Final Project: What to Eat for Lunch?

Group 8

Group members：

郭姿筠 B07705007、陳韋傑 B07702011、Louise Ligonniere T08201105、

陳威廷 B06310024、黃季昕 B06705035、林俊諺 B07705029、楊鈞智 B07705016

Problem

We want to solve a problem that every NTU student comes across everyday while studying on campus: What to eat for lunch?

Since we may have afternoon classes, we may have a limited time to enjoy lunch. Therefore, we need to consider the time it takes to transport between restaurants and classrooms, to make sure that we can be in time for afternoon classes. The approximate prices of restaurants are also in consideration because we do not want our spendings to exceed our monthly lunch budgets.

While making decisions, we cannot choose to go to restaurants on days when they are not open. If we have lunch appointments with others, we will eat at certain restaurants on those specific days. Eating at the same restaurant too often can be tiring, so we will avoid eating at the same restaurant in the same week.

Under the constraints above, we formulate a program to find optimal lunch solutions on weekdays over a month for an NTU student. Our goal is to maximize restaurant preferences of the student, the amount of time and money the student saves.

To give the objective function a clear meaning, we have decided to convert the restaurant preferences and the time the student saves both into money units. Therefore, we express the restaurant preferences of the student with his/her willingness to pay for lunch in each restaurant. Restaurant preferences are often context-sensitive, for example, a student's preference for a restaurant is likely to decrease if he/she has already eaten at the restaurant the day before. In our program, we let the willingness to pay for a restaurant decrease every time the student eats there. We multiply the amount of time saved (the available time for lunch minus the biking time between classrooms and restaurants, and the average time customers spend in the restaurant) by the minimum wage.

The objective function is defined as to maximize the total benefit, calculated by the student's willingness to pay for lunch in each restaurant, the amount of money the time saved is worth, and the money he/she saves.

Data

1.Restaurant-Related

We collected the information of 71 restaurants near NTU, including:

(1) Price approximation: we reviewed the menu of restaurants and approximate with the median of its price interval

(2) Days-off: 0 for no days-off, 1 for Mondays, 2 for Tuesdays, etc.

(3) The average time customers spend at the restaurant, which can be found on Google Review

(4) The estimated biking time to main buildings of NTU, which can be found on Google Map.

Below is a part of the data of restaurants:

Name of the Restaurant	Approximate Price (NTD)	Days-off	Average Staying Time (minutes)	Estimated Biking Time (minutes)	共同	普通	新生	管一	新體	社科院	男一	女一
鍋in	175	0	90		4	5	6	3	7	6	6	5
韓天閣	175	0	90		4	5	6	3	6	6	7	4
大埔鐵板燒（公館）	150	0	45		4	5	6	3	7	6	6	5
阿英滷肉飯	125	6	30		4	4	4	4	4	6	8	3
柒食貳	100	0	45		4	4	4	4	4	6	7	3

2.Student-Related

As for the information of the student, we need the location where his/her morning class ends, the location where his/her afternoon class begins, and the amount of time he/she has for lunch each day. Also, we consider the monthly lunch budget, and the willingness to pay for each restaurant. The specific restaurants in which he/she will have lunch appointments on certain days are also recorded.

Below is an example:

Day	Mon.	Tue.	Wed.	Thu.	Fri.
Available Time (min.)	Unlimited	Unlimited	120	70	10
Class-ending Location	無	管一	管一	管一	普通
Class-beginning Location	無	無	管一	新生	新體

Name of Restaurant	Willingness to pay
鍋in	180
韓天閣	100
大埔鐵板燒（公館）	130
阿英滷肉飯	100
柒食貳	100

Budget (NTD/month)	4000

Variables

$$x_{ij} = \begin{cases} 1, & if\ on\ date\ i\ restaurant\ j\ will\ be\ chosen \\ 0, & otherwise \end{cases}$$

Parameters

1. Restaurant-related

- Price : R_j is the average price of restaurant j.
- Traveling time : B_{jk} is the traveling time from location k to restaurant j.
- Days-off :

  $$O_{ij} = \begin{cases} 1, \ if \ on \ date \ i \ restaurant \ j \ will \ be \ open \\ 0, \ otherwise \end{cases}$$

- Actual dining time :

  E_j is the average dining time of restaurant j, based on historical data on google maps.

2. Student-related

- Class-ending location :

  $$S_{ik} = \begin{cases} 1, \ if \ on \ date \ i \ the \ student \ will \ finish \ his \ or \ her \ morning \ class \ at \ location \ k \\ 0, \ otherwise \end{cases}$$

- Class-starting location :

  $$D_i = \begin{cases} 1, \ if \ on \ date \ i \ the \ student \ will \ finish \ his \ or \ her \ afternoon \ class \ at \ location \ k \\ 0, \ otherwise \end{cases}$$

- Available time :

  T_i is the available time for the student on date i, i.e. the time he/she has for a lunch break.
- Willingness to pay :

  W_j is the amount of money that the student is willing to pay for a meal of restaurant j.
- Budget :

  M is the budget of the student (monthly).

3. Others

- C_i is the number of weekdays on date i, 1 for Mondays, 7 for Sundays.

- H is the basic hourly wage, in order to calculate time in the unit of dollars. In our model, we set it to 158 NT dollars.
- A is a constant used to calculate the decrease of W_j every time a customer eat at restaurant j.

4. Notations

- i denotes date, from 1 to 31.
- j denotes the number of restaurants, from 1 to 71.
- k denotes the location where student have a class, from 1 to 9 (8 locations & no class).

Objective Function

Maximize Total benefit:

$$\sum_{i=1}^{31}\sum_{j=1}^{71}(x_{ij}(W_j - R_j)) + (M - \sum_{i=1}^{31}\sum_{j=1}^{71}(x_{ij}R_j)) - \sum_{i=1}^{31}\sum_{j=1}^{71}\sum_{k=1}^{9}((S_{ik}+D_{ik})B_{jk}x_{ij}H) + \sum_{i=1}^{31}\sum_{j=1}^{71}((T_i - E_j)x_{ij}H) - 10 \times \frac{1}{2}(\sum_{j=1}^{71}((\sum_{i=1}^{31}x_{ij} - 1)(\sum_{i=1}^{31}x_{ij})))$$

We divide the objective function into five parts:

1. Consumer surplus

$$\sum_{i=1}^{31}\sum_{j=1}^{71}(x_{ij}(W_j - R_j))$$

The willingness to pay minus the actual payment equals to consumer surplus, which represent the level of satisfaction of consumer(student).

2. Left of monthly budget

$$M - \sum_{i=1}^{31} \sum_{j=1}^{71} (x_{ij} R_j)$$

After the whole month, if we have more money we will be happier, so the money we have in the end of the month can also represent our level of satisfaction.

3. Total traveling time(in the unit of money)

$$-\sum_{i=1}^{31} \sum_{j=1}^{71} \sum_{k=1}^{9} ((S_{ik} + D_{ik}) B_{jk} x_{ij} H)$$

The less traveling time the better. So the negativity of total traveling time can also mean the level of satisfaction.

4. Total saving time(in the unit of money)

$$\sum_{i=1}^{31} \sum_{j=1}^{71} ((T_i - E_j) x_{ij} H)$$

If we spend less time eating lunch we have more time to do whatever we want to do, maybe reading, chatting with friends and so on. So the total saving time also represent the level of satisfaction.

5. Decreasing willingness to pay

$$-A \times \frac{1}{2}((\sum_{j=1}^{71} (\sum_{i=1}^{31} x_{ij} - 1)(\sum_{i=1}^{31} x_{ij}))$$

We assume each time the student eats at the restaurant, his/her willingness-to-pay will decrease afterwards. However, in the customer surplus section previously discussed, W_j is a constant parameter. To adjust this, we came up with the following method:

Each time a student eats at a restaurant j, the willingness-to-pay value for this restaurant will decrease by A dollars. That is, W_j will be the original value given on the first time he/she eats at restaurant j, and then on the second time, it will be $W_j - A$ on the third time $W_j - 2A$; on the fourth time $W_j - 3A$, and so on. The more often he/she go to that restaurant, the more penalty will be given.

So the total decrease in W_j will be:

$$A \times (0 + 1 + ... + \sum_{i=1}^{31} x_{ij})$$,

which can then be calculated by the formula of an arithmetic sequence, as we have written in our objective function. In our model, we assume that $A = 10$, but this value can be modify by user's preference.

Constraints

- Time constraint

  $$\sum_{j=1}^{71}(E_j x_{ij}) + \sum_{k=1}^{9}((S_{ik} + D_{ik})B_{jk}x_{ij}) \leq T_i, \forall i = 1, 2...31$$

  The total dining time plus traveling time cannot exceed the available time the student has. If the student has no class in the morning or afternoon, which means that his/her available time is unlimited, we then set T to a really large value so that eating at every restaurant is possible.

- Budget Constraint

  $$\sum_{j=1}^{71}\sum_{i=1}^{31}(x_{ij})R_j \leq M$$

  The total cost of lunch cannot exceed the money the student has(i.e. budget).

- Days-off Constraint

  $$O_{ij} \geq x_{ij}, \forall i = 1, 2...31,\ j = 1, 2...71$$

  The student can only make his/her choice among the restaurants which is open for business.

- Date Constraint

  $x_{ij} = 1$, for some i and j

  If on some specific date we have a date with someone at some specific restaurant, then the choice on that day will be fixed.

- Consecutive constraints

  $$\sum_{i=n}^{n+6} x_{ij} \leq 1, \forall n = 1, 2...i - 6$$

  For any given seven consecutive days, the student can only go to the same restaurant once. Usually you won't go to the same restaurant in a week.

- Single Choosing Constraints

  $$\sum_{j=1}^{71} x_{ij} = \begin{cases} 1, \ if \ date \ i \ is \ a \ weekday \\ 0, \ otherwise, \ i.e. \ date \ i \ is \ a \ holiday \end{cases}$$

  We only take weekdays into consideration, since in holidays, students who live in Taipei usually will not eat lunch near NTU, for those who live in school dormitory, in holidays they sometimes go home or go to somewhere far from NTU.

Solution

Below is the optimal solution, with the maximal benefit = 7067.767 (NTD), for one of our team members:

Date (Day)	Name of Restaurant
1 (Monday)	四面八方
2 (Tuesday)	安好食 (新生)
3 (Wednesday)	鳳城燒臘
4 (Thursday)	五九麵館
5 (Friday)	不吃
8 (Monday)	四面八方
9 (Tuesday)	咖哩戰線
10 (Wednesday)	安好食 (新生)
11 (Thursday)	鳳城燒臘

12 (Friday)	不吃
15 (Monday)	四面八方
16 (Tuesday)	咖哩戰線
17 (Wednesday)	安好食（新生）
18 (Thursday)	鳳城燒臘
19 (Friday)	不吃
22 (Monday)	四面八方
23 (Tuesday)	五九麵館
24 (Wednesday)	安好食（新生）
25 (Thursday)	鳳城燒臘
26 (Friday)	不吃
29 (Monday)	此燈亮有餅
30 (Tuesday)	五九麵館
31 (Wednesday)	安好食（新生）

When we are running our model, we also observed that since the program is non-linear, it took quite some time to get an optimal solution. Therefore, we set the absolute MIP optimality gap to 10 dollars, to omit those iterations when the gap between the upper bound and optimal solution are less than 10 dollars.

Suggestions and some Modifications after the Presentation

In our solutions, we find that although there are more than 70 restaurants for us to choose from, it is likely that having lunch at the same 5 to 11 restaurants in a month gives us the maximum benefit. We think that our method to cope with the fact that restaurant preferences are context-sensitive might have oversimplified the matter. Perhaps we can come up with more comprehensive approaches. For example, we can add in more parameters that might affect preferences, such as the weather, or whether the student is eating alone or with companions.

After listening to the instructor's feedback, we have decided to make a few modifications in our formulation. since M is a constant and the value of $\sum_{i=1}^{31}\sum_{j=1}^{71}(x_{ij}R_j)$ is already subtracted once in the part "consumer's surplus", it may be more reasonable to eliminate this part in the objective function to decrease the complicatedness of our program.

Moreover, we have used a non-linear way to present the decrease of willingness-to-pay. It may be more accurate than a linear presentation but does make our program become less effective. Therefore, for further revisions, we can try to think of a better solution to improve its effectiveness, while still accurately presenting the condition.