied by the unit weight of food *i* (w_i) and then summing it up.

(2) The first constraint is for the nutritional type. It is to make sure that for each household *j*, the total amount of nutrition given meets the total nutritional requirements for each nutrition type *m*.

(3) The second constraint is to account for the inventory. It is to make sure that for each food *i*, the total weight of food *i* sent to all the households is less than or equals the weight of food *i* available in the inventory.

(4) The third constraint is to account for variety. We wanted to make sure that the model would not select the same product too many times, thus we limited the number of units of food *i* sent

to each household *j* to 3. This constraint also serves as the non-negative constraint for our decision variable x_{ij}.

3.4 Interpretation of Solution

The output of our model is a matrix of x_{ij}, which is the number of each food item *i*, that would be delivered to each of the households *j*. We converted the matrix output into a dataframe with the names of the food items such that it will be easier for the volunteers to read and understand the output so that they can pack the food items accordingly. An example of the 'final food allocation.csv' file is shown in Figure 3.

Food Item	Househould											
	0	1	2	3	4	5	6	7	8	9	10	11
Doritos Spicy Nacho Tortilla Chips	0	0	0	1	0	0	2	0	0	1	0	1
Eucalipto	0	0	1	0	0	0	0	0	0	0	0	0
M & m Peanut M & MS 40 GR	0	1	0	0	0	1	0	0	0	0	0	0
Peanut butter crunch	3	3	3	1	1	3	3	3	3	0	1	1
Veggie Chips	2	3	0	0	0	3	0	0	0	0	0	0
Protein bar	3	3	3	0	0	3	1	3	3	3	0	0
Montanas Chocolate Chip Cookies	3	3	3	0	0	3	3	3	3	1	0	0
Ca Phe Sua Da	3	3	3	2	2	3	3	3	3	3	2	2
Poppadoms	0	3	0	1	0	3	0	0	0	0	0	1
Cacao & noisettes bio, sans gluten	1	3	3	0	3	3	2	2	2	3	3	0
White Coffee	2	1	1	1	0	1	0	3	3	0	0	1
Peri Peri Lime Soya Crisps	3	3	3	0	0	3	3	3	3	0	0	0

Figure 3: Example of Food Allocation Output from the Food Selection Model

In this simulation, the total optimal weight (from the objective function) that is minimised is 5242.786g or 5.2 kg. From this output, we can see that the chosen food items are mostly biscuits, chips, crackers and energy bars. These food items are diverse in nutritional contents that we considered for constraints (carbohydrates, sugar, protein). Similarly, such food items are also of lower unit weights, which surely makes them the preferred choices of the model when the objective is to minimise the total weight. Considering these factors, our model is correct in choosing suitable food items as a proof of concept.

4 Analysis of Solution

4.1 Limitations of Solution

Long Run Time

Our model produced a consistent and correct output that fits all constraints. However, the initial running time is long. For 12 households and 331 food items, the model required about 1.7 hours (6002.3888s) to produce an outcome. This might be due to the high computational complexity when running "for-loops". To manage this issue, we applied both the "for-loop" method and the matrix method when coding the model. We expected the matrix method (using @ for matrix multiplication) to be faster by direct multiplication while the "for-loop" method has to iterate through all data points in a brute force manner. When testing with 12 households and 331 food items using matrix form, the running time was only about 19 min (1155.6380 s), which is only about 1/6 of the "for loop" method.

However, the actual model gave a longer running time for the matrix method when the dataset is small (0.5498s for matrix form and 0.4263s for "for-loop" method). This happens when 5 households and 331 food items are used for running the model. Therefore, we suspected that the running time depends on other factors as well.

As the difference lies in the number of households (12 vs 5), the number of households could be the reason. Thus, we ran the model multiple times, changing the number of households (5,10,11,12,13) each time to check the running time..

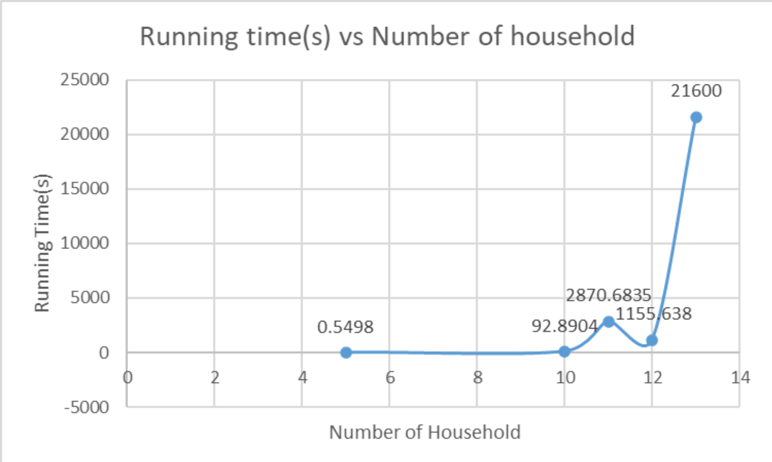

Figure 4: Graph of Running time vs Number of Household

From Figure 4, we can see that the running time increases exponentially per unit increase of the number of households (with the exception of 11 households). When the household number reaches 13 and above, the model took more than 6 hours to produce an outcome. As this model is a proof of concept, we stopped at 12 households.

<u>Bias towards lighter items</u>
Our objective to minimise the weight of all the food items delivered to households will lead to a bias towards lighter food items where lighter items will more likely be selected by the model. This will lead to food items like rice, which often comes in large quantities, to be excluded in our model. Foods that come in large packages that could have balanced nutritional content could also be excluded by the model. Subsequently, heavy food items could end up accumulating in the inventory, which could lead to these items expiring, resulting in the generation of unnecessary food waste.

<u>Generalised nutritional needs</u>
As this is a proof of concept for FBSG, the constraints we used for the model were based on the nutritional needs of an average person living in Singapore. However, this is not always representative of reality and applicable in the real world. Our model does not take into account beneficiaries that have specific needs. This includes dietary restrictions such as gluten or dairy free diets, health requirements such as diabetes which require food with lower sugar content, and religious requirements such as Muslims requiring their food to be certified halal. These are not taken into consideration and thus our solution might not be optimal for these cases.

<u>Single packing list per household</u>
Our model outputs one packing list per household. This solution is feasible since we have limited the number of households in our dataset to 12. However, in reality, FBSG serves thousands of beneficiaries. This then makes our solution logistically infeasible since volunteers will have to manage thousands of packing lists for each individual household. This will also take a large

amount of time for the volunteers to pack, and the FBSG might not have sufficient manpower for them to be able to complete packing every week.

Skewed datasets with more beverages and snacks

Our solution is not fully realistic because of the skewed dataset. We were unable to get access to the FBSG's actual inventory and so we picked a dataset online that contained food items sold in Singapore as well as their nutritional content and unit weights. From Figure 1 (Section 3.2), we can see that the dataset that we used is highly skewed toward beverages and snacks, which will affect the choice of food items by the model. For a better solution, a balanced dataset is preferred. This is likely the reality as well, where FBSG probably receives more donations from a particular food category. However, this skewed dataset is the inherent nature of the food dataset and is difficult to correct.

4.2 Recommendations

Reducing the long running time

Integer programming (IP) using Gurobi often faces the problem of exponentially increased running time. Therefore, other methods should be explored when the running time cannot be further reduced by varying the model. We believe that as a big organisation, FBSG has the capacity and ability to employ other methods such as other LP solvers (MPSolver/CP-SAT solver) and cloud computing through services like AWS or Gurobi Cloud to ensure faster computation with a wider scope (Solver, 2012).

Accounting for the bias towards lighter items

To ensure that heavy but necessary items are also being selected, we can add in more constraints to our model to make sure that it selects at least one food item from each food category. This will allow households to have the opportunity to get heavy food items like rice and noodles from the basic staple food category.

More tailored solutions to cater to specific households needs

In order to tackle the issue of both generalised nutritional needs and single packing lists for each household, our recommendation is to group households together in different categories so that we have a few customised packing lists.

1. Group households together

We can group households with similar specific needs together (eg. all the households with diabetic beneficiaries will be grouped together. This resolves the issue of having one packing list per household by creating one packing list per group of households.

2. Specific Datasets

After grouping the households together, we will use different datasets and adjust the constraints for our model so that we can meet the needs of this group of households. During data cleaning, we can split the datasets according to the different requirements of the household. This will ensure that our solutions will cater to their needs. For example, categorising the dataset into halal or non halal food to meet the dietary requirement of Muslims (Appendix 7.2).

We can also adjust the constraints in order to fit the specific needs of each household. If a household contains people with diabetes, we could adjust the sugar constraint accordingly, or if they have someone with hypertension we could adjust the saturated fat constraint as well.

5 Conclusion and Future Work

In general, considering the scope of our project, this is a model that could work feasibly and its limitations can be overcome through the recommendations that we have provided in Section 4.2.

If deployed, this model could provide a solution to FBSG's current problems. Currently, food items are packed by volunteers as outlined by the packing policy in Section 2.1. The beneficiaries thus suffer from fixed food listings, which gives rise to food wastage when the food chosen is not needed or liked. Deployment of the model ensures the nutritional requirement for its beneficiaries are being met while reducing potential food waste.

The successful implementation of this model could benefit the 300,000 beneficiaries across Singapore (Lim, 2022) that are currently being served by the FBSG, ensuring that they get the food they need while also making sure that their nutritional and caloric needs are being met. Food Bank Singapore will ultimately be able to meet the needs of their beneficiaries better, while also keeping their logistics costs low so that they can better utilise their monetary donations to feed more people.

In terms of actual implementation of this project, we propose that a trial run should be first run on a smaller scale with a smaller population. For example, this can be run in a place like Bukit Merah, that has a small population of slightly more than 150,000 people (Ng, 2017) and has many low-income families and seniors living in rental units (CNA, 2019). The success of the implementation of the model can then be measured by conducting surveys to measure beneficiaries' satisfaction with regard to the types of food they are receiving now as compared to the past. This trial run will then allow us to further improve our model in order to implement it to the other regions in Singapore.

To further improve and expand our model, we can require the help and support of Food Bank Singapore, which will enable us to come up with a more tailored solution for them. For example, they can provide us with more information on their inventory and the expiry dates of their food. We can then incorporate this information into our model so that the food items that are going to expire first, or with a shorter shelf life, will be packed and distributed first. This will certainly reduce food waste since food that is more likely to expire will not be kept for a long time then thrown away.

Another way that we can work with FBSG to improve our project is to get information on the dietary preferences and requirements of beneficiaries. While it may not be possible to go to every single household to get their likes and dislikes and food preferences, it is important that we at least have some rough gauge of their religious food requirements, or health-related dietary requirements. With this, we will be able to distribute slightly more customised food bundles to them to better meet their needs.

Further expansion into other FBSG projects is also possible in the future, where we could look into incorporating fresh fruits and vegetables into our list of foods so that they can be distributed in a more efficient way as well.

6 References

Channel News Asia. (2019, May 6). *CNA | don't call us poor | E01: Life in Bukit Merah*. YouTube. Retrieved April 15, 2022, from https://www.youtube.com/watch?v=Wf6tQcGBpM8&ab_channel=CNA

Channel News Asia. (2020, February 17). *Feeding the hungry, and how to do it better | special report, part 2/2*. YouTube. Retrieved April 15, 2022, from https://www.youtube.com/watch?v=dLVSKx8WI70

Food Bank Singapore. (2018). *CSR Opportunities - Food Bundles*. Facebook. Retrieved April 15, 2022, from https://m.facebook.com/thefoodbanksingapore/posts/1108300989336544?_se_imp=1ZegG4WCCWxm4sFMF

Food Bank Singapore. (2020, June 30). *Food Bank annual report 2019*. Issuu. Retrieved April 15, 2022, from https://issuu.com/thefoodbanksg/docs/the_food_bank_singapore_bank_book_2020

Food Bank Singapore. (2020, October 11). *What to expect when volunteering at our Warehouse*. YouTube. Retrieved April 15, 2022, from https://www.youtube.com/watch?v=vfQ5-qlBCbE&t=163s

Food Bank Singapore. (2020, September 28). *The foodbank model - the food bank singapore*. The Food Bank Singapore. Retrieved April 15, 2022, from https://foodbank.sg/the-foodbank-model/

Food Bank Singapore. (2021, January 19). *How to pack boxes with the Food Bank Singapore*. YouTube. Retrieved April 15, 2022, from https://www.youtube.com/watch?v=oOWZvI-Ls8c&ab_channel=TheFoodBankSG

Food Bank Singapore. (2021, June 30). *Ever wonder how the food that comes to us gets delivered?* YouTube. Retrieved April 15, 2022, from https://www.youtube.com/watch?v=5ogK3Mtimxw&ab_channel=TheFoodBankSG

Food Bank Singapore. (n.d.). *Joy In Every Bundle Step by Step Guide*. Retrieved April 15, 2022, from https://foodbank.sg/wp-content/uploads/2020/08/Joy-In-Every-Bundle-Step-by-Step-Guide-1.pdf

Gunnars, K. (2020, April 2). *How many carbs should you eat per day to lose weight?* Healthline. Retrieved April 15, 2022, from https://www.healthline.com/nutrition/how-many-carbs-per-day-to-lose-weight#why-eat-fewer-carbs

HealthHub. (2021). *Getting the fats right!* HealthHub. Retrieved April 15, 2022, from https://www.healthhub.sg/live-healthy/458/Getting%20the%20Fats%20Right!#:~:text=So%20how%20much%20fat%20should,if%20one%20is%20not%20mindful.

HealthHub. (2021). *How much calories do I need a day?* HealthHub. Retrieved April 15, 2022, from https://www.healthhub.sg/live-healthy/1341/how-much-to-eat-at-each-meal#:~:text=The%20average%20recommended%20daily%20caloric,average%20male%20and%20female%20Singaporean.

HealthHub. (2021). *How to eat right to feel right*. HealthHub. Retrieved April 15, 2022, from https://www.healthhub.sg/live-healthy/15/dietary_guidelines_adults#:~:text=Total%20fat%20should%20be%20limited,10%25%20is%20from%20saturated%20fat.

Lim, J. (2022, February 24). *Cold Storage expands partnership with the Food Bank Singapore to provide needy families with food*. The Straits Times. Retrieved April 15, 2022, from https://www.straitstimes.com/singapore/consumer/cold-storage-expands-partnership-with-the-food-bank-singapore-to-provide-needy-families-with-food

Ng, A. W. Y. (2017, June 12). *Singapore's Baby Town Punggol: Some interesting things to know about other URA planning areas*. The Straits Times. Retrieved April 15, 2022, from https://www.straitstimes.com/singapore/housing/singapores-baby-town-punggol-some-interesting-things-to-know-about-other-ura#:~:text=Bukit%20Merah%20%2D%20With%20oldest%20population,above%20the%20age%20of%2060.

Singapore Heart Foundation. (n.d.). *Heart smart eating habits*. Singapore Heart Foundation. Retrieved April 15, 2022, from https://www.myheart.org.sg/healthy-living/heart-smart-eating-habits/#filter_content_reduce-sugar-intake

Solver. (2012, April 26). *Optimization problem types - mixed-integer and constraint programming*. solver. Retrieved April 15, 2022, from https://www.solver.com/integer-constraint-programming

Toh, E. M. (2021, November 24). *As covid-19 rages, more in Singapore go hungry*. Coronavirus pandemic News | Al Jazeera. Retrieved April 15, 2022, from https://www.aljazeera.com/news/2021/11/10/as-covid-19-rages-more-in-singapore-go-hungry#:~:text=In%202019%2C%20Singapore%20ranked%20as,Lien%20Centre%20for%20Social%20Innovation.

World Health Organisation. (n.d.). *Nutrition*. World Health Organization. Retrieved April 15, 2022, from https://www.who.int/health-topics/nutrition#:~:text=Nutrition%20is%20a%20critical%20part,cardiovascular%20disease)%2C%20and%20longevity.

Yap, L. W. M. (2020, September 24). *Can too much protein hurt your health?* Gleneagles Hospital. Retrieved April 15, 2022, from https://www.gleneagles.com.sg/healthplus/article/too-much-protein#:~:text=to%20health%20issues.-,How%20much%20protein%20is%20too%20much%3F,grams%20for%20females%20(adult).

7 Appendix

7.1 Nutritional values used in Calculating Nutritional Needs in Each Household

Nutrition	Value (average per person)	Raw	Source
Calories	2000	Men: 2200 Women: 1800	Healthhub
Fat	67	M: 74 W: 60	Healthhub
Saturated Fat	22	M: 24 W: 20	Healthhub
Carbohydrates	276.5	M: 303 W: 250	Healthline
Sugar	45	-	Singapore Heart Foundation
Protein	63	M: 68 W: 58	Gleneagles Hospital
Salt	5	-	Singapore Heart Foundation
Sodium	2	-	Singapore Heart Foundation

7.2 Categories of Food Items